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Being safe and productive in this modern world

by Richard Hartshorn

I think it is fair to say that 2020 is a year when personal safety is something of a preoccupation. The Covid-19 pandemic is currently ravaging the world, and it seems inescapable that by the time this article goes to press there will be many thousands more deaths, and countless more infected and sick. As individuals, communities, and countries, we will rightly be focused on staying safe and reducing the chances of exposure and infection.

Staying safe, however, is something that we, as chemists, regularly think about even in more normal times, particularly in the context of chemical hazards. Our experiments and processes often involve the use of toxic or dangerous compounds, and carry the inherent risk that the reactions we are performing may produce new ones with unknown and perhaps dangerous properties. This is even before we consider the possibilities of unanticipated reactions and perhaps even some that run out of control, or occur violently, perhaps explosively.

It is standard practice for researchers to conduct risk assessments before they attempt reactions, and one element of this will typically involve examining the toxicities of the reagents, often by consulting Safety Data Sheets (SDSs), which have normally been produced according to the United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS, http://www.unece.org/trans/danger/publi/ghs/ghs_welcome_e.html). Many countries have regulations and standards that require and use such approaches, and the harmonisation of the GHS is a vital part of making it easier for users to find and employ the information that they need. Reaction scales and conditions (e.g. temperatures and pressures) are also vital considerations during these risk assessments.

Typically there will be some kind of sign-off process for a risk assessment that a researcher has prepared. This will hopefully decrease the chances that something important to the assessment has been missed, and it provides an opportunity to discuss the degree to which the hazards that have been identified can be mitigated or, better yet, removed entirely. The key problem with this approach is that it is reliant on the collective experience of the assessor and reviewer. They need to be able to recognise situations that may be problematic and to be able to offer suggestions about how to deal with them. This is one of the reasons why chemists often share lab-nerd anecdotes that tell of bad experiences and near-misses, and serve as a form of early warning system. Unfortunately, sometimes even relatively innocuous reagents can combine to produce unexpectedly dangerous situations.

Wouldn’t it be better to have a way to share such experiences more formally and to provide a resource that can be consulted and searched as part of planning reactions and processes?

The Pistoia Alliance (https://www.pistoiaalliance.org/) has developed the Chemical Safety Library project (https://www.pistoiaalliance.org/projects/current-projects/chemical-safety-library/) to address this very issue. Anyone can contribute detail on a reaction incident or hazard to the database, which is curated by an advisory panel, and then made available to the public. Openly sharing data of this kind can only make the chemical community safer, and I encourage you and your organisations to contribute to and use this new resource.

IUPAC also undertakes projects in the area of safety, and among these, perhaps the highest profile belongs to the Safety Training Program (STP) that is run by the Committee on Chemistry and Industry (https://iupac.org/body/022-1). In these projects, STP fellowship candidates from developing countries are trained to deliver environmental, health, and safety programs to their institutions and home countries.

In the meantime, in many places around the world, the day to day safety challenges revolve around regular handwashing, physical distancing, and appropriate personal protective equipment (PPE). We have also been learning a great deal about the strengths and weaknesses of teleconferences and the challenges of rapid conversion of courses to on-line teaching modes. Much of our chemistry, be it in research labs, lab courses, or company facilities, is heavily dependent on actually being there together, so lock-downs may have been hard and possibly very unproductive for you. If that is you, you have my sympathy, and I wish you all the very best for a rapid but safe return to productivity.

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The developing science that will fight the pandemic and reshape the chemical landscape

by Fernando Gomollón-Bel

In 2019, IUPAC introduced the “Top Ten Emerging Technologies in Chemistry” [1]. This initiative commemorated both IUPAC’s 100 anniversary and the International Year of the Periodic Table, a worldwide event that celebrated 150 years since the first publication of Mendeleev’s most famous chemistry icon. Now, IUPAC wants to transform this project into yet another landmark. Every year, the “Top Ten Emerging Technologies in Chemistry” will identify innovations with tremendous potential to change the current chemical and industrial landscape [2].

Throughout the past year, chemists around the globe have suggested remarkable technologies and innovations in their respective fields. A team of experts recruited by IUPAC curated the proposals and selected the most disruptive and forward-thinking—promising ideas with excellent chances for achievement. Some of them have already started weaving a network of spin-offs and attracting the interest of the chemical enterprise.

The “Top Ten Emerging Technologies in Chemistry” are also aligned with the United Nations’ Sustainable Development Goals (SDG). The selected technologies will change our world for the better, making a more thoughtful use of our resources, favouring more efficient transformations, and providing more sustainable solutions in applications ranging from new materials and more efficient batteries to extremely precise sensors and personalised medicine.

Furthermore, this year the world is facing an unprecedented challenge—fighting one of the worst pandemics since the Hong Kong flu in 1968. COVID-19 has affected our society across many levels, and will most likely transform our lives in ways we are yet unable to anticipate. In this global fight against coronavirus, chemists will play a key role. From soap and clean water to tests and new drugs, chemistry will be paramount to defeat this new threat. Thus, two of the technologies focus on solutions that will be crucial—rapid tests and RNA vaccines.

Dual-ion batteries

Electricity as we know it has a major flaw—it is surprisingly hard to store. To date, one of our best solutions are lithium-ion batteries, an advancement that was recently recognised with the 2019 Nobel Prize in Chemistry. During the past few decades, these devices have enabled the miniaturisation of energy-storage devices, currently used in laptop computers, mobile phones, and electric vehicles. Despite their high energy density, lithium-ion batteries still present some downsides. In fact, if you were to use state-of-the-art batteries to power your house, you would need a device of over one ton to store enough energy for one week. Moreover, the scarcity of lithium and cobalt limit future developments, and their links to conflict minerals clashes with SDG 12 on sustainable production patterns. Hence, newer devices such as dual-ion batteries (DIBs) have attracted the attention of the scientific community [3]. Whereas in classic lithium-ion batteries, only cations move along the electrolyte, in DIBs both anions and cations participate in the energy storage mechanism. They also exhibit some fundamental differences in the cell setup—in DIBs the ions in the electrolyte are also active, which directly influences characteristics such as capacity and voltage [4].

DIBs could be an interesting alternative for grid storage applications. Their electrodes can be manufactured out of cheap and abundant materials using greener routes. Traditionally, the fabrication of lithium-ion batteries involves the use of toxic organic solvents. On the other hand, researchers envisioned fabricating DIBs using water processing, enhancing sustainability and reducing the cost. Although the first DIB prototypes also relied on lithium, now chemists have found new solutions that use sodium, potassium, or aluminium—all of which are copious and widely available worldwide. Discovered only a few years back
Ten Chemical Innovations That Will Change Our World

[5], DIBs are still facing some challenges—researchers need to better understand their mechanism in order to improve their capacity, reversibility, and lifetime. Yet, industrial innovations are starting to blossom. Recently, a team in China reported the first prototypes for viable pouch cells based on the dual-ion approach [6], and companies such as Ricoh and Power Japan Plus are already investing in this attractive technology. The latter has even tempted electric car maker Tesla with “a fully recyclable battery that charges faster than lithium while still allowing a range of 300 miles.” In brief, DIBs present a series of advantages in terms of cost, lifetime, and sustainability that align with SDG 7. Besides, they provide a safer choice, according to experts. Since there is no intrinsic oxygen available in the cell, the ‘fire tetrahedron’ is incomplete, preventing accidental combustion.

Aggregation-induced emission

Nowadays, luminescent materials are ubiquitous: from LEDs to bio-imaging techniques. Since most of these substances usually feature a plethora of aromatic moieties, molecules tend to stack at high concentrations, which eventually kills luminescence. This effect is known as aggregation-caused quenching. In contrast, back in 2001 researchers observed the opposite phenomenon [7]—certain luminogens showed very weak emission in diluted solutions and an intense emission when the molecules piled up. At first, the concept received very little attention, but now it has become a vast field of study [8]. Aggregation-induced emission (AIE) has transformed the way people think about luminescence.

Molecular shapes are the key to understanding this effect. Unlike classic luminogens, the molecules that are AIE-active are non-planar. They are like miniature propellers, continuously moving. However, when they aggregate, rotation stops, and all of their energy is released in the form of light. Since the discovery of AIE, chemists have identified several families of compounds that exhibit this effect, including classic luminogens such as polyaromatic compounds and organometallic complexes, and more exotic products such as polymers, oligosaccharides, and nanoparticles [9]. AIE has opened new avenues in the development of luminescent materials—it has already found applications in OLED devices, sensors, and novel bio-imaging tools. The New York Times highlighted AIE’s potential to reach the real-world very soon. In fact, start-ups that market AIE technology are blossoming—two good examples are AIEGEN Biotech, in Hong Kong, and Luminicell, in the US. The latter also sells their fluorescent nanoparticles for live cell tracking through leading chemical supplier Merck.

Microbiome and bioactive compounds

We contain multitudes. Over 10 trillion microbes live in our guts, respiratory track, and skin. Our microbiome may be modifying our behaviour, and research suggests it could also trigger diseases such as cancer, as well as determine our response to treatment. All of these bacteria constantly release metabolites in response to different stimuli in their environment. Chemistry could play a key role in screening and identifying all these different molecules, which could eventually be isolated and used as novel therapeutic candidates.

Very recently, a team in Princeton took this approach to the next level [10]. Using different computational tools, they analysed bacterial genomes and identified gene clusters that codified the biosynthesis of small molecules. Then, they expressed these instructions in genetically-modified bacteria and obtained a series of molecules with strong antibacterial activity. Although this field—functional metagenomics—has progressed slowly in the past few decades, this new development has been characterised as “a game-changing approach, [with] the potential to revolutionise discovery.” [11] The microscopic life within us is immensely diverse. Chemists and biochemists may find a myriad of new bioactive compounds encoded in the genomes of bacteria, contributing directly to SDG 3. Understanding and unravelling the secrets of our microbiome could revolutionise the future of healthcare.
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Liquid gating technology
The idea of using liquids as a structural material to build responsive gates sounds counterintuitive—even verges on science fiction. However, this idea, originally proposed in 2015 [12], has already become a reality, and could soon bring many novel applications. Usually, liquid membranes work thanks to differences in concentration and potential astride the border. However, liquid gating membranes respond to pressure changes that rely on capillarity. At the microscale, phenomenon allows certain liquids to selectively open and close pores on-demand.

Liquid gates can selectively process mixtures of fluids without clogging. Thus, researchers predict that they could become extremely useful for large-scale filtration and separation processes. Among other things, liquid gates could accelerate the progress towards SDG 6, which looks to ensure access to clean water and sanitation for all. Moreover, since liquid gates require no electricity at all, they ensure huge energy savings.

Besides separation, liquid gates could find uses in many other fields, such as chemical sensors, microfluidic arrays, high efficiency catalysis [13], biological tissue printing [14], and lab-on-chip applications. Despite its novelty, liquid gating technology has already been recognised as a key innovation by prospecting company TechConnect, in the U.S. “It is sufficiently mature and attractive for licensing and investment,” they said. Hopefully, liquid gates will soon be scaled-up and adopted by key players in the chemical enterprise.

High-pressure inorganic chemistry
We all perform differently under pressure. Chemicals are no exception, and the most exceptional phenomena take place at extreme conditions. For instance, researchers have squeezed benzene into super-strong, ultra-thin diamond nanothreads and recently provided spectroscopic evidence of having prepared metallic hydrogen. High-pressure science is no longer a niche field. The newest technological advances allow to closely monitor samples under high-pressure environments, enhancing our understanding of materials [15].

These experiments involve pressures of up to 500 GPa—equivalent to five million times the average atmospheric pressure. To reach these immense strengths, scientists need to trap their samples between two diamond tips, which is commonly known as a diamond anvil cell. Further enhancements, such as combining diamond anvils with high energy X-rays, allow even higher pressures, reaching limits around 640 GPa.

Under ultra-high pressure, the rules of chemical bonding reshape. Stoichiometry laws blur—researchers have isolated ‘cousins’ of common salt from Na$_3$Cl to NaCl$_7$. In addition, some compounds that are undoubtedly inert at ambient conditions suddenly become reactive. Traditionally inactive species, such as dinitrogen, carbon monoxide, and carbon dioxide polymerise under extreme pressure and temperature, yielding products that, in some cases, survive depressurization and can be isolated at atmospheric pressure [16]. High pressure also enhances well-known effects such as luminescence and superconductivity.

Chemistry gets very complex in these conditions, but at the same time it gets really interesting. Discerning the transformations that take place under ultra-high pressures could lead to new molecular species and novel materials with unprecedented properties, such as room temperature superconductivity or superhardness. Moreover, some of the knowledge acquired could be translated to room pressure processes—researchers hope to open new frontiers in chemistry.

Macromonomers for better plastic recycling
2020 marks the 100 anniversary of Hermann Staudinger’s prestigious manifesto on polymerisation. Chemistry played a key role in the development of artificial polymers—durable and versatile materials that transformed our civilisation. However, said durability has turned against us: the building blocks of the twentieth century are now everywhere, accumulating in our landfills and polluting our oceans. Some experts predict that by 2050, the total amount of plastic in the oceans will weigh more than the total amount of fish [17]. Now, chemists must find a solution.

Many research groups are looking into more efficient ways to recycle the polymers we know, as reflected by last year’s IUPAC Top Ten Emerging Technologies in Chemistry [1]. Additionally, other groups are investigating new types of polymers that can be easily recycled. Solutions include plastics that break down upon exposure under UV light, and macromolecules bearing responsive “end caps” that trigger depolymerisation on-demand.
Redesigned monomers and macromonomers are an up-and-coming strategy to craft more sustainable plastics. Chemists rely on radical ring-opening reactions, which allow them to incorporate heteroatoms and functional group—such as ester—in structures that, traditionally, have an all-carbon backbone. The resulting polymers are easier to hydrolyse and recycle. Recently, several groups have optimised this technology, delivering a broad-range of biodegradable plastics that keep the attractive characteristics of conventional polymers [18]. Starting from a widely-available lactone, researchers developed a strong and stable polymer that can be recycled again and again under mild conditions [19].

These methods are far from being widely adopted. Nevertheless, chemists are moving in the right direction—re-thinking polymers and designing structures that ensure recyclability. Undoubtedly, chemistry is our best chance to find a solution to the plastic problem, contributing to at least five different SDGs at the same time.

**Artificial intelligence**

Artificial intelligence is transforming our society. Its market value is growing exponentially as it finds uses in finance, justice, transportation, and even healthcare. Chemistry is no exception. Researchers train algorithms to speed-up structure elucidation, enhance retrosynthetic analyses, design optimised reaction sequences, discover new drugs, and even run futuristic robotic laboratories. The possibilities are endless. “In the future, we will forget chemists used to be humans,” believes chemist and inventor Lee Cronin.

The applications of artificial intelligence in chemistry are only just beginning—the biggest leaps in progress are yet to come [20]. Researchers predict that these technologies have a tremendous potential. Among other things, they expect chemical reactions will become more reproducible, more easily scalable and eventually, greener and more efficient. Thanks to the combination of high-throughput methodologies and automated analyses, chemists could control and accelerate serendipity—turning accidental discoveries into a thorough and carefully-planned search [21]. All these strategies could expedite scientific breakthroughs and solve increasingly-sophisticated problems.

Algorithms could also tackle broader issues. For instance, machines can systematically analyse the scientific literature and learn from virtually every piece of data ever published. This could not only help us recognise trends, but also identify possible solutions to bigger challenges related to energy, climate change, environment, and health. In fact, recent studies suggest that artificial intelligence has a positive impact towards achieving the SDG—enabling the accomplishment of 134 targets across the goals.

Technology will upgrade our role as chemists. Rather than replacing us, artificial intelligence will enhance chemical discoveries while freeing us from mundane and repetitive tasks. Thus, we will focus on creativity, enabling leaps only limited by our imagination [20].

**Nanosensors**

Sensors detect changes in the environment. In chemistry, the process of sensing involves two steps—recognition, when analyte molecules meet their receptor; and transduction, the ‘translation’ of that event into an output signal [22]. Nanosensors work in a similar way, only they use nanomaterials as the active element. Chemical nanosensors are used in a myriad of applications, from monitoring pollution and food quality control to security and healthcare.

The field of sensors has progressed to the point of detecting single molecules. This has been dubbed “the
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ultimate sensitivity,” and is paramount in healthcare applications [23], where detecting a single entity can be a matter of life or death. Single-molecule sensing provides additional benefits, such as easily measuring heterogeneity in a sample or enabling calibration-free measurements. Experts believe that these technologies could be “paradigm changing” [23].

Advances in chemistry and materials science have allowed significant improvements. Researchers have explored a tremendous variety of nanostructured materials—metal, oxides, carbon nanotubes, graphene, polymers—that, thanks to their high surface to volume ratio, provide significant benefits for sensing. Nano-sensors are used across a number of fields in analytical chemistry. Recently, antibodies have attracted a great deal of attention due to the pandemic caused by coronavirus SARS-CoV-2. Luckily, chemists have used the unique properties of nanomaterials to create antibody nanosensors that are extremely sensitive and specific [24]. Gold nanoparticles, for instance, enable the detection of SARS-CoV-2 in under 15 minutes.

We are surrounded by sensors—they are inside our phones, fitness bands, smartwatches, and computers. Nanosensors will become increasingly popular, helping us distinguish fresh food from products about to expire, or upgrading our ability to detect previously unknown brainwaves, unlocking potential treatments for diseases such as epilepsy. Sensors will help us better understand the world in which we live.

RNA vaccines

Vaccines prepare our immune system to fight diseases. Through different agents, vaccines induce the production of antibodies, molecules that recognise and trigger the destruction of pathogens. In particular, RNA vaccines have a very clever approach to this goal—the patient is administered an RNA sequence encoding the production of antigens, which eventually stimulate an immune response and the synthesis of antibodies. Although RNA vaccines have not been approved as yet for human use, they have shown promising results in clinical trials [25]. Their potential to supply a speedy solution to prevent the infection caused by the novel SARS-CoV-2 coronavirus has again put them under the spotlight.

One of the advantages of RNA vaccines is that their synthesis can be easily scaled-up. To develop classic vaccines, researchers need to grow the infectious agent in a cell culture, which requires using high volume reactors and a significant amount of time. On the other hand, RNA strands can be synthesised using methodologies that have been optimised—and even automated—for decades. Moreover, RNA vaccines can be designed very quickly. Robin Shattock’s team at Imperial College London developed a candidate vaccine against COVID-19 within two weeks of getting the virus’ genomic sequence. The team is confident they could have preliminary results by next year. This is a true advantage when compared to classical vaccines, which usually need up to ten years of development—and an average investment of half a billion dollars—before they reach the market.

In addition to COVID-19, scientists are exploring the potential of RNA vaccines to prevent other infectious diseases such as Zika, rabies, HIV, the flu, and even cancer. Studies show that RNA vaccines could stimulate an immune response against cancer cells, making them an attractive alternative for novel immunotherapy treatments [26]. The Bill & Melinda Gates Foundation have invested an initial amount of $52 million for the further development of this technology.

Moreover, several companies are investigating RNA vaccines. Among them stand out CureVac and BioNTech, both in Germany, and Moderna in the U.S. All of them have adjusted their pipelines to investigate RNA vaccines against SARS-CoV-2, and are confident that they could upscale production if needed. RNA vaccines advance quickly—in fact, Moderna’s candidate (mRNA-1273) was ready to start Phase III clinical trials on thirty thousand volunteers in mid-June.

While still young, the field of RNA vaccines will probably grow tremendously in the coming years—especially given how rapid and adaptable production is. Plus, if RNA vaccines against COVID-19 are successful and get fast-tracked into the market, this could further foster the advancement of the technology [27].
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Rapid diagnostics for testing

Rapid diagnostic tests are chemical assays suitable for swift medical screening. They normally involve a series of easy-to-follow steps and provide results within a few minutes. Moreover, these tests seldom require additional equipment, facilitating their use in resource-poor settings. Probably the best-known example is the home pregnancy test, of which more than thirty-five million units are sold annually in the U.S. alone. There are also rapid tests to diagnose diseases such as malaria, aids, and the flu.

Rapid tests work thanks to chemical reactions. Often, they use antibodies to detect the presence of antigens. Antibodies are linked to different types of probes that undergo a certain chemical reaction if the test is positive—this usually involves a colour change, making the interpretation of the results very straightforward.

The current COVID-19 pandemic has led to shortages of laboratory equipment to perform more thorough PCR tests. Thus, scientists around the globe have prioritised the development of rapid tests to detect SARS-CoV-2 and diagnose people suffering the disease this virus causes, COVID-19. Some of them rely on the detection of RNA strands rather than antigens, and deliver results in under half an hour. Pharmaceutical company Abbott, developed a COVID-19 test that allegedly [28] uses loop-mediated isothermal amplification, which gives results in only five minutes. However, the latter requires some laboratory equipment.

At the moment, the World Health Organization (WHO) does not recommend the use of rapid diagnostic tests that detect antigens for COVID-19 patient care. So far, only three companies have received both an emergency use authorisation from the U.S. Food and Drugs Administration and the CE Mark from the European Commission—Autobio Diagnostics, CTK Biotech, and Hangzhou Biotech. Hence, chemists need to race against the clock to develop a suitable alternative that can yield significant results in a timely manner.

Chemistry for a sustainable future

Chemistry provides us with an unlimited set of tools to reshape our world into one that is safer and promises a more sustainable future. From designing more efficient tests to developing a successful treatment, chemistry will be central to tackle the current COVID-19 pandemic, one of the most difficult challenges our society has faced in the last few decades. Furthermore, while we flatten the curve to stop the spread of the coronavirus and grant access to healthcare for those in need, we must remember other threats on the horizon, such as pollution, climate change, and circular
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economy. Innovation in the chemical sciences is essential to attain most of the SDG, the aspirational goals set by the United Nations to promote prosperity while protecting the planet. This aligns flawlessly with the main mission of IUPAC -to apply and communicate chemical knowledge for the greatest benefit of humankind and the world. This new edition of the “Top Ten Emerging Technologies in Chemistry” keeps the same spirit—promoting the fundamental role of chemistry to protect society and our planet.

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More than 100 references are embedded in the online version of this article.

Selected References


The next search for the Top Ten Emerging Technologies in Chemistry is on. The deadline for nomination is 31 March 2021.
https://iupac.org/what-we-do/top-ten/
The Minamata Convention

A tool for global regulation of mercury pollution

by Eisaku Toda, Claudia ten Have, and Jozef M. Pacyna

Considerable scientific knowledge has been developed on sources and emissions of mercury, its pathways and cycling through the environment, human exposure and impacts on human health. Mercury has been recognized as a toxic, persistent, and mobile contaminant. This contaminant does not degrade in the environment, and it is mobile because of the volatility of the element and several of its compounds. Mercury has the ability to be transported within air masses over very long distances and deposited far away from emission sources.

Current emissions and environmental fluxes of mercury

Although mercury is a naturally occurring element, the United Nations Environment Programme (UNEP) Report (UNEP, 2019) indicates that the level of mercury in the atmospheric environment is 450 percent higher than the natural level, including the contribution of historical anthropogenic emission. Current emission inventories of anthropogenic sources indicate the total global anthropogenic emission accounts for 2225 tonnes per year (for the year 2015) and that major point source categories include artisanal and small-scale gold mining (ASGM), coal-fired power plants and coal-fired boilers, non-ferrous metals production, waste incineration and cement clinker production. Emission source contribution estimates for the year 2015 are presented in Fig. 1.

Current estimates of mercury emissions from natural sources and re-emissions, including mercury depletion events, were reviewed in Pacyna et al. (2016). The total emission amount of about 5200 metric tonnes per year was estimated, which represent nearly 70% of the global total mercury emissions. Oceans are the most important sources among natural and re-emission sources, contributing 36% to the emissions of mercury, followed by biomass burning (9%), deserts, metalliferous and non-vegetated zones (7%), tundra and grassland (6%), forests (5%), and evasion after mercury depletion events (3%).

Once emitted to the environment, mercury travels a long distance within the atmosphere, deposits on land and water, and is partly re-emitted to the atmosphere from land and ocean surfaces. Another part of deposited mercury is methylated in the ecosystem, bioaccumulates in organisms and is transported within the food chain. In this pathway mercury finds its way to human body through contaminated food. Global mercury budget showing the anthropogenic impact on the Hg cycle since the pre-anthropogenic period (prior to 1450 AD) is presented in Fig. 2 after updates of various estimates prepared for the Arctic Monitoring and Assessment Programme (AMAP) and UNEP (UNEP, 2019).

Mercury exists in the environment in different forms, the most toxic being methylmercury. This is also the form that bioaccumulates in aquatic food chains. Consumption of fish is one of the most important exposure pathways for humans. It has been documented that a portion of humans and wildlife throughout the world are exposed to methylmercury at levels of concern (summarized in AMAP 2018, UNEP 2019). Elevated Hg exposures in key groups of people of concern include foetuses, Arctic populations, who regularly consume fish and marine mammals, tropical riverine communities, coastal and/or small-island communities that are high seafood consumers, and individuals who either work or live among artisanal and small-scale gold mining sites, or who otherwise have high occupational exposures (UNEP 2019).

Methylmercury is a developmental neurotoxicant at dangerously high environmental levels in many regions of the world. It can cause neurological effects, including reductions in IQ among children. Among adults, neurobehavioral effects can be observed at moderately elevated exposures. There is also an evidence indicating...
elevated risk for cardiovascular diseases, especially myocardial infarction. In the case of severe exposure, there is a risk for reproductive outcomes, immune system effects and premature death.

**Future projections of mercury emissions**

Future projections for mercury emissions from anthropogenic sources are dependent on economic development in individual countries, particularly on energy production. There were already a few attempts to develop such projections, one of them by Pacyna et al. (2016). Reduction of mercury in the future can be achieved as a co-benefit when reducing emissions of sulfur and nitrogen oxides, greenhouse gases, as well as through implementation of mercury-specific controls. The choice of future non fossil energy sources will have large effects on mercury emissions: biomass combustion will continue to mobilize mercury present in the fuels (even if some of this mercury is natural), whereas non-combustion solutions such as solar or wind-based power generation will, of course, not cause additional emissions of mercury.

A comparison of the 2035 anthropogenic emissions estimated for various scenarios indicates that the 2010 emissions will remain the same in 2035 if mercury continues to be emitted under current control measures and practices (CP—current policy scenario). A full implementation of current and some new policy commitments and plans (NP—new policy scenario) will imply a benefit of reducing mercury emissions by up to 48% in 2035 compared to the emissions in 2010. It should be added, that both CP and NP scenarios do not include the Minamata Convention measures. Therefore, the scenario analysis should be repeated now when the Convention is in force.

Projections of future changes in mercury deposition on a global scale modelled for the CP, NP and MFR emissions scenarios of 2035 are also available (Pacyna et al., 2016). The CP scenario predicts a considerable decrease (20–30%) of mercury deposition in Europe and North America and strong (up to 50%) increase in South and East Asia. According to the NP scenario a moderate decrease in mercury deposition (20–30%) is predicted over the whole of the globe except for South Asia (India), where an increase in deposition (10–15%) is expected due to the growth of regional anthropogenic emissions. Model predictions based on the MFR scenario demonstrate consistent mercury deposition reduction on a global scale with a somewhat larger decrease in the Northern Hemisphere (35–50%) and a smaller decrease (30–35%) in the Southern Hemisphere. Thus, the most significant changes in mercury deposition (both increase and decrease) during the next 15 years for all considered scenarios are expected in the Northern Hemisphere and, in particular, in the largest industrial regions, where the majority of regulated emission sources are located.

**Development of Minamata Convention supported by science**

In the 1990s, the international community started to address mercury pollution as transboundary and global issue. The Aarhus Protocol on Heavy Metals under the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Council...
The Minamata Convention

for Europe was adopted in 1998. UNEP published its first Global Mercury Assessment in 2002, which presented information on chemistry, toxicity and risk of mercury, its production and use, environmental pathways, and preventive and control measures. The key findings of this first Assessment included the fact that mercury is affecting the environment far from any significant source of releases, that elevated methylmercury levels are observed in numerous freshwater and marine fish species, that mercury may be more problematic to less developed regions, and that actions implemented in Europe, North America and elsewhere have successfully reduced uses and releases of mercury. The Assessment estimated the global anthropogenic emission of mercury to the atmosphere at about 2,000 metric tonnes per year, 77% of which was attributed to stationary combustion of fuels.

Based on these key findings, the Governing Council of UNEP agreed at its 22nd meeting in 2003 that there is sufficient evidence of significant global adverse impacts from mercury to warrant further international action to reduce the risks to human health and the environment. The 23rd Governing Council in 2005 established a Global Mercury Partnership as a non-legally-binding mechanism to reduce the environmental and health risk of mercury. The 25th Governing Council in 2009 decided to elaborate a legally binding instrument on mercury and the prevention of such events in the future. Article 1 sets out the objective of the Convention to protect the human health and the environment from anthropogenic emissions and releases of mercury and mercury compounds. Articles 3 to 12 establish the obligation of parties to control the whole life cycle of mercury—from its supply to trade, use, emissions, releases, storage, disposal and
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the management of contaminated sites (see Fig. 3). Articles 13 to 15 provide for measures to support the parties in implementing the Convention. Articles 16 to 20 relate to information and awareness raising. Articles 21 to 35 concern administrative and procedural matters regarding the Convention.

After the adoption of the Convention, the INC met twice to prepare for the entry into force and the implementation of the Convention. A technical expert group on emission was established to develop guidance documents on best available techniques and best environmental practices on the control of mercury emission to air, and on the development of emission inventory. The Global Mercury Partnership worked on the development of a guidance document on ASGM national action plans. Such work, involving scientific

<table>
<thead>
<tr>
<th>Date</th>
<th>Article</th>
<th>Description</th>
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<tr>
<td>2018</td>
<td>Art. 5, para. 2, and annex B</td>
<td>Acetaldehyde production in which mercury or mercury compounds are used as a catalyst is to be phased out.</td>
</tr>
<tr>
<td>2020</td>
<td>Art. 4, para. 1, and annex A</td>
<td>Manufacture, import or export of various mercury-added products is no longer allowed (including batteries, switches and relays, compact and linear fluorescent lamps, high pressure mercury vapour lamps, cold cathode fluorescent lamps and external electrode fluorescent lamps for electronic displays, cosmetics, and pesticides, biocides and topical antiseptics, as well as barometers, hygrometers, manometers, thermometers and sphygmomanometers).</td>
</tr>
<tr>
<td>2020*</td>
<td>Art. 5, para. 3, and annex B</td>
<td>In vinyl chloride monomer production, reduce the use of mercury in terms of per-unit production by 50 percent by the year 2020 against 2010 use. For sodium or potassium methylate or ethylate, reduce emissions and releases in terms of per unit production by 50 percent by 2020 compared to 2010.</td>
</tr>
<tr>
<td>2020*</td>
<td>Art. 5, para. 5 (c)</td>
<td>Submit to the secretariat, no later than three years after the date of entry into force for the party, information on the number and types of facilities that use mercury or mercury compounds for processes listed in annex B, and the estimated annual amount of mercury or mercury compounds used in those facilities.</td>
</tr>
<tr>
<td>2020*</td>
<td>Art. 7, para. 3 (b)</td>
<td>For a party that determines that ASGM in its territory is more than insignificant, submit a national action plan to the secretariat no later than three years after the date of entry into force for the party or three years after the party notifies the secretariat of its determination, whichever is later.</td>
</tr>
<tr>
<td>2020*</td>
<td>Art. 9, para. 3</td>
<td>Identify relevant point source categories no later than three years after the date of entry into force for the party.</td>
</tr>
<tr>
<td>2021*</td>
<td>Arts. 8, para. 3, and art. 9, para. 4</td>
<td>Submit an implementation plan, if one has been developed, within four years of the date of entry into force for the party.</td>
</tr>
<tr>
<td>2022*</td>
<td>Art. 8, para. 4</td>
<td>For new sources, require the use of best available techniques and best environmental practices no later than five years after the date of entry into force for the party.</td>
</tr>
<tr>
<td>2023*</td>
<td>Art. 8, para. 7</td>
<td>Establish and maintain an inventory of emissions sources no later than five years after the date of entry into force for the party.</td>
</tr>
<tr>
<td>2025</td>
<td>Art. 5, para. 2, and annex B</td>
<td>Chlor-alkali production is to be phased out.</td>
</tr>
<tr>
<td>2027</td>
<td>Art. 5, para. 3, and annex B</td>
<td>For sodium or potassium methylate or ethylate, reduce the use of mercury, aiming at phase-out of this use as fast as possible and within 10 years of entry into force of the Convention.</td>
</tr>
<tr>
<td>2027*</td>
<td>Art. 8, para. 5</td>
<td>Implement control measures for existing facilities no more than 10 years after the date of entry into force for the party.</td>
</tr>
</tbody>
</table>

* Denotes first possible date, depending on when the Convention entered into force for that party.

Table 1: Minamata Convention timelines
and technical experts, resulted in the adoption of these guidance documents at the first meeting of its Conference of the Parties (COP), held in Geneva in September 2017. COP-1 established an ad hoc expert group on effectiveness evaluation (Article 22), and also put in place processes to involve experts nominated by parties and stakeholders on interim storage of mercury (Article 9) and mercury waste thresholds (Article 11) and the management of contaminated sites (Article 12). COP-2, held in November 2018, adopted a guidance document on interims storage, and established expert groups on mercury releases to land and water (Article 9) and mercury waste thresholds. COP-3 in November 2019 adopted a guidance document on the management of contaminated sites, and established an expert group on the review of Annexes A and B which list mercury-added products and processes that use mercury.

Work on technical issues continues in preparation for COP-4 to be held in Bali, Indonesia in November 2021. The ad hoc group of experts on the review of Annexes A and B works on the compilation of information on alternatives to mercury-added products and manufacturing processes using mercury. The group is reviewing the information submitted by Parties and non-parties, and working to organize and enrich the information. The document will be used by COP-4 for reviewing the Annexes pursuant to the provisions of Articles 4 and 5 which require that the review be done no later than 2022.

The group on mercury release works on the identification of relevant point sources and the development of guidance on release inventory, pursuant to Article 9. The group reviews information on release estimation methods submitted by Parties and stakeholders, and plans to collect further information, as well as to pilot-test these methods. Parties have an obligation to submit release inventory no later than five years after the entry into force.

The group of technical experts on mercury waste thresholds works to establish thresholds for defining waste contaminated with mercury, starting with an analysis of three approaches to thresholds—total mercury concentration, exposure potential (e.g. leaching test) and qualitative determination (listing approach). The group will further work on specific threshold values for this category of waste, as well as on thresholds for tailings from ASGM and non-ferrous metals mining.

Although the Minamata Convention currently does not have permanent scientific advisory bodies, it is supported by scientific and technical knowledge provided through these technical groups and processes involving experts nominated by parties and other stakeholders.

**Initial implementation efforts by countries**

The Global Environment Facility, which is designated as part of the financial mechanism of the Minamata Convention, supports developing country parties and parties with economies in transition in developing Minamata Convention Initial Assessments (MIA), which consists of the following:

- National Mercury Profile, including identification of significant sources of emissions and releases, as well as inventories of mercury and mercury compounds;
- Overview of structures, institutions, and legislation already available to implement the Convention;
- Challenges to implementation, including identification of legal and/or regulatory gaps to be addressed prior to ratification; and
- Capacity building, technical assistance as well as other needs required for the implementation of the Convention.

MIA is intended for supporting the ratification and early implementation of the Convention. Minamata Convention has 128 signatories, which signed the Convention within one year after its adoption in 2013. Signatories become Parties by ratifying, accepting or approving the Convention. Non-signatories can become Parties by acceding to it. As of 1 June 2020, the Convention has 120 Parties and 37 Signatories have yet to ratify it (Fig. 4). The MIA project has been or is being implemented in 72 Parties and 42 non-parties.

MIA reports provide a basis for examining parties’ needs for capacity-building and technical assistance. The secretariat analyzed 39 MIA reports submitted by August 2019, and found that mercury-added products (Article 4) and mercury waste (Article 11) are recognized as priority areas by almost all the parties (Secretariat of the Minamata Convention, 2019). Other major priority areas include ASGM (Article 7), emissions (Article 8), releases (Article 9) and monitoring (Article 19).

The national mercury profile in MIA includes mercury inventory, developed using a toolkit provided by UNEP. Burton and Evers (2019) reviewed the inventories of 43 countries, and concluded that while these inventories provide valuable baseline information for these countries, the synthesis of these inventories is complicated by discrepancies between the levels and versions of the UNEP Toolkit. MIA inventories are expected to form the basis for emission and release inventories under Articles 8 and 9, and for evaluating...
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the effectiveness of the Convention at the national and global levels.

Control measures under the Convention have different timelines. The obligations that have immediate effect include Article 3, which prohibits new primary mercury mining, limits the use of primary-mined mercury and excess mercury from the decommissioning of chlor-alkali facilities, and requires prior informed consent for international trade in mercury. Obligations for environmentally sound interims storage (Article 10) and environmentally sound management of mercury waste (Article 11) also have immediate effect. Timelines for other articles are summarized in Table 1. The 2020 deadline for phase-out of mercury-added products, except for those parties that registered exemption up to five years, is of particular importance, since mercury-added products are ubiquitous in all Parties.

Another important obligation with a short timeline is the development of national action plans on ASGM. ASGM is not only the largest source of global emission and releases of mercury to the environment, but a significant challenge to the health of miners and community members. Under Article 7, all Parties that have ASGM in their territory have an obligation to reduce, and eliminate where feasible, the use of mercury in ASGM. Those Parties with more than insignificant ASGM are required to develop a national action plan (NAP). The GEF has supported 41 countries in developing NAPs. So far three plans have been submitted to the secretariat, and many others are expected to be available soon. Parties have an obligation to implement the plan, and review its progress every three years. GEF places its particular attention to ASGM, with its 45 million dollar programme called planetGOLD. This programme, implemented in Burkina Faso, Colombia, Ecuador, Guyana, Indonesia, Kenya, Mongolia and Peru, aims at unlocking capital flows to transform ASGM, integrating miners into the formal economy and regulatory system, and disseminating better practices and technology to reduce mercury and improve efficiency. The GEF Council at its meeting in June 2020 approved an additional 44 million dollar ASGM programme for Bolivia, Congo, Ghana, Honduras, Madagascar, Nigeria, Suriname and Uganda.

Future challenges

Effectiveness evaluation and monitoring

The Minamata Convention has a mechanism for evaluating its effectiveness embedded in its text. Article 22 requires the COP to evaluate the
effectiveness of the Convention beginning no later than 6 years after the entry into force, and to initiate the establishment of arrangements for using comparable monitoring data for this purpose. COP-1 established an ad hoc group of experts consisting of members nominated by parties and observers to discuss effectiveness evaluation framework and monitoring arrangements. The group considered these issues learning from the experience of the Stockholm Convention on POPs which has a similar provision, and submitted a report to COP-2. COP gave the group a further mandate to elaborate on effectiveness evaluation framework, methodology, schedule and the use of monitoring data. The group submitted a report to COP-3.

The report proposed the following four policy questions as a basis of the effectiveness evaluation:

- Have the parties taken actions to implement the Convention?
- Have the actions taken resulted in changes in mercury supply, use, emissions and releases into the environment?
- Have those changes resulted in changes in levels of mercury in the environment, biotic media and vulnerable populations that can be attributed to the Convention?
- To what extent are existing measures under the Convention meeting the objective of protecting human health and the environment from mercury?

Sources of information were identified to address these questions, methodologies for compiling, synthesizing and integrating such information were described, and a list of indicators for evaluating individual provisions of the Convention was proposed.

COP-3 reviewed the report of the group and extensively discussed the evaluation framework. In spite of the week-long discussion at COP, it could not agree on the full details of the evaluation framework such as the terms of reference for the Effectiveness Evaluation Committee or global monitoring arrangements. The decision on the arrangements for the first effectiveness evaluation adopted at the closing minutes of COP-3 included three work elements. Firstly, COP requested the Secretariat to compile the views submitted by Parties on the evaluation indicators. The decision included a list of the proposed indicators, starting with a cross-cutting monitoring indicator for the evaluation against the Convention’s objective (Article 1), followed by specific process indicators and outcome indicators responding to individual articles, organized into several clusters such as supply, demand, pressure, support,
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information and research. Secondly, COP requested the Secretariat to work on guidance on monitoring to maintain harmonized and comparable information on mercury levels in the environment. Thirdly, it requested the Secretariat to work on a trade, supply and demand report which includes mercury waste flows and stocks, and a synthesis report on Article 21 national reporting. Other three reports, i.e. emissions and releases report, monitoring report and modelling report, although mentioned in the framework institutional arrangements (Fig. 5), were left for further discussion.

In May 2020, the Secretariat developed plans of work on indicators and monitoring guidance, in consultation with the COP-4 Bureau. Regarding indicators, the Secretariat will first develop guiding questions on the proposed indicators listed in the COP-4 decision, and convene an online information session in September 2020. Then Parties are invited to submit their initial comments by November 2020, and will have opportunities for an online exchange session. Parties are invited to submit their views by March 2021, which the Secretariat will compile into a COP-4 document.

Regarding the monitoring guidance, the work started with developing a draft annotated outline, and issuing a call for interest to contribute to the drafting. The Secretariat will convene online sessions of identified experts starting in September 2020 and draft guidance supported by consultants in air monitoring, biotic media and human biomonitoring. Draft guidance will be subject to comments from January to March 2021, and the guidance will be finalized through a final consultation meeting.

Effectiveness evaluation needs to be supported by sound science. It should be noted that Article 19 of the Convention requires Parties to cooperate to develop and improve modelling and geographically representative monitoring of levels of mercury in vulnerable populations and in environmental media. Such cooperation would support the effectiveness evaluation and effective implementation of the Convention.

Mercury levels in the atmosphere are directly linked to the anthropogenic mercury emissions addressed by the Minamata Convention. Atmospheric monitoring will indicate whether mercury levels in the air are increasing or decreasing due to the control measures, and also contribute to refining source-receptor models. Human biomonitoring has an advantage of covering exposure from all types of sources, and integrating the result of risk-reduction measures. Monitoring of the biotic media can track changes in environmental mercury levels that have ecological impact and relate to human dietary exposure. Key needs for monitoring include the following (Gustin et al., 2016):

- Development of a measurement infrastructure based on simple and affordable protocols that will enable traceable and comparable assessments of mercury and the compounds in air and their deposition;
- Development of advanced active sensors for atmospheric mercury monitoring to facilitate the extension and management of long-term monitoring programs to support policy implementation;
- Biological measurements conducted within a properly designed biomonitoring program within geographic areas of greatest concern for ecological and human health.

Policy making based on sound science

The history of the Minamata Convention started with the shared scientific knowledge on the global nature of mercury pollution. The work of INC and COP to support the implementation of the Convention, including the development of technical guidance and effectiveness evaluation, has been and will continue to be carried out on the basis of scientific and technical knowledge.

The International Conference on Mercury as a Global Pollutant (ICMGP) is an important avenue for scientific-policy interface in relation to the Convention. Established in 1990, ICMGP has worked as a primary forum to advance mercury science such as environmental and health assessment, global mercury cycle and control technology. To strengthen the linkage between the Convention and the scientific community, COP-3 included a special session on mercury science, inviting co-chairs of ICMGP 2019 (Krakow) and 2022 (Cape Town). Further collaboration is being pursued.

The Minamata Convention has an important role in the broader agenda of chemicals management, environmental protection and sustainable development. The Minamata Convention is a direct contribution to Target 3.9 of the Sustainable Development Goals to substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination, and Target 12.4 to achieve the environmentally sound management of chemicals throughout its life cycle. Moreover, it contributes to protecting the ecosystem services, by reducing the mercury levels in fish and other food and thus enhancing the life-supporting capacity of the global ecosystem. It also protects the wildlife, especially in the polar region where scientific evidence
indicates significant concern of mercury exposure for many species (AMAP 2018). Policy measures on ASGM will bring about multi-faceted benefits on protecting ecosystems and preventing land degradation, as well as protecting human health and improving the livelihood of local communities.

Link between the Minamata Convention and climate change should also be highlighted. Climate change affects the global cycle of mercury with increased volatility, forest and peat fires, melting permafrost, etc. Reducing dependence on coal will have a co-benefit of reducing mercury emission. Common technologies are used for controlling the emission of mercury, black carbon and other air pollutant. While the global community faces the challenge of “building back better” from the COVID-19 pandemic with reduced environmental footprint, Minamata Convention forms part of the transformational change towards a healthy planet.

Sound science is at the center of strengthening synergies between multilateral environmental agreements and other global actions for environmental protection and sustainable development.

References
1. AMAP. 2018. AMAP Assessment 2018: Biological effects of contaminants on Arctic wildlife and fish. Arctic Monitoring and Assessment Programme (AMAP), Tromso, Norway, vii+84pp; https://www.amap.no
7. UNEP. 2006. Summary of supply, trade and demand information on mercury.

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A Path for Tracking Funded Research and Compliance

by Howard Ratner and Susan Spilka

To better understand how CHORUS [1] is creating a future where the output flowing from funded research is easily and permanently discoverable, accessible, and verifiable, this article will share the story of its origins, present an overview of its services, and look at what’s in the pipeline. Working closely with organizations from all corners of the scholarly community, CHORUS is helping to establish new foundational standards, metrics, and metadata. This work is enabling CHORUS to introduce new and expanded capabilities—notably, tracking research datasets and integrating institutional identifiers—that support the continuing evolution of a sustainable and connected open-science infrastructure.

Taking Shape

As founding CHORUS member Fred Dylla (American Institute of Physics, 2007–2015) and Jeffrey Salmon (U.S. Department of Energy Office of Science, 2002–2017) tell the story [2], CHORUS was conceived on the February 2013 day that the U.S. White House Office of Science and Technology Policy (OSTP) issued a public access directive. That memorandum mandated new requirements for major U.S. funding agencies to set goals and timelines to make the published output of the research they funded freely accessible to the public [3]. The same day, a group of industry leaders met under the aegis of the Association of American Publishers (AAP) to discuss the formation of an organization that could assist U.S. federal agencies in their implementation of the OSTP directive. They wanted to provide a flexible and efficient route to compliance. Central to their objectives was avoiding additional researcher burdens and incorporating the process within existing publishing workflows.

In short order, the publishers mapped out the strategy for the sustainable path to public access that became CHORUS, continuing their earlier collaboration with the Department of Energy (DOE), and the National Science Foundation (NSF) that began after the America Competes Act became law in the U.S. in 2010. This earlier group wanted to utilize the relatively new Crossref funding-agency identifier called FundRef, based on the Digital Object Identifier (DOI), the underlying data in scholarly literature that enables online reference linking. Now known as the Crossref Funder Registry [4], the tagging system they developed efficiently and economically identifies the funders who support the research reported in all articles receiving DOIs. NASA and Wellcome Trust joined the effort to help design the new persistent identifier (PID). For the solution to work, the founding CHORUS group determined that it had to also provide access to the open content and information about license terms, and ensure archival longevity to the research output. That is why CHORUS came to exist.

The initiative was incorporated as CHOR, Inc., a non-profit membership organization. Its founding mission, which remains largely unchanged, is “to support and promote open access to and continued availability of publications reporting on funded research by leveraging new and existing technologies used throughout the publishing and scholarly communications community.” What has changed, in response to the needs of the scholarly community, is that the CHORUS mission now supports and promotes open access and continued availability of the underlying datasets, in addition to the articles. Based on the public benefit of that work and the rigor of its governance practices, the organization was designated as a 501(c)(3)—a tax-free category for charitable non-profit organizations—by the U.S. Internal Revenue Service.

Just as it efficiently leverages the technical infrastructure, CHORUS relies on the active engagement of a members-elected Board of Directors on its committees and task forces to advance its mission and objectives. A small team, led by Executive Director Howard Ratner, manages its operations. The Board membership represents key constituencies, including society and commercial publishers, publishing service companies, industry organizations, and academic libraries from major research institutions. Other stakeholders in the scholarly community also influence the operations of CHORUS through participation in working groups and advisory committees. Crossref remains an important CHORUS service provider. CHORUS also partners with CLOCKSS and Portico to ensure the archiving and preservation of research papers, and with other industry initiatives such as ORCID, DataCite, SCHOLIX, Metadata Registry 2020, and the Research Organization Registry.

Adding Value

CHORUS hit the ground running because of the substantial investments made over the years by the scholarly publishing community in an open, interoperable, and scalable research communications infrastructure. This framework set CHORUS apart from the start. As American Physical Society Publisher Matthew Saltar explained, “There’s an important process that goes on between discovery in a laboratory or in an academic setting, and communicating that research to other researchers and the public. CHORUS coalesces best
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practices, streamlines workflows, and aligns the interests of researchers, publishers, government agencies, research officers, and librarians.”

CHORUS currently counts as members 42 society and commercial publishers (Publisher Members) who collectively publish over 11,400 journals—the vast majority of articles reporting on publicly funded research. Six related businesses and organizations that provide essential technology and services participate as Affiliate Members. To participate, members follow the Publisher Implementation Guide outlined and updated by the Technical Working Group. Members have commented that onboarding with CHORUS propelled them to implement metadata best practices that they hadn’t done previously, and that collaboration with other working group members was helpful to their internal workflows.

Self-sustaining through memberships and fees, CHORUS offers a growing portfolio of services for publishers, funders, and institutions. Ten U.S. government funding agencies, and one in Japan, are currently working with CHORUS as part of their public-access plans. Funders and institutions both play a key advisory role in CHORUS development and are beneficiaries of the services it provides. Their engagement has been a factor in CHORUS’ success in broadening open access, clearing a collective path to compliance, and providing a tool to assess the return on research investments. Facilitating coordination among publishers, institutions, and funders is an important CHORUS value-add.

How CHORUS Works

By weaving existing systems and services together with new ones, CHORUS has been able to quickly facilitate an efficient, data-driven solution that is interoperable across the spectrum of publishing models, platforms, and portals. As a result of its distributed access approach, there are now paths to compliance covering research on publication sites as well as on agency portals and repositories. By directing users to the publication sites where article-level metrics accrue, CHORUS helps to enable more accurate assessments of research impact and return on investment. The underlying metadata make research outputs more discoverable.

To initiate CHORUS’ services, authors simply have to identify their funding sources when submitting a paper for publication with a participating publisher. That action associates the article with Crossref Funder Registry identifiers. Publisher submission workflows also gather other identifying information and metadata that become part of the record and help to determine when and which version of an article will be made openly available and other functions, such as researcher identity disambiguation with their ORCID identifier.

Publishers deposit article metadata records to the Crossref database, where they are assigned DOIs. CHORUS continuously ingests and indexes the metadata associated with those records, audits for open accessibility (tracking whether the content will be open immediately on publication or after a designated embargo period), availability of reuse licenses, archival and preservation arrangements, public grant information, author ORCID ID records, datasets associated with the published article, and links from funder open or public access repositories. CHORUS then analyzes the audited data and creates dynamic information dashboards, reports, and APIs of key performance indicators that enable funders, publishers, and institutions to monitor and report on compliance with open-access requirements.

The initial CHORUS offerings were its dashboards and associated reports for monitoring and tracking publisher contributions. The first dashboards released were for funder partners, which continue to be publicly accessible on the CHORUS website. The records contain links to the content on publisher site(s), but metadata can be exported to agency portals (e.g., National Science Foundation) and publisher platforms through the CHORUS open API. Other valuable resources that CHORUS provides include a tool to find agency funder IDs and a detailed compendium of funding agency public access plans.

Early on CHORUS also introduced dashboards and reports for Publisher Members, providing a one-stop resource for tracking access status and funder compliance requirements for the journal articles they publish. While research grant holders are ultimately
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accountable for compliance, embedding the verification process in the manuscript submission workflow—without adding tasks for author(s)—serves the greater good. As Rockefeller University Press Executive Director Dr. Susan King articulated, “Given the importance of government-funded researchers to RUP’s success, we believe we have an obligation to give something back to them, as well as the agencies and the public. As an added bonus, implementation of the CHORUS workflow has revealed that the breadth of funding for RUP published research is much, much wider than we originally thought.” [5]

Piloting New Territories

U.S. Academic Institutions—Research institutions have a fiduciary interest in making sure that their faculty researchers comply with funder requirements. Yet there is considerable inconsistency in how they meet the challenge. To collaborate on the best approach to monitoring faculty research output and increasing compliance rates, the CHORUS Institution Dashboard pilot program was launched in 2017, with seven Publisher Members taking part. The initial pilots allowed CHORUS to better understand and respond to the challenges institutions face, as their experience with the first participants illustrates:

University of Florida conducted a survey that found faculty put a high priority on the widest dissemination of their research publications, but could not devote the necessary time and resources. The UF Libraries saw CHORUS as a way to ease mandate compliance without further burdening researchers. The CHORUS Institution Dashboard was employed as a central portal for identification of faculty articles from a variety of publishers, forming the corpus of UF scholarship metadata to which its institutional repository (IR@UF) linked. UF developed its own email notification process tied to the CHORUS Dashboard deposit data, to keep faculty and administrators informed about compliance milestones. According to Dr. Sherry Larkin, UF Associate Dean for Research, “The CHORUS dashboard and the availability of downloadable .csv files have the potential to ease the time and financial burden of this annual process on our organization.”

University of Denver faculty researchers reported they were unaware of or confused by funder mandates, what version (author accepted manuscript, publisher version of record, etc.) should be deposited, and which archives would satisfy compliance. Compliance wasn’t “high on the priority list of many researchers at the University,” noted UD Libraries Associate Dean Jack Maness. He explained that the administration “don’t want it to be. Their [researchers] role is to do research. Ours is to ensure that the results of that research are as widely available as possible, now and for future generations. As librarians, we want to do what we can to help shoulder what could be considered an administrative burden, because it aligns with our values as a profession: providing access to knowledge that benefits humanity.” By using dashboard data and services in conjunction with their own internal data, UD librarians were able to develop an automated solution to monitor public accessibility to the University’s publicly funded research.

Both pilot participants found the CHORUS Institution Dashboard so effective at helping monitor
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compliance of their federally funded research that they signed an agreement for services in 2018. CHORUS recently launched the new service and began to sign on academic libraries as CHORUS Institution Dashboard subscribers.

**CHORUS in Japan**

With the significant growth in research output in the Asia-Pacific region, it was logical for CHORUS to seek international expansion in this region as a next step. Australia and Japan over many years have sustained their prolific presence in the global top-ten economies by research output as measured by the annual output of published articles; in 2016 CHORUS started pilot projects in both countries. The Australian Research Council (ARC) partnered with La Trobe University; and Japan Science and Technology Agency (JST) with Chiba University. Both agencies have clear OA compliance needs with the two universities having significant research profiles.

Encouragingly the pilot in Japan led to JST partnering and Chiba subscribing to the CHORUS services—the first relationships outside the U.S., and they are both doing well four years later. CHORUS collaborated with JST to improve Japanese funder information in the Crossref Funder Registry and to educate grantees on how to reference JST grants, and worked with some member publishers to improve metadata. As a result, over time they have seen a much higher capture of journal articles associated with JST funding. Dr. Yasushi Ogasaka of JST, who wrote *Landscape of Open Science* in Japan [6] was a speaker at the CHORUS Forum on Open Access Policies and Global Compliance in a Global Context on 30 July 2020.

Working through some technical challenges with Chiba, CHORUS established the author affiliation reports that are now a standard offering for all institutions. This enabled Chiba to develop a workflow that uploads links to OA published work from their research programs for access by the wider Chiba community from their institutional repository as explained in the Japan National Library publication *Current Awareness* (translation) [7].

Not only does Chiba have a more comprehensive picture on research output funded from within Japan but “we also value the references to funders outside of Japan in the CHORUS data where Chiba University researchers have been able to access funding from overseas and where they have collaborated with researchers in other countries,” as Professor Hiroya Takeuchi, Vice President and University Librarian, explained.

The relationships with JST and Chiba since 2016 have been reviewed and highlighted at a number of open science and library events from the end of 2017 through to 2020, most recently with a joint JST/CHORUS workshop in February. Keio University, National Institute for Materials Science, and RIKEN and Tohoku Gakuin University subscribed in 2019 with National Institute for Environmental Studies of Japan and Tokyo Metropolitan Institute of Medical Science joining in 2020.

**Taking it to the Next Level**

Professor Takeuchi touched on something important when he commented, “we expect that CHORUS could be our best route to OA, especially since they began to offer research datasets for integration. We were delighted when CHORUS began to work with SCHOLIX, allowing us to upload links to research datasets in our IR.” What he was referring to was CHORUS’ important new capability: tracking datasets and related code and connecting them to the related publications via the SCHOLIX framework, employing metadata from DataCite and other sources.

The work is an outgrowth of collaboration with organizations (including Enabling FAIR Data Repositories, DataCite, Research Data Alliance, Crossref Funder Registry, and ORCID) that are developing critically needed standards to support researchers with data management requirements, and funding bodies with compliance monitoring. It showcases how CHORUS has continued to find ways to develop better interoperability between existing systems, serve compliance with evolving funder mandates, and further the discovery of and access to funded research outputs.

CHORUS has also created a centralized index of its member publishers’ data availability policies with links to the policies on the publisher’s site. (https://www.chorusaccess.org/resources/chorus-for-publishers/publisher-data-availability-policies-index/). CHORUS plans to integrate the open identifier for institutions now being developed by the Research Organization Registry. While the main focus for now is identification and links to relevant datasets, future efforts could focus on more actively engaging researchers.

Another recent enhancement has been the significant expansion of the published content CHORUS covers. Until last year, CHORUS tracked published articles reporting on research funded by its funder partners. But in 2019, CHORUS began a project to identify all content assigned DOIs that reported on research funded by all agencies worldwide with a funder ID. After the release of the second phase in June 2020, CHORUS now tracks more than 2.4 million research artifacts,
A Path for Tracking Funded Research and Compliance

and has identified more than 260,000 DOIs associated with its publisher members as openly accessible. These totals will continue to rise as newly published and previously uncovered items are identified.

2020 & Beyond

Seven years ago, CHORUS set out to advance sustainable public access via an approach of leveraging existing open infrastructure and working closely with stakeholders. The strategy worked, delivering flexible, neutral, and interoperable solutions as policy implementation progressed and evolved around the world. Measurable progress has been made:

In 2013, funders were rarely identified in articles. Finding relevant datasets was a wish-list item. Reuse licenses were impossible to find. Funders rarely intersected with publishers and articles reporting on funder research were rarely publicly accessible.

Now in 2020, funder IDs are part of publication workflows. Identifying relevant datasets has begun in earnest. Reuse licenses are easier to find. Articles reporting on funder research are much more publicly accessible. Public access and license workflow issues are being enhanced. It is significant that 13 publishers, academic institutions and organizations named CHORUS as a solution for linking data and grant information to publications and facilitating public access to content in their responses to the OSTP RFI on Public Access to Peer Reviewed Scholarly Publications, Data, and Code Resulting from Federally-Funded Research.

One of the most important CHORUS achievements is the collective and transparent way for funders, institutions, publishers, and researchers to work together. To that end, the CHORUS Forum on Open Access Policies and Compliance in a Global Context, https://www.chorusaccess.org/events/forum-on-open-access-policies-and-compliance/, postponed from March due to the pandemic, was rescheduled to 30 July 2020 as an open virtual event. Funders, societies, publishers, and academic institutions came together to examine and discuss the current and future issues about access to publications and data reporting on funded research. Attendees learned about the state of play at government agencies globally regarding access policy, as well how the flow of funding impacts universities, and what Research Offices are doing about the challenges of compliance. In addition, CHORUS co-hosted a free webinar, with the STM and the Center for Open Science, Towards a US Research Data Framework, on 17 Sep 2020.

CHORUS will continue to look for ways to reinforce funders, publishers, and institutions around the world as their needs and capacities to drive open science continue to grow.

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References

1. CHORUS, https://www.chorusaccess.org
In 2020, IUPAC celebrates the 60th anniversary of its scientific journal Pure and Applied Chemistry. The journal was established in part to record written accounts of plenary lectures presented at IUPAC-sponsored conferences. This brought back personal memories and prompted me to take a look in the archives in relation to the beginning of the Natural Products Symposium series. The inaugural IUPAC International Symposium on the Chemistry of Natural Products was also held in 1960, from 15-25 August, in Australia, and was a veritable moving feast from Melbourne to Canberra and Sydney. It was a remarkable event that featured no fewer than five Nobel Laureates and two IUPAC Presidents, and set the stage for a wonderful series of conferences that continues still. Records of that event in Pure and Applied Chemistry are published in 1961, Volume 2, issue 3 [1].

The year 1960 also has special significance for me, as I moved from Sydney to Cambridge in July to begin PhD studies with then Sir Alexander, later Lord Todd. I considered staying in Australia for the IUPAC conference but I accepted advice that there would be many more opportunities in Europe.

The 60th anniversary is an opportunity to reflect on some of the insights revealed by the chemical giants and personalities who exhibited a courteous and respectful style reflective of a less frantic and competitive world than we see today. Despite this, they were always looking keenly to the future of their science. It should immediately be noted that the very first paper in this conference was delivered by Arthur Stoll [2] who was IUPAC President from 1955 to 1959 and was followed by Todd [3], who received the Nobel Prize in 1957 and became IUPAC President in 1963. The last paper in the PAC collection—a Summary of scientific achievements of the Symposium—is authored by Sir Robert Robinson [4] who received the Nobel Prize in 1947. Others would later become Nobel Laureates: Robert Burns Woodward (NP 1965) [5], Sir Derek Barton (NP 1969) [6], and Sir John (Kappa) Cornforth (NP 1975) [7].

Todd’s role was to give an overview of natural product chemistry [3]—review and prospect—and it is rewarding to focus on the prospect and compare his vision with the actual outcome. At the outset, Todd claims “it is undoubtedly true that the study of substances which are found in living organisms has provided most of the major stimuli to the advance of organic chemistry throughout its history, and there is every reason to believe that it will continue to do so.” He also states that “the direct study of substances found in living matter or, more briefly, of natural products, is as old as chemistry itself. It has been evident in organic chemistry throughout its history, although it has only become a dominant feature of the science during the present century.”

Looking then at the development of organic chemistry, Todd notes that it had “progressed to a point where it had the experimental techniques and the background knowledge necessary to ensure real progress in the study of complex natural materials. Furthermore, the rise of the organic chemical industry and the growing outlets for new materials encouraged work on natural materials with the aim of producing synthetic analogues which might at once have their virtues and be free of their defects, just as the synthetic dyes had in many cases proved better than their natural counterparts. Finally, the steady development of scientific medicine and the opening up of tropical colonial territories by the major powers had provided a further stimulus to the search for new natural drugs and their synthetic analogues as well as to the study of bodily components, both normal and pathological.”

More recent technical advances included “the development of reliable microanalytical methods by Pregl,…the introduction of chromatography, first by adsorption on alumina, as developed by Kuhn and Brockmann in particular, then partition chromatography on paper, ion-exchange chromatography, and finally vapour or gas phase chromatography.” For the study of structure, there were the applications of “ultra-violet spectroscopy,…infra-red spectroscopy,…and, even more recently, the new and powerful technique of nuclear magnetic resonance,…and the development of X-ray and electron diffraction methods.”

Now Todd reaches a major point, “in broad terms, it seems to me that for about the first twenty-five to thirty years of the century most organic chemists dealing with natural products were preoccupied almost entirely with the structure of compounds, and paid relatively little attention to their function, which formed the main interest of the biochemists who were becoming increasingly prominent. This preoccupation with structure led, of course, to the development of a vast array of experimental methods...for the synthesis of molecules, and our catalogue of types occurring in nature increased by leaps and bounds...Today the organic chemist’s methods of synthesis are so powerful that it might almost be
said that, macromolecules apart, almost any natural product can in principle be synthesized—and, indeed, this would seem to be emphasized by the successful total synthesis of substances as complex as cholesterol and cortisone, the carotenes, strychnine, chlorophyll, and cozymase. But let us face the fact that, in the past, many people have looked to the natural products merely as suitable materials for exercising chemical ingenuity, rather in the way that one might tackle a difficult crossword puzzle. This kind of approach has doubtless increased our store of actual knowledge, but I doubt myself whether it will nowadays lead to any major advances in science, however convenient it may remain from the standpoint of producing exercises for Ph.D. students, and whatever its commercial importance. It is certainly not in the van of progress today, and it has been dwindling in importance since about 1930. It was about this time that a new interest began to appear, slowly at first and later with increasing rapidity, an interest in structure in relation to function among natural products. It is this which has brought organic chemistry much closer to biology than it has ever been before....And so the advancing front of the subject began to take a definite orientation towards the solution of biological problems.”

Then, after highlighting the importance of natural products research, through providing chemists with a stream of challenging problems, its impact on medicinal chemistry and the pharmaceutical industry, and its role in bringing chemistry closer to biology, Todd looks to the future.

“But what of its significance today? Is it still a developing field and will it retain its importance? My own answer to both questions is yes; the changing pattern of natural product chemistry is to be expected, but the importance of the subject remains. I have already suggested that the older type of structural study applied to isolated plant products is no longer a spearhead in the advancement of the science, but this does not mean that it has everywhere lost its importance from a practical standpoint. We have seen in recent years the medical value and industrial stimulus provided by such a natural alkaloid as reserpine, isolated from plant material for long used in oriental folk-medicine. It is likely that still other substances with significant and valuable pharmacological properties remain to be isolated from plant materials, and that, incidentally, clues to some of them may still be found in the folk-medicine of primitive people....The spectacular success of some antibiotics should not blind us to the possibility

The younger David StC Black with Rita and John Cornforth on 30 May 1985, during one of their visits to the University of Sydney. In 1939, Cornforth left Sydney to study in Oxford with Sir Robert Robinson.
that interesting materials may still be found in the higher plants as well as in the fungi and bacteria. I believe, however, that now and in the future, the real spearhead of the subject will lie in studies closely associated with biological investigations, in studies where questions of structure and function are closely linked. In the animal kingdom, the arthropoda have been relatively little studied by the chemist, partly because of their small size and the trouble associated with collection of material. But they differ in many ways from other types of animal, and, even from our present scanty knowledge of their hormones and their pigments, it is clear that a rich field of investigation lies waiting here. The whole problem of parasitism in plants and animals also lies open. Already, from investigations with nematodes of the Heterodera genus, with which I have myself been concerned, it is clear that the factors which make a parasite specific to one type of host are chemical in nature and, in some cases at least, of relatively low molecular weight. Clarification of such problems in parasitology could be of considerable importance in agriculture and forestry as well as in veterinary and human medicine, and they warrant the most serious attention. It would be possible to provide many examples of such unexplored or partially explored fields, but I would mention here only the natural macromolecules as a further field, a field which includes as its most interesting members the carbohydrates, proteins and nucleic acids. For these macromolecular substances are the very stuff of life, and ultimately it is on progress in their chemical study that a real understanding of enzymology, of immunochemistry, of virology, and of the chemical basis of heredity will depend. These materials present a tremendous challenge to the organic chemist as well as to the biophysicist. For, without in any sense underestimating the vital importance of physical and physicochemical properties in determining the way in which molecules such as those of the nucleic acids behave in the cell, I believe that the chemist still has his contribution to make if we are to solve the problems of the self-replicating molecule and the information code which seems to reside in the natural nucleic acids and which in some way controls the synthesis of specific proteins. But work in these fields is difficult, and it will demand the development of still more refined techniques of experimentation and probably the inclusion of others, heretofore more common in the biochemical field. The new techniques necessary will be found—of that I am sure—and, using them, the future natural products chemist will go forward into these new and exciting fields and will continue as in the past to contribute at once to the advancement of science and to the well-being of the human race.”

It fell to Sir Robert Robinson to provide a summary of the scientific achievements of the Symposium [4]. In doing so, he provides interesting comments on the lectures of Woodward, Barton, and Cornforth—the three future Nobel laureates.

“We were greatly privileged to hear the lecture of Professor Woodward, in which he described, I believe for the first time, the outstanding achievement of the total synthesis of chlorophyll.
Professor Woodward is not only a most brilliant synthetic organic chemist, who gives us metaphorical left hooks and right jabs in bewilderingly quick succession, but also an expositor able to convey a sense of the drama of the development to his audience. His lecture was thoroughly enjoyable, even thrilling, as an experience. No doubt in places he admitted to a little good fortune, though he also made it clear that it was expected.

I was reminded of Benjamin Franklin’s wise saying “Luck is the bonus that accrues to industry”. Well, Woodward and his team were surely industrious. This achievement of the synthesis of chlorophyll is a very good example of the kind of comment that one often sees, “what good is it?” Presumably the “good thing”, as Woodward has so admirably pointed out himself, is the new knowledge that is obtained; increased understanding of the chemistry of chlorophyll, and of how it is likely to behave in a variety of circumstances. We do not know where that new knowledge may lead us, but it is certainly a most important substance and, therefore, we must know everything we can about it.”

Barton presented “some aspects of terpenoid and steroid chemistry” providing a wealth of new alicyclic polycyclic chemistry. Robinson noted that “the brilliant lecture of Professor Barton requires detailed attention for its appreciation.”

Robinson was more expansive in referring to the lecture by Cornforth on “the biosynthesis of polyisoprenoids.” He remarked

“I think that the lecture of Dr Cornforth was another extremely important event in the Symposium—one of the real highlights. The way in which Cornforth was able to describe the complete story of the synthesis of the isopentane skeleton, and then, for example, that of squalene, and through lanosterol to cholesterol and similar compounds, was quite remarkable. It was an extremely well prepared lecture, and of very great value to all of us. We admired the way in which the lecture was delivered, and found the matter, especially that which was contributed by Cornforth himself, quite fascinating.”

However, nothing can match the gracious conclusion of Cornforth’s lecture [7]. “Perhaps I may end on this note, for if even one of those present should be moved to experiment by the story I have tried to tell, then your patience in hearing it might be rewarded.”

Robinson’s more general concluding remarks summarized the value of international symposia.

“Running right through the Symposium were lectures and other contributions dealing directly with the methods and principles, physical and physicochemical, applicable to the determination of molecular structure, or to various examples of the use of such techniques in the solution of particular problems….Enthusiastic physicists and physical chemists are entirely justified in the exclusion of the organic chemist in order to prove a point, namely, their contention that it is possible to determine molecular structure by physical methods alone. Although this is true, it must not be supposed that the molecular structure is the be-all and end-all of the matter. It has been the objective of the classical organic chemist, who has approached molecular structure by the methods of analysis and synthesis which are familiar to all of us. But the great value of this work has been the approach—the analysis and the synthesis—and the region of chemistry which has been explored in that way. It has not been, perhaps, so much the final result. Even if we know the structure, we shall still have to explore the surrounding chemical territory….The scientific value of a symposium such as this is not wholly concentrated in the contributions. The opportunities it affords for personal contacts and discussions are also exceptionally valuable. That, I think, is part of the true raison d’être of a symposium such as this. It has been without question the most successful which I have ever followed. Never before has there been a symposium, concentrated on this section of organic chemistry, in which so many really significant papers have been delivered. Clear evidence of the enthusiasm of organic chemists in the last twenty years has been presented. The resurgence of interest has evidently been connected with the powers conferred by new techniques, which investigators have been as quick to adopt as the delays in delivery of apparatus permitted….Naturally, the micro-methods, of analysis and manipulation, and the new physical methods of examination of the products have taken much of the tedium from our bench work and freed us for the harder tasks. The availability of isotopes has enormously stimulated interest in biogenesis because this can now be studied experimentally, instead of from the conjectural point of view; all these things have come together to produce a flood of research, of which
we have had the clearest evidence in this Symposium. It has, therefore, been a most significant occasion, and we hope that it will be repeated, as is promised, in Czechoslovakia in 1962."

Indeed it was, and has been repeated up until the present time, in what is one of the most successful conference series sponsored by IUPAC. In recent years the thematic material has been expanded by the merger of the Natural Products series with the younger Biodiversity conference series. It will continue to adapt to stimulate the important developments in this important area of chemistry.

As a personal footnote, although I failed to attend the inaugural conference in Australia, I did participate, as a graduate student, in the second one in Prague in September 1962. Todd was there of course and introduced me to Guy Ourisson—a future IUPAC Secretary General (1975-1983)—who invited me and another Todd student to visit him in Strasbourg on our return by car to Cambridge. So we attended a Saturday morning seminar and were taken by Ourisson to lunch with the speaker and some local students—which is where I met for the first time the future Nobel laureate Jean-Marie Lehn.

So when I was asked in 2003 to run for IUPAC Secretary General, I immediately thought of Ourisson and figured if it was good for him, I would be honoured to do it too.

References

David S.C. Black <d.black@unsw.edu.au> is a professor of organic chemistry at the University of New South Wales in Sydney, Australia. He was IUPAC Secretary General from 2004 to 2011 and has been a member for more than 25 years. Following his service to IUPAC, he became the Secretary General of ICSU (now as the International Science Council, ISC), position that he held until 2018.
Every two years, IUPAC holds an election for its officers and committee members. About 120 individuals are to be elected or reelected either as Titular Members, Associate Members, or National Representatives. Information concerning the voting process and the role of each kind of member is contained in the Union bylaws (see https://iupac.org/who-we-are/organizational-guidelines/).

Any qualified individual who is interested in being nominated is invited to contact his/her National Adhering Organization (NAO) and/or the current committee officers. The election will cover a two-year term that will start in 2022. Every division committees and standing committees will have vacancies. As part of the nomination procedure, NAOs are invited to submit curriculum vitae for each nominee to the IUPAC Secretariat no later than 1 February 2021.

In addition, Affiliate members in good standing who are current for the years 2020 and 2021 are eligible to participate in the nomination process via self-nomination. They are eligible for AM positions on Divisions and Standing Committees, irrespective of country of residence. Similarly, employees of current Company Associates are eligible for AM positions.

Elections for each committee will take place during the second trimester of 2021 and the 2022–2023 memberships for all committees will be finalized during the next IUPAC General Assembly in August 2021.

Individuals interested in becoming IUPAC officers or members of the IUPAC Bureau should contact their NAOs. Nominations for officers have a different timeline and can only be made by an NAO. Officers elections will take place at the Council Meeting during the next General Assembly in Montreal.

Expected duties and qualifications

Each member of an IUPAC body (Division, Standing Committee, or Commission) is expected to become an active participant in the work of the body in helping to decide on the program and in reviewing proposals for projects. These duties require the members to have expertise in the relevant disciplinary area and also to be able to exercise sound scientific judgment. Much of each Committee’s work is conducted by e-mail correspondence.

In a concerted effort to improve membership diversity, nominations for well-qualified female chemists, “younger” chemists with the required expertise, and industrial chemists are encouraged. Each nomination for consideration for membership on a Division or Standing Committee or Commission must identify the intended Committee or Commission and must be accompanied by a curriculum vitae. Each nominee will be considered for all vacant positions on the Committee unless otherwise specified. Nominations will only be accepted through the online form, to be available 15 October 2020.

Contact information for all NAOs and division and standing committee officers is available on the IUPAC website, or upon request at the IUPAC Secretariat; e-mail <secretariat@iupac.org>.

IUPAC Announces the 2020 Top Ten Emerging Technologies In Chemistry

IUPAC has released the results of its 2020 search for the Top Ten Emerging Technologies in Chemistry. The goal of this project is to showcase the value of Chemistry and to inform the general public as to how the chemical sciences contribute to the well-being of society and the sustainability of Planet Earth. Following the same guidance as it did last year, the jury identified emerging technology as one in between a new scientific discovery and a fully-commercialized technology, and one that has the capacity to open new opportunities in chemistry and beyond. The 2020 finalists are (in alphabetical order):

- Aggregation-induced emission
- Artificial intelligence
- Dual-ion batteries
- High-pressure inorganic chemistry
- Liquid gating technology
- Macromonomers for better plastic recycling
- Microbiome and bioactive compounds
- Nanosensors
- Rapid diagnostics for testing
- RNA vaccines

“The selected technologies will change our world for the better, making a more thoughtful use of our resources, favoring more efficient transformations, and providing more sustainable solutions in applications ranging from new materials and more efficient batteries to extremely precise sensors and personalized medicine” wrote Fernando Gomollón-Bel in a feature published in this issue Chemistry International (see page 3) outlining details of each of these technologies. The jury was an international group of objective and unbiased experts.
who reviewed and discussed a pool of nominations, and ultimately selected the final top ten.

The first selection of Top Ten Emerging Technologies in Chemistry was released in 2019 as a special activity in honor of IUPAC’s 100th anniversary; the results were published in the April 2019 (Chem Int, 41(2), pp. 12-17, 2019; https://doi.org/10.1515/ci-2019-0203).

The next search for the Top Ten Emerging Technologies in Chemistry is on and the deadline for nomination is 31 March 2021. The search will be led again by Prof. Dr. Michael Droescher.

https://iupac.org/what-we-do/top-ten/

* The following comprised the panel of judges for the 2020 Top Ten Emerging Technologies in Chemistry: Michael Droescher, Chair, (Treasurer and General Secretary of the German Association for the Advancement of Science and Medicine) Javier García-Martínez (Universidad de Alicante, Spain), Ray Kookana (CSIRO Land & Water, Australia), Ken Sakai (Kyushu University, Japan), and Bernard West (Life Sciences Ontario, Canada).

2021 IUPAC-Solvay International Award for Young Chemists—Call for applicants

The 2021 IUPAC-SOLVAY International Award for Young Chemists is intended to encourage outstanding young research scientists at the beginning of their careers. The awards are given for the most outstanding Ph.D. theses in the general area of the chemical sciences, as described in a 1000-word essay. The award is generously sponsored by Solvay.

In 2021 IUPAC will award up to five prizes. Each prize will consist of USD 1000 cash award and up to USD 1000 of travel expenses to the 2021 IUPAC Congress in Montréal (13-20 Aug 2021; see iupac2021.org) where the awards will be presented. Each awardee will be invited to present a poster on his/her research and to participate in a plenary award session, and is expected to submit a review article for publication in Pure and Applied Chemistry.

In keeping with IUPAC’s status as a global organization, efforts will be made to assure fair geographic distribution of prizes.

Complete applications must be received at the IUPAC Secretariat by 15 February 2021.

For criteria, procedure and application form, see https://iupac.org/2021-iupac-solvay-international-award-for-young-chemists/

2021 Distinguished Women in Chemistry or Chemical Engineering Award—Call for nominations

IUPAC is pleased to announce the call for nominations for the IUPAC 2021 Distinguished Women in Chemistry or Chemical Engineering Awards. The purpose of the awards program, initiated as part of the 2011 International Year of Chemistry celebrations, is to acknowledge and promote the work of women in chemistry/chemical engineering worldwide.

In 2011, 23 women were honored during a ceremony held at the IUPAC Congress in San Juan, Puerto Rico, on 2 August 2011. At each of the subsequent IUPAC Congresses, 12 women received this recognition; in Istanbul, Turkey in 2013, in Busan, Korea in 2015, in Sao Paulo, Brazil in 2017, and in Paris, France in 2019. A similar award ceremony will take place during the 2021 IUPAC Congress in August 2021 in Montreal, Canada.

Awardees will be selected based on excellence in basic or applied research, distinguished accomplishments in teaching or education, or demonstrated leadership or managerial excellence in the chemical sciences. The Awards Committee is particularly interested in nominees with a history of leadership and/or community service during their careers.

Each nomination requires a primary nominator and two secondary nominators who must each write a letter of recommendation in support of the nomination. A CV of the nominee is required. Self-nominations will not be accepted. Nominations should be received by 1 December 2020.

For additional information on the IUPAC 2021 Distinguished Women in Chemistry Awards, contact Fabienne Meyers at <fabienne@iupac.org>.

https://iupac.org/2021-women-in-chemistry/
IIUPAC Awards in Analytical Chemistry—Call for nominations

The Analytical Chemistry Division of IUPAC has established two awards, including:

- The Emerging Innovator Award in Analytical Chemistry—an award to recognize outstanding work undertaken by an emerging analytical scientist that corresponds to the aims of the Analytical Chemistry Division.
- The IUPAC Analytical Chemistry Medal—an award to recognize a significant lifetime contribution to the aims of the Analytical Chemistry Division.

The awards are open worldwide to researchers working in the field of analytical chemistry. The Emerging Innovator Award is for researchers who are at an early stage of their independent career, as measured by the completion of a PhD within the last ten years. Appropriate consideration will be given to those who have taken a career break or followed a different study path. Nominations must be based on published works in the field of analytical chemistry. The Analytical Chemistry Medal is for researchers who have a substantial record of achievements demonstrated by the number and quality of their publications, by being actively involved in international partnerships as well as by their commitment in the training of the next generation of analytical chemists.

The Award will be presented every two years during the IUPAC General Assembly/World Chemistry Congress. The awardees will be invited to the meeting of the Analytical Chemistry Division to receive their award and to present a lecture.

Complete applications must be received via the submission form no later than 31 January 2021.

Medal The Prize is managed by the Analytical Chemistry Division (ACD, Division V) of IUPAC. For information, please contact IUPAC by email at <ACD-award@iupac.org>.

https://iupac.org/iupac-awards-in-analytical-chemistry-call-for-nominations/

UMRS Survey on the Evolution of Scientific Publishing

In 2018, the International Union of Materials Research Societies (IUMRS) initiated a survey with the intention of collecting opinions and some related demographics which, when aggregated, may provide a fresh perspective on the scientific publishing enterprise from viewpoint of the very people who are most closely affected by it.

The results represent an attempt to portray the current attitudes and actions connected with the broad topic of scientific publishing, as perceived by many different communities served by, or dependent upon, the publication process. The report, in its full 57 pages, includes the detailed analysis of responses from various types of respondent. Some broad conclusions are presented, while common themes repeatedly arise. They reflect a general concern about several major aspects of the social and professional environment in which we work. These include:

- Widespread unhappiness with the linkage between personal or professional success and both the number of publications produced and the obligation to publish in journals with high impact factor.
- Concern about the proliferation of new narrowly focused journals designed for easy acceptance of low-quality manuscripts.
- An ongoing concern about the fairness and objectivity of the peer-review system.
- A concern about the wide range of fees charged for open access publication as well as about non-uniform subscription costs paid by various subscribers—ranging from university libraries to individual projects and funding agencies.

The data analysis and full text report (PDF 57 pages) is available online at https://tinyurl.com/SurveyAnalysis-and-Report.
Open Science for a Global Transformation: CODATA-coordinated submission to the UNESCO Open Science Consultation

UNESCO is preparing a Recommendation on Open Science to be adopted by Member States in 2021. To contribute to this process, UNESCO launched a global consultation gathering inputs from all regions and all interested stakeholders, through online consultations, regional and thematic meetings and numerous debates on implications, benefits and challenges of Open Science across the globe. Following exchanges on the CODATA International Discussion list, CODATA agreed to coordinate a joint response from a number of data and information organisations. That document—Open Science for a Global Transformation—was submitted to UNESCO on 15 June and, following minor editorial adjustments: https://doi.org/10.5281/zenodo.3935461

Open Science is best characterised as the necessary transformation of scientific practice to adapt to the changes, challenges and opportunities of the 21st century digital era to advance knowledge and to improve our world. This requires changes in scientific culture, methodologies, institutions and infrastructures. These changes are already present in many research domains and institutions, where their transformative effects can be witnessed, but they are unevenly distributed. One of the purposes of Open Science viewed as a call for transformation, is to ensure that “no-one is left behind.”

Open Science for a Global Transformation was prepared by an expert group, coordinated by CODATA and including representatives from the ISC World Data System (WDS), GO FAIR and the International Council for Scientific and Technical Information (ICSTI). These global data and information organisations have responsibilities for policy advice and promoting collaborations in relation to data and information; they are advocates of Open Science and are convinced of its necessity and benefits. The organisations believe—fundamentally—that it is important to win hearts and minds, to significantly transform science policy and practice, in order to facilitate the application of the technologies and methodologies associated with Open Science to improve our world and address global challenges. Open Science requires policy interventions and investments to ensure equitable participation and access to its benefits and to mitigate some negative consequences. The perspective brought by these organisations lays particular emphasis on maximising appropriate access to (re-)usable data.

https://codata.org/open-science-for-a-global-transformation-codata-coordinated-submission-to-the-unesco-open-science-consultation/

The IUPAC Periodic Table Challenge available in multi-language

Mid July, IUPAC and the Egyptian Academy of Scientific Research and Technology (ASRT) have launched the Arabic version of the Periodic Table Challenge. The challenge is targeting young people and students around the world and an Arabic version of the challenge will extend participation from the Middle East and North Africa region.

The English version of PT Challenge 2.0 was launched in June, and during the first six weeks over 15,000 tests have been taken from 110 countries/regions. Arabic is the second language for this challenge. The challenge provides basic information about periodic table elements in the form of multiple-choice questions divided into different levels: beginners, intermediate and advanced. At the end of the challenge the players are able to find all the correct answers, to enrich their knowledge of the chemical elements. The original PT Challenge took place last year, the International Year of the Periodic Table (IYPT2019), and was highly successful.

Prof. Mahmoud Sakr, ASRT president said “the launch of the periodic table challenge in Arabic is part of ASRT’s endeavor to promote scientific culture in society.” He added “looking at the map of PT challenge participants, we noticed the weak participation from the Arab region. We hope that an Arabic version of the challenge will allow better participation from the Arab region.” Prof. Sameh Soror, the supervisor of scientific and culture relations at ASRT and responsible for the preparation of the Arabic version of the challenge said “providing the challenge in the Arabic language was an initiative from ASRT, as part of its role to promote scientific culture all over the Arab world. It reflects its care to offer a fair chance for Arab youth to participate in such festive international activity regardless of any language barriers.”

The ability to incorporate multiple languages is a noticeable enhancement of the PT Challenge platform. This initiative represents a step towards the long-term
goal of having a multi-language Periodic Table Challenge to better reach IUPAC global communities. Besides Arabic, the multi-language pilot now also offers the PT Challenge in Chinese and in Spanish. For the Chinese version, the translation has been provided by the Chinese Chemical Society (Lidong Han, et. al.) and for the Spanish version, the translation was prepared by Sergio Menargues and Javier García-Martínez.

Prof. Christopher Brett, IUPAC president said “It is very encouraging to see the huge enthusiasm and interest that has been generated worldwide by the PT Challenge and will certainly be enhanced by its being available in other languages.”

If you have an interest in supporting an effort to have a language that is important to your involvement in the Periodic Table Challenge, made available to the global science and chemistry community, please contact Dr. Lynn Soby <executivedirector@iupac.org>.


Emeritus Fellows

Starting in 2020, IUPAC has established across all Divisions a new category of membership—Emeritus Fellow—that is to be bestowed upon meritorious individuals who have earned by service a special recognition upon their retirement from one or more Division administrative positions or from a multiple of key Division Project roles.

Emeritus Fellows retain a standing invitation to attend Division and Subcommittee Meetings appropriate to their interest and technical background and are kept abreast of Division activities. Fellows are encouraged to remain active with the Divisions as ad hoc consultants and can still hold future IUPAC position and participate in future IUPAC Projects. The Chemistry and Human Health Division (Div VII) has had such a EF program since 2010.

Thus far the 2020 class of Emeritus Fellows includes:

Polymer Division (Div IV)

Prof. Michael Buback (Germany) - Member since 1997; Division President in 2012-2015

Prof. Jung-II Jin (Korea) – Member since 1991; Division President in 2006-2007 and IUPAC President in 2008-2009

Prof. Richard (Dick) G. Jones (UK) - Member since 1997

Chemistry and the Environment (Div VI)

Dr. Laura L. McConnell (US) – Member since 2004; Division President in 2012-2015

Chemistry and Human Health (Div VII)

Prof. Michael Schwenk (Germany) - Member since 2004; Division Secretary from 2010 to 2016; currently corresponding member with the Interdivisional Standing Committee on Green chemistry for Sustainable Development.

Chemical Nomenclature and Structure Representation (Div VIII)

Prof. G. Jeffery Leigh (UK) – Member since the late 60s starting in the Inorganic Chemistry Division (Div II); Div II President in 1996-1997. Member on Div VIII starting its creation inception in 2002.

Dr. Alan McNaught (UK) – Member since the later 70s, starting on the Commission on Nomenclature of Organic Chemistry; later member on the Division of Organic Chemistry (Div III) and on the IUBMB-IUPAC Joint Commission on Biochemical Nomenclature. In the 90s, members and Secretary on the Interdivisional Committee on Nomenclature and Symbols (IDCNS), and also member on the Committee of Printed and Electronic Publications. First Div VIII President from 2002 to 2005.

Dr. Warren Powell (USA) – Member since the mid 60s, first in the subcommittee on carotenoid nomenclature. Later member and secretary (for 10 years) of the Commission on Nomenclature of Organic Chemistry, member of Div III and of IDCNS. First Secretary of Div VIII from 2002 to 2007.

The selection and appointment are coordinated by each Division. Biographical curricula vitae of each fellows are available online.

https://iupac.org/who-we-are/emeritus-fellows/

CI Green is back, online

For about 24 years, from 1979 to 2003, Chemistry International was print only and easily recognizable with its glossy green cover. It was so green that it stained the readers fingers! Today, the early volumes of CI are freely available online, and without stains.
Working with the Internet Archive, the project of digitizing the print collection has been recently completed. The scanning and processing were managed by Tim Bigelow in Boston. For each volume, high-quality, text-searchable PDF files have been created. The collection is part of Internet Archive search and each volume is displayed via their open source Book Reader.

Making the collection available online is a CI present to IUPAC100 and a gift to the community of scientists and historians interested in the stories surrounding the Union in the ’80s and ’90s. In the Epilogue of the CI Special IUPAC 100 issue (July 2019, p. 58), Brigitte Van Tiggeelen issued a call to arms and asked anyone who has historical materials to share it. She and her colleagues, who contributed to that special issue, have presented fascinating accounts of specific aspects or point-in-time in the early years of the Union. A closer look at the last decades of the 20th century will no doubt be equally interesting. Therefore it became evident to this CI editor that one small step forward was to make CI archives digital and broadly available online.

Curious wonderers will rejoice flipping through these pages, discovering the Union’s recent past. Over the years, the styles evolved and each successive editors left their marks. To start, it was Martin Gellender until 1982, followed by Roger Fennell until 1985, and Michael Freemantle for about 10 years until July 1994. Following that longer steady period Michael Ward appeared as acting editor for a couple of years until John Jost took the baton in 1997. Then, Alan Senzel managed CI from 1999 to 2001 and at last, starting in 2002, Fabienne Meyers morphed CI into the magazine you still receive today, implementing colors and an online version in 2003.

The Internet Archive is a non-profit building a digital library of Internet sites and other cultural artifacts in digital form. Like a paper library, they provide free access to researchers, historians, scholars, the print disabled, and the general public. It began in 1996 by archiving the Internet itself. Today they have 20+ years of web history accessible through the Wayback Machine and they work with 625+ library and other partners through their Archive-It program to identify important web pages.

https://archive.org/details/chemistryinternational
Nomenclature of Sequence-Controlled Polymers

The field of sequence-controlled polymers has grown considerably during the last years (even though first approaches have been around for more than 50 years) and it has become a major topic in fundamental polymer science [Science 341, 1238149 (2013); Sequence-Controlled Polymers, Jean-François Lutz (Editor), Wiley-VCH 2018, ISBN: 978-3-527-34237-2]. A growing number of synthetic approaches allow for the synthesis of more and more precise polymers that feature a defined sequence of incorporated monomer units without a currently existing nomenclature and terminology. Hence, until today, no IUPAC nomenclature and terminology recommendations have been worked out for this class of precision polymers. Yet, first attempts of a glossary have been collected recently [Macromol. Rapid Commun. 38, 1700582 (2017)].

A nomenclature for the class of sequence-controlled polymers is challenging because the degree of precision along a polymer chain can dramatically vary. Sequence-controlled polymers cover non-natural macromolecules and bio-hybrid polymers that aim to mimic structurally defined natural occurring polymers (e.g. DNA, proteins). On one hand, a completely precise sequence of incorporated monomers can be installed leading to sequence-defined oligomers/polymers with lower molecular weights and dispersities approaching or being $D = 1.0$, while on the other hand the synthesis of multiblock copolymers with overall higher molecular weights (and $D > 1.0$) but leads to distributions of incorporated monomer units for each sequential step (i.e. sequence-controlled polymers). Accordingly, the synthetic approaches to polymers with a perfect sequence control and low molecular weights have to be compared to the approach with a less perfectly defined sequence control but with higher molecular weight. Yet, it is important to note that with synthetic advances this gap between sequence-defined and sequence-controlled polymers is about to vanish. Therefore, clear classifications have to be given, which shall be defined within the present project. To cope with the diversity of polymers and their synthesis (ranging from chain polymerization, addition polymerizations and polycondensations to solid-phase synthesis) the following proposed subprojects will be worked on:

- Precise positioning of single units along a polymer chain
- Sequence-controlled polymers
- Sequence-defined oligomers/polymers
- Degree of irregularity allowed in a sequence-defined polymer
- Stereoisomers
- Generalized structures as reduced structure motifs

The task group will collect and review all reported cases in the scientific literature of sequence control in polymer synthesis in order to work out a first set of rules for the development of a nomenclature. Emphasis will be laid on monomer sources suitable for precision sequence-control. The main task will be to develop and unify the recommendations for nomenclature of polymer structures with different degree of precision of sequence control. Additionally, considerations for recommendations for nomenclature of multiblock (segmented) copolymers will be given.

In all cases, the analogy and in ideal cases, the compatibility with nomenclature recommendations for polypeptides should be maintained. At the moment, the discipline of sequence-controlled polymers is rapidly taking momentum and definitions and terminologies are still malleable and should be manifested as soon as possible. Consequently, the present project will provide a recommended terminology.

For more information and comments, contact Task Group Chair Patrick Théato <patrick.theato@kit.edu> | https://iupac.org/project/2019-041-3-400

ChemVoices—IYCN-IUPAC Younger Chemists Showcase

During the IUPAC Congress 2019 the final inductees into the IUPAC100 Periodic Table of Younger Chemists were announced. Those who were recognized with the award of an element (the PTChemists as they are affectionately known) were selected as a result of their contribution to the scientific community and their embodiment of IUPAC’s core values. As an extension of this legacy project, IUPAC and IYCN are once again partnering to recognize early-career chemists around the world with a monthly webinar series called ChemVoices. The overall goal of ChemVoices is to provide a platform through which early-career researchers can discuss issues that are relevant, and of immediate concern to them, while simultaneously giving them a platform to highlight their impact on the broader scientific community.

ChemVoices webinars will be headlined by the PTChemists, with additional presentations given by
Digital Representation of Units of Measure

The current state of the digital representation of units of measure across domains is a significant problem relative to the interoperability of data. Across the scientific disciplines there is a wide variety of knowledge about, focus on, and care with the recording of a unit of measure with each piece of experimental, calculated, modeled or derived data. Much information is available for annotation of units for humans, however there is no authoritative source for how to represent and store units of measures (in any units’ system) in digital systems. This is a fundamental problem for data science currently and a major problem for the future integration of large, heterogeneous datasets both within and across disciplines. It is the most important single issue for the development of general or domain repositories, for the ideas behind Big Data and Open Data and the implementation of systems that support Findable, Accessible, Interoperable, and Reusable (FAIR) data.

To finalize the first phase of ChemVoices, an event at IUPAC2021 will be held to celebrate the PTChemists and all of those who participated in the webinars. Whilst still in the early stages of our planning, we are additionally working to enhance the programming and opportunities for early-career researchers at IUPAC2021, with this event being a key piece in that effort.

We are excited to bring ChemVoices to life, and we encourage you all to visit the website: www.ChemVoices.org to learn more about the team behind the webinars, and to register for our next event!

For more information and comments, contact Task Group Chair Lori Ferrins <l.ferrins@northeastern.edu> | https://iupac.org/project/2020-012-2-020 | https://chemvoices.org/
On the discovery of new elements (IUPAC/IUPAP Report)


Pure and Applied Chemistry, 2020
published online ahead of print 4 Aug 2020
https://doi.org/10.1515/pac-2020-2926

Almost thirty years ago the criteria that are currently used to verify claims for the discovery of a new element were set down by the comprehensive work of a Transfur- mium Working Group, TWG, jointly established by IUPAC and IUPAP. The recent completion of the naming of the 118 elements in the first seven periods of the Periodic Table of the Elements was considered as an opportunity for a review of these criteria in the light of the experimental and theoretical advances in the field. In late 2016 the Unions decided to establish a new Joint Working Group, JWG, consisting of six members determined by the Unions. A first meeting of the JWG was in May 2017. One year later this report was finished. In a first part the works and conclusions of the TWG and the Joint Working Parties, JWP, deciding on the discovery of the now named elements are summarized. Possible experimental developments for production and identification of new elements beyond the presently known ones are estimated. Criteria and guidelines for establishing priority of discovery of these potential new elements are presented. Special emphasis is given to a description for the application of the criteria and the limits for their applicability.

https://iupac.org/project/2017-014-2-200

A concise guide to polymer nomenclature for authors of papers and reports in polymer science and technology (IUPAC Technical Report)

Hodge, P., Hellwich, K., et al.

Pure and Applied Chemistry, 2020
Volume 92(5), 797-813
https://doi.org/10.1515/pac-2018-0602

It is the goal of the IUPAC Polymer Division and the IUPAC Division of Chemical Nomenclature and Structure Representation to improve communication between polymer scientists and chemists and scientists in general by recommending unambiguous, standardized, and universally understood names and structure representations of polymers. The concise guide to polymer nomenclature is based on official IUPAC recommendations. In the online version of the report, the main points carry hyperlinks to the source documents and IUPAC color books, i.e. the Gold Book, Purple Book (polymers), Blue Book (organic chemistry), etc.

The report includes sections on source-based nomenclature, on structure-based nomenclature, on traditional names of polymers, on abbreviations, and on polymer class names.

https://iupac.org/project/2008-020-1-400

IUPAC Provisional Recommendations

Provisional Recommendations are preliminary drafts of IUPAC recommendations. These drafts encompass topics including terminology, nomenclature, and symbols. Following approval, the final recommendations are published in IUPAC’s journal Pure and Applied Chemistry (PAC) or in IUPAC books. During the commentary period for Provisional Recommendations, interested parties are encouraged to suggest revisions to the recommendation’s author.

Structure-Based Nomenclature for Irregular Linear, Star, Comb and Brush Polymers
Comments by 31 December 2020
Corresponding Author: Jiazhong Chen <Jiazhong.Chen@dupont.com>
https://iupac.org/project/2019-036-1-800

https://iupac.org/recommendations/under-review-by-the-public/

Metrological and quality concepts in analytical chemistry
Comments by 31 December 2020
Corresponding Author: D. Brynn Hibbert <b.hibbert@unsw.edu.au>
https://iupac.org/project/2012-007-1-500
Interlaboratory comparison of humic substances compositional space as measured by Fourier transform ion cyclotron resonance mass spectrometry (IUPAC technical report)

Zherebker, A., Kim, S. et al.
Pure and Applied Chemistry, 2020
published online ahead of print 18 Aug 2020
https://doi.org/10.1515/pac-2019-0809

Interlaboratory comparison on the determination of the molecular composition of humic substances (HS) was undertaken in the framework of IUPAC project 2016-015-2-600. The analysis was conducted using high resolution mass spectrometry, nominally, Fourier transform ion cyclotron resonance mass spectrometry (FTICR MS) with electrospray ionization. Six samples of HS from freshwater, soil, and leonardite were used for this study, including one sample of humic acids (HA) from coal (leonardite), two samples of soil HA (the sod-podzolic soil and chernozem), two samples of soil fulvic acids (FA) (the sod-podzolic soil and chernozem), and one sample of freshwater humic acids (the Suwannee River). The samples were analyzed on five different FTICR MS instruments using the routine conditions applied in each participating laboratory. The results were collected as mass lists, which were further assigned formulae for the determination of molecular composition.

The similarity of the obtained data was evaluated using appropriate statistical metrics. The results have shown that direct comparison of discrete stoichiometries assigned to the mass lists obtained by the different laboratories yielded poor results with low values of the Jaccard similarity score—not exceeding 0.56 (not more than 56% of the similar peaks). The least similarity was observed for the aromatics-rich HA samples from leonardite (coal) and the chernozem soil, which might be connected to difficulties in their ionization. The reliable similarity among the data obtained in this intercomparison study was achieved only by transforming a singular point (stoichiometry) in van Krevelen diagram into a sizeable pixel (a number of closely located stoichiometries), which can be calculated from the population density distribution. The conclusion was made that, so far, these are descriptors of occupation density distribution, which provide the metrics compliant with the data quality requirements, such as the reproducibility of the data measurements on different instruments.

https://iupac.org/project/2016-015-2-600

Structure, processing and performance of ultra-high molecular weight polyethylene (UHMWPE) (IUPAC Technical Report) (4 parts)

Part 1: characterizing molecular weight
Part 2: crystallinity and supra molecular structure
Part 3: deformation, wear and fracture
Part 4: sporadic fatigue crack propagation

Clive Bucknall, Volker Altstädt, et al.
Pure and Applied Chemistry, 2020
published online ahead of print 24 Aug 2020

The aim of this project was to study the efficacy of current methods of quality control and quality assurance for ultra-high molecular weight polyethylene (UHMWPE) products, and find improvements where possible. Intrinsic viscosity tests were performed on three grades of polyethylene with weight average relative molar masses of about 6x10⁵, 5x10⁶, and 9x10⁶. Results from three laboratories showed substantial scatter, probably because different methods were used to make and test solutions. Tensile tests were carried out to 600% extension at 150 °C under both constant applied load and constant Hencky strain rate, on compression mouldings made by a leading manufacturer of ultra-high molecular weight polyethylene. They gave low values of \( M_w \), suggesting incomplete entanglement at ‘grain boundaries’ between powder particles. Results from conventional melt-rheology tests are presented, and their relevance to quality control and assurance is discussed. Attempts to calculate molecular weights from these data met with limited success because of extended relaxation times. Suggestions are made for improving international standards for intrinsic viscosity testing of UHMWPE, by investigating the various factors that can cause significant errors, and by introducing methods for checking the homogeneity (and hence validity) of the solutions tested.

Part 2 addresses characterization of crystallinity and structure. Part 3 covers mechanical properties, and Part 4 focuses on the sporadic crack propagation behavior exhibited by all three grades of UHMWPE in fatigue tests on 10 mm thick compact tension specimens.

https://iupac.org/project/2010-019-1-400
Women in their Element


reviewed by Neil Gussman

My delight in reading the book *Women in their Element* begins with the title. The play on words in the title says the place of women is in the research lab while echoing the theme made explicit in the subtitle “Selected Women’s Contributions to the Periodic System.” The work of the 38 women profiled in the book’s 500 pages covers four centuries up to nearly present day. From these essays readers learn about some of the contributions women have made to the periodic table of elements over several centuries.

The stories illuminate both the place of women in the history of chemistry and the struggle of taking their place in a world that ranged from skeptical to hostile. But this is a solid work of the history of science which does not lapse into imagined narratives or sentimentality. Each story has solid documentation and is a work of scholarship, yet the stories are entertaining and give real insight into the history of scientific discovery.

In most of the essays in this book, women are shown collaborating to achieve a discovery or insight. For those outside the world of discovery, the dominant narrative focuses on the lone genius who makes a great discovery in a flash of insight. But those moments of genius came most easily to those who had support by teams of collaborators, trained assistants, and the machinery of the modern university system. The collaborative method is how most science is done, and this book shows pioneers in chemistry as pioneers in collaboration.

The book is divided into seven parts covering large themes in chemical discovery. Since the book is part of the celebration of the Year of the Periodic Table in 2019, it’s appropriate that the biggest sections are parts 2 and 4, with 7 and 10 essays respectively:

Part 2—The Glory of Analytical Chemistry: The Elements Multiply

Part 4—Clusters of Women in Radioactivity

Part 2 begins with “Elementary Chemistry: Mrs. Jane Marcet and the Popularisation of Chemistry.” In this essay we learn how one woman who knew many leading chemists at the beginning of the 19th Century brought chemical science to the general public. One of her “Conversations in Chemistry” is reproduced in the essay, showing how Marcet explains chemistry to someone who sees the elements as “fire, air, earth and water.”

On the following page is a table listing the twenty elements discovered by Marcet’s friends and contacts: Humphrey Davy, J.J. Berzelius and his students, William Wollaston, Smithson Tennant and Charles Hachett. Her friends discovered more than one in five of the naturally occurring elements.

The ten essays of Part 4 begin, appropriately, with “Marie Skłodowska Curie—Polonium and Radium” and continues through nine more essays on the whole world of chemistry that opened up in the nuclear age. One of those essays concerns the career of Lise Meitner. In contrast with Curie, who won both the Nobel Prize in both Physics and Chemistry, Meitner was nominated 19 times for the chemistry prize and 29 times for the physics prize and won neither. But the woman who discovered protactinium was eventually enshrined in the Periodic Table of Elements when the element 109 was named meitnerium.

Throughout the rest of the book are essays that illuminate the worlds women of discovery inhabited. The second essay in Part 1 is on Émilie du Châtelet. It is a fascinating story of a short, brilliant and tragic life. In
Bookworm

Part 3 are six essays on how the development and use of new instruments change chemistry and chemical discovery. Part 5 and 6 show the reader many aspects of “Big Science” and the interface between science and industry. Part 6 ends with the fascinating story of Reatha Clark King and her work with fluorine. Part 7—“Social Activism, Sisters in Arms” ends with two essays on the uses and dangers of lead; a look at the darker side of the century of chemical discovery.

The thematic division of the book continues into the three indices at the book’s end. There is an Element Index which includes old and new element names, so fire, air, earth and water are listed; a Name Index with organizational names as well people, and a General Index for everything else.

Sweden is the only country listed in the Element Index. Under Sweden are the fifteen elements discovered in this Nordic country that is the home of Alfred Nobel. Radium is the element with the most references in the index, partly because Marie Curie is the most referenced name in the Name Index. The indices are very useful and fun to browse to look for themes in the book. The International Union of Pure and Applied Chemistry is referenced six times in the Name Index.

The book could be used in many ways for those studying women in chemistry, scientific innovation, the history of discovery of elements, as well as larger themes of radioactivity, social activism and the history of science. Women in their Element brings together 38 stories over four centuries that put women at the center of the long story of discovery that takes the world from “fire, air, earth and water” to the Periodic Table of Elements in all of its complexity.

For Science, King & Country: The Life and Legacy of Henry Moseley


reviewed by D. Brynn Hibbert

Henry (“Harry”) Gwin Jeffreys Moseley (1887–1915) was, or perhaps would have been, the pin-up scientist of a world entering the atomic age. In this well-produced, extensively-illustrated collection of essays coming from thirteen scholars we have “a more detailed analysis” of his life and research as promised by the editors in the preface to the book. They were prompted by the 2015 exhibition Dear Harry … Henry Moseley: A Scientist Lost to War at the Museum of the History of Science at Oxford [1]. Roy Macleod, Historian of Science, and Russell Egdell, Inorganic Chemist, explain in the introduction that Moseley’s brief life, but long legacy, can only be seen through the comparative lenses of history, science, and the history of science. They do justice to each of these.

In some ways the science is straightforward. With hindsight and our present knowledge of atomic structure we read Moseley’s two papers The High-Frequency Spectra of the Elements published in 1913 and 1914, as nailing the concept of atomic number, which he identifies “with the number of positive units of electricity contained in the atomic nucleus”. But there is still some confusion as to the exact nature of “Moseley’s Law,” as detailed by John Heilbron (Chapter 10), the author of the first biography of Moseley in 1974. Russell Egdell’s account of “X-ray spectroscopy 100 years on” (Chapter 9) shows how ubiquitous X-rays have become with the inevitable miniaturisation leading to spectrometers in scrap yards and even in space, spawning acronyms galore (in surface analysis alone: XRF, ESCA, XPS, XAS, EXAFS, NEXAFS, SEXAFS, XANES, TXRF, PIXE [2]). As an analytical chemist, I might take up MacLeod and Egdell’s assertion that “… X-ray spectroscopy did develop to become arguably the most important of all chemical analytical techniques, …”. My chromatographic and mass spectrometric colleagues might wish to argue, but we should not be so churlish, having rather few war heroes in our ranks.

To a contemporary audience the burning question must be whether Moseley would have won a Nobel Prize, and whether in Physics or Chemistry? There are several contenders and it may be unkind (to Barkla) to suggest the work of C. G. Barkla, recognised in 1918, was a “posthumous tribute to Moseley,” as Robert Friedman raises in his introduction to Chapter 6. This is a fascinating chapter that looks at the deliberations of the five-member Nobel Committee for Chemistry, augmented by the great chemist Arrhenius. In a section “Biased Neutrality” the problems of a Germany-leaning neutral country (Sweden) Friedman tells us what difficulties the Nobel Committees faced, not being able to postpone the prize in wartime. Friedman sums up “Today Henry Moseley stands as one of the greatest scientists of the past century, we do not need the award of a Nobel Prize to command our appreciation and respect.”

Earlier, in Chapter 4, Eric Scerri puts Moseley in context of the work that was happening around him. Antonius van den Broek is credited with the concept of the ordering of elements on a whole number scale, and
indeed, Moseley started his work with the “express purpose of verifying van den Broek’s hypothesis.” While van den Broek’s work was flawed, it provided a vital stimulus to the understanding that was to come after. Scerri reminds us that science rarely progresses in quantum leaps by geniuses with bursts of insight that make good television, but “develops as an organic whole.”

The history of his early years by Clare Hopkins (Chapter 1) in which his life at the English private school Eton, and then Oxford University paints the picture of a bright, upper middle class, Edwardian boy. Armed with a Second Class Honours degree Moseley went to Manchester where Ernest Rutherford was discovering X-rays, radioactivity and the “chemical atom” (Neil Todd, Chapter 2). A stock of radium meant that Rutherford’s laboratory had the wherewithal to conduct the experiments that would become Moseley’s legacy. Photographs of the science laboratories reminded me of my undergraduate years at King’s College London from 1969. Not much had changed, so I assume they were cutting edge in 1900. However, Todd regrets that the building housing the basement in which Moseley researched, the “cradle of modern physics,” has been allowed to fall into disrepair after the physics department moved to a new building in 1968.

The story of Lt. Henry Moseley, his desire to serve actively in the war, and his brief time in Gallipoli is told by Elizabeth Bruton (Chapter 5). There is unintentional irony in the reactions to Moseley’s death deploring that one of England’s foremost scientists should be allowed to go to the front line and be killed (send some ignorant fellow, is the inference), instead of being kept safe to work on ever better methods of waging war. Living in Australia with the landings at Gallipoli being cause for a major national holiday I was interested to read that any other troops were involved. (In fact, Australian and New Zealand troops, ANZACs, were a minority in this ill-conceived and ultimately failed attack).

The book is a reflection on the special exhibition “Dear Harry...” at the Museum of the History of Science, and concludes with a chapter by Elizabeth Bruton, Silke Ackermann and Stephen Johnston that describes the exhibition, its reception and how it told the story of Moseley the man, the scientist, the soldier, one hundred years after his death.

There is a nice link with the IUPAC community. Henry Moseley was given element 72 (hafnium) in the Periodic Table of Younger Chemists (https://iupac.org/100/pt-of-chemist/), part of the celebration of the 150 years of the modern periodic table. He was the only dead scientist, and the only physicist, and his element was the one of the four ‘missing’ elements identified by gaps in the frequencies of X-ray lines when plotted according to Moseley’s Law. A chapter author, Kristen Frederick-Frost, who describes Moseley’s diagram in the book, has also written a fascinating account of his search for element 72 in Chemistry International [3].

References
1. Dear Harry... project and special exhibition at the Museum of the History of Science, Oxford, UK; http://www.mhs.ox.ac.uk/moseley/ (last accessed 10 August 2020, on Mosely’s 105 death anniversary)
Young Ambassadors for Chemistry (YAC) achievements in Mongolia

by Masahiro Kamata, Mei-Hung Chiu, and Jan Apotheker

YAC is a project that trains teachers around the world to communicate the benefits of chemistry to the general public with the help of their students as young ambassadors. A typical YAC event encompasses two to three days of teacher workshops, followed by a one-day, public event where students—the Young Ambassadors for Chemistry—share their enthusiasm and interest with the public at large, either in a public square or as part of a science festival. That last day of the YAC event is usually a festive time and fun for everyone involved. From 2004 to 2016, Lida Schoen and Mei-Hung Chiu organized 41 events, both small and large, in 29 different countries.

YAC in Mongolia

In September 2019, another YAC was held in Mongolia as an IUPAC Committee on Chemistry Education (CCE) project (2018-015-2-050) following CCE (Flying Chemistry Education Program) (see Chem. Int. Jan 2020, pp. 37-14). YAC in Mongolia was made possible by National University of Mongolia (NUM), especially vice president Ochirkhuyag Bayanjargal, professors D. Khasbaatar and C. Nyamgerel, the Ministry of Education, and Green Chemistry LLC. The YAC was three days long, and workshops for school teachers were held in the library of NUM on the first two days of the conference. On the third day, we had an open event for the public with students in Bluemon Center (a restaurant mall) near the university in Ulaanbaatar. Until the previous YAC, cosmetic chemistry had been used as main materials to illustrate how useful and important chemistry is in our daily lives. This time, we chose functional polymer instead because there are many kinds of functional polymers available around us which are safe and inexpensive, and some of them can be used in regular chemistry classes in high school. In addition, some polymers play important roles in the field of green chemistry, and we are expecting young students to be more interested in them.

Workshop for School Teachers (days 1 & 2)

The workshop for school teachers was composed of two parts. The first part featured lectures presented by project members of IUPAC and a polymer expert coming from Mongolian University of Life Sciences. In the beginning of day 1, Jan Apotheker explained IUPAC and Mei-Hung Chiu talked about the roles of YAC and how previous YACs have been carried out in many countries. After that, Masahiro Kamata made a lecture on relating school chemistry with our daily lives using simple examples. Later a polymer expert, Galaaraidi Otgondemberel, explained the basics of polymer and how they are used in our lives.

In the second part of the workshop, we introduced three experiments to the school teachers: 1) making slime using a polyvinyl alcohol (PVA) solution sold as laundry starch, 2) evaluating water absorption ability of the polymer taken out of a diaper, 3) science craft using UV resin. Although we did not use functional polymers in the first experiment, it is effective to make students recognize the phenomenon of polymerization. Then, the teachers were asked to design and prepare the open event by arranging the experiments that had been introduced to them. The teachers were divided into four groups and each group was assigned to one experiment. The teachers discussed how to use what they had learned so far. They also prepared chemicals and apparatuses for the experiments as well as paper materials such as worksheet for the students.
Open Event (day 3)

Although we had planned to use a large shopping mall as a venue for the open event, the permission for the usage was suddenly canceled a few weeks before the event. Thanks to big efforts of Mongolian members, the YAC open event was allowed to be held in the gallery space next to the entrance of Bluemon Center. We set tables and chairs so that over 40 participants could be seated.

The event started at 10 a.m.; after the opening speech by D. Dorj (former rector of NUM), 57 high school students experienced three experiments using PVA, water absorption polymer and UV resin guided by teachers. After they got an idea of what a functional polymer was, the students discussed their dreams of future polymer in each group. What kind of polymer do they want? How and where do they want to use their dream polymer? Then the students presented their posters in front of the judges.

When the students finished their presentations, the students invited the public to their tables and let them do the experiments together. Before ending the morning session, awards for good presentations were given to three groups with some gifts from IUPAC.

In the afternoon session, elementary school students were invited and shown polymer experiments guided by high school students. This allowed the high school students to practice, demonstrate, and reflect upon their understanding of polymer experiments from the morning session and then act them out with the younger students.

After the experiments, every kid was asked to write their impression on the event on a post-it and orally presented it in front of all. Then the public (mainly the parents of the kids) were invited to the tables and enjoyed the experiments with high school students.

In the closing ceremony, a certificate of attendance was sent to all high school students and elementary school students with small gifts sent from IUPAC. The event ended around 3 p.m. with a group photo of all participants.

Polymer experiments for the open event

The materials used in open event needed to be safe and inexpensive in addition to being explicit about the relation between chemistry and our daily lives. For those reasons, we chose functional polymer as a topic and the following three experiments using it.

As a first step the following demonstration is considered to be very useful. When borax is added to aqueous solution of PVA, molecules of PVA are bridged by borate ions and the viscosity of PVA solution is changed drastically. Therefore, this experiment is a good example for high school students to understand how cross-linking reaction works on the property of the material. In addition, students can easily recognize large amount of water can be trapped in a cage of polymer, which is closely related to a water absorption polymer. As for elementary school kids,
although they usually cannot fully comprehend the explanations, they can enjoy the property (viscosity) change by adding some chemicals. Something elusive is unusual for kids and most of them like to handle it with their bare hands.

**Water absorption polymer (or superabsorbent polymer, SAP)**

Water absorption polymer is one of the functional polymers that are used most widely in our daily lives as diapers. The materials itself is safe, inexpensive and easy to obtain almost everywhere (you can take it out of diapers). We planned to demonstrate 1) a large amount of water can be absorbed in small amount of SAP and 2) absorbed water cannot be released easily. In addition to simple experiment using measuring cups to demonstrate 1), a tiny glass bottle with a narrow neck and a colored SAP ball were prepared to show how much water a very small SAP ball (~1mm in diameter) can absorb. The SAP ball gets so large as 10 mm in diameter as it absorbs water. Therefore, those who have not seen the initial state cannot imagine how the ball got in a bottle through a narrow neck, which enhance observers’ interest in the function of SAP.

**UV resin**

UV resin is also one of the functional polymers that are used for many purposes; such as dental treatment, nail art, and so on. In the demonstration, students made a rubber stamp by placing a printed mask over the resin and irradiating it with UV. Through this experiment, they can easily recognize only the part of the resin that are irradiated by UV is solidified. As for elementary school kids, a much more simple activity to make a “YAC badge” was devised by Mongolian school teachers.

**Communication to the public**

During the open event on day 3, there was a chance for the public to enjoy the experiment with high school students both in the morning and afternoon sessions. Since this session was less than 15 minutes and the number of the people who can participate it was limited, we prepared a leaflet which illustrates our activities and distributed them with a questionnaire to the people who visited the venue. In the leaflet, we explained briefly the demonstrations presented in the open event. We also explained what IUPAC and YAC are.

During the open event, we were interviewed for internet TV in Ulaanbaatar, and our activities were introduced via facebook and twitter by the tovch.mn social media agency.

**Dream polymers presented by high school students**

A lot of unique and creative ideas were presented by high school students. Some of them are listed below:

**Shine Mongol school**

*Using polymer in a 3D printer to make a miniature model of a building or machine. A polymer that can be combined with inert gas and made light.*
The polymer can be used as vegetable soils by absorbing water and minerals. Water absorption polymer can be used to remove rainwater, and to prevent flooding by making a dam. Polymers that are easily hardened can be used for plaster and bandage at the hospital. Polymers are easy to change, so they can be used as a tool (robot) to reach a place where the person cannot reach.

**School No 33**
Polymers that emit heat, light and transmit electricity are the solution to energy issues and greenhouse gases in human life. If in the future combustion and heat resistant polymers are available, they may be used for building insulation and fuel. In the future, if there are light-transmitting polymer compounds, they may be used instead of glass. My dream polymers are very light and as hard as metal. I believe it will be widely used in road and bridge construction.

**Baigal Ekh, affiliated school of NUM**
Smoke absorbing polymer, make building material by polymer, to reduce pollution using polymer, increase polymer household use, such as the use of polymer filters.

**School No 11**
We want to have a super absorbent polymer. Absorbing the environmental pollution and releasing only the water will make an ecologically clean water cycle. However, the polymer that absorbed the other contaminants can be processed into fertilizers.

**Feedback from the participants**
Three kinds of questionnaires were prepared for teachers, high school students and ordinary people, respectively. 37 high school students responded and most of them answered “After this activity, I acquired more about the application of chemistry in our daily life,” and “After this activity, my image of chemistry gets positive.” They also showed strong interest in the experiment and most of them answered that they would like to participate again if similar activities are organized. 13 school teachers responded and most of them answered “I think I learned much from this activity” and “I am satisfied with the content of teaching materials of this activity.” All of them answered that they would like to participate again if similar activities are organized. As for the ordinary public, 18 results were collected. Although eight of them provided rather negative answer regarding the question “How much do you think you know about chemistry?”, twelve of them answered they had positive impression after the event. Most answered that they liked what the students are doing.

Twenty elementary school kids (most of them in 5th grade) participated in the event and we asked them to write down their impressions as mentioned above. All of their answers were positive and some of them are listed below:
• I liked it very much. We have done many beautiful experiments and we made stamp. Thank you for making these beautiful experiments.
• My school did not do such experiments. I am very excited today.
• I understand what chemistry is from this experiment. I did not know what chemistry was first. I knew that we use chemistry every day.

The impact on the high school students and the school teachers was much larger than expected. In addition, we got positive feedback from university professors and chemistry company who were involved in this event. Therefore, it is highly expected that the benefits of chemistry will be informed to the public in the future via students (young ambassadors) and teachers, and that this kind of activity will be continued in Mongolia.

Acknowledgements
We would like to take this opportunity to thank IUPAC CCE for providing the grant for the YAC event to be held in Mongolia. We would also like to express our sincere thankfulness to National University of Mongolia for their full support in many ways to make the event possible, in particular, special thanks to vice president Ochirkhuyag Bayanjargal, Professors D. Khasbaatar and C. Nyamgerel, Ministry of Education, and Green Chemistry LLC for their kind support. At last, two graduate students, (Mina Tsuchiya, and Taiga Inamura) were very helpful to conduct the experiments and to facilitate teachers’ and students’ activities.

21st Mendeleev Congress on General and Applied Chemistry*
by Nikolay E. Nifantiev

The 21st Mendeleev Congress on General and Applied Chemistry was held on 9-13 September 2019 in Saint Petersburg under the auspices of IUPAC. Mendeleev Congresses are the main Russian chemical forums which, typically, take place every 4 or 5 years, and usually proceed in major regional centers of the country. Saint Petersburg is one of the biggest industrial, cultural and scientific centers of Russia with renowned universities, academic research institutes and industrial corporations, including giant metallurgical plants.

The first Mendeleev Congress was held in Saint Petersburg in 1907 in memory of the prominent Russian chemist D. I. Mendeleev (1834-1907). Further Congresses were held in a number of famous scientific centers all over the former USSR: in Moscow, Volgograd, Leningrad (now Saint Petersburg), Kazan, Kharkov, Kiev, Alma-Ata, Baku, Tashkent, and Minsk. The 19th Mendeleev Congress (Volgograd, 2016) was associated with the International Year of Chemistry, while the jubilee 20th Congress (Ekaterinburg, 2016) was dedicated to “New horizons of chemistry in the 21st century.” The 21st Mendeleev Congress was associated with worldwide celebration of the 150th anniversary of Dmitry Mendeleev’s discovery of the Periodical Table. It was proclaimed by the United Nations General Assembly in December 2017 as the “International Year of the Periodic Table of Chemical Elements” (IYPT 2019) following the initiative by the Russian Federation supported by IUPAC, the International Union of Pure and Applied Physics (IUPAP), the European Association of Chemical and Molecular Sciences (EUCHEMS), the International Council for Science (ICS), the International Astronomical Union (IAU) and the International Union of History and Philosophy of Science and Technology (IUHPS) and of numerous scientific organizations from more than 80 countries.

Led by UNESCO, IYPT 2019 brought together hundreds of national and international partners to raise awareness of the importance of chemistry and periodicity in areas such as sustainable development, health, food, water, energy, education, climate change and biodiversity. All the above listed critical topics were discussed during the 21st Mendeleev Congress which traditionally welcomed scientists from all over the world and provided the highest level of scientific discussion on contemporary problems in various areas of modern chemistry. It also provided a wide range of participants (students, graduate students, teachers, researchers from different countries) a possibility to get in touch with the world advanced scientific achievements in the field of chemistry including its fundamental aspects and industrial achievements. That is why Mendeleev Congresses are recognized as the largest Russian scientific events focusing on most priority directions of chemical research. They traditionally maintain interdisciplinary programs that highlight new research prospects, as well as advances in chemical industry and professional education. In addition to the scientific discussions, Mendeleev Congresses feature the networking links between business, industry, and academy.

The 21st Mendeleev Congress was co-chaired by the President of the Russian Academy of Sciences, Academician Alexander M. Sergeev; Russian Minister of Science and Education Mr. Mikhail M. Kotukov; and Vice-governor of Saint Petersburg Mr. Vladimir V. Kirillov, while the...
Program Committee was chaired by Academician Aslan Yu. Tsivadze—the President of Dmitry I. Mendeleev Russian Chemical Society and Deputy Secretary of the Division of Chemistry and Material Sciences of RAS.

The Congress was opened by Sergeev who delivered the address to the Congress from President Vladimir V. Putin. The next talk was delivered by Russian Prime Minister Mr. Dmitry A. Medvedev who emphasized the importance of the discovery of Periodic Law which is acted now as the common language for science and outlined importance of chemistry nowadays. The Prime Minister also informed participants about the initiative of the Government of the Russian Federation which proposed, as a part of IYPT 2019, to establish and fund the joint UNESCO/Russian Federation International Prize in the name of the Russian chemist Dmitry I. Mendeleev for the Basic Sciences. Soon after the Congress at the 207th session of the UNESCO Executive Board it was decided to establish the Dmitry I. Mendeleev UNESCO-Russia International Prize for Achievements in the Basic Sciences. The UNESCO Executive Board adopted the decision by acclamation supporting the establishment of the Prize by applause.

Over 2500 Russian scientists and their colleagues from 60 foreign countries from all over the world (they included about 1300 young researchers and students) took part in the extensive scientific program. It included plenary sessions, 10 parallel sections, 5 international satellite symposia, a conference of young researchers “Mendeleev-2019,” 4 roundtable discussions and poster sessions. Altogether the programs broadly covered essential directions of chemical science, technology and education including material sciences and nanotechnology, molecular electronics, supramolecular chemistry, electrochemical power engineering, catalysis, energy resources and raw materials, reproducible biomass conversion and biorefinery, drug discovery and biomolecular chemistry, immunological and biochemical, agrochemistry, ecology and many other directions of chemistry and related interdisciplinary studies. Plenary sessions of the Congress comprised 17 outstanding talks by distinguished scientists including Nobel Prize winners Professor Jean-Pierre Sauvage (2016 laureate) and Professor William E. Moerner (2014 laureate), Academician Yuri T. Oganessian, Sir Martin Poliakoff (School of Chemistry, University of Nottingham).

As the President of the Division of organic and biomolecular chemistry of IUPAC I am honored to dedicate this and one of the following issues of Pure and Applied Chemistry to the 21st Mendeleev Congress. It comprises selected papers related to plenary contributions, keynote and invited lectures presented at the Congress.

I am very grateful to Professor Hugh Burrows, editor in Chief of PAC for his kind consent to dedicate this issue to the 21st Mendeleev Congress, and all authors for their contributions which present modern chemistry and its indispensable importance for sustainable development.

This year, Prof. Pavel Kratochvíl celebrated his 90th birthday (born 6 Feb 1930). To mark this occasion, the Polymer Division organized a special celebration for him working closely with Mrs. Daniela Illnerova from the Institute of Macromolecular Chemistry in Prague. We created a IUPAC Polymer Division plaque and a card signed by all living Past Presidents, current President, and Vice-President. Mrs. Illnerova arranged that the plaque be presented to Prof. Kratochvíl during the play “An elegant molecule,” the hit of the season at the Dejvice theatre in Prague. The play is about another outstanding Czech chemist Prof. Antonín Holý, who in the 90s synthesized the molecules against viral infections such as HIV and Hepatitis B. Even today, these inventions bring in tens of millions of Euros annually in royalties to the Institute of Organic and Bioorganic Chemistry AS CR by Gilead in California reflecting a true success story of how chemistry can help mankind. The play is somewhat closely related to Prof. Kratochvíl’s life since he was the Director of the Institute of Macromolecular Chemistry of the Academy of Sciences of Czech Republic in Prague (IMC AS CR) at the same time when Prof. Holý was the Director of his Institute. Prof. Kratochvíl can compare the play with his personal experience.

As soon as the first burst of COVID-19 decayed and the theatres in Prague reopened in the beginning of June 2020, the Polymer Division Vice-President Dr. Igor Lacík was able to visit Prague. On 12 June, at the Dejvice Theatre, the plaque as presented to Prof. Kratochvíl on behalf of the Division. It was a memorable occasion. The art director of the theatre Mr. Martin Mysicka, featured in the role of Antonin Holy, introduced Prof. Kratochvíl, Dr. Lacík, and the IUPAC Polymer Division prior to the play and announced that this play would be dedicated to Prof. Kratochvíl. Then, Prof. Kratochvíl was invited on stage, and Dr. Lacík handed the plaque to him (both wearing masks reflecting current times due to COVID-19). During the standing ovations after the play, all actors and audience applauded Prof. Kratochvíl, which was highly emotional.

This story reflects the life of the IUPAC Polymer Division, the connection between generations and appreciation of our peers, such as Prof. Kratochvíl, for their work for the Division. The IUPAC mission could not be achieved without involvement of numerous scientists around the world, nor without their wisdom, vision and dedication. Prof. Pavel Kratochvíl, from the IMC AS CR, is one of those who contributed significantly to the life of IUPAC and its Polymer Division. Prof. Pavel Kratochvíl was mainly involved in the former Committee on Nomenclature, and has continued to influence the Polymer Division for many years. More details on his scientific achievements and the roles in the IUPAC can be found in the tribute by Michael Hess and Máximo Barón marking the occasion of his 80th birthday. (CI 2011, Vol. 33(2), p. 21, http://publications.iupac.org/publications/ci/2011/3302/iw6_tribute-ratochvil.html. This year, Prof. Kratochvíl was also elected Emeritus Fellow of the Polymer Division as the recognition earned by his service for IUPAC.
The 2020 calendar of conferences has been disrupted by the COVID-19 pandemic. Most events originally planned are been cancelled, postponed, and in a few instances reframed as virtual events.

**Note:**

All IUPAC-endorsed events originally scheduled in 2020 and that are postponed will retain their endorsement. We invite you to review regularly the calendar of IUPAC endorsed events at https://iupac.org/events/

### 2020 – see online for updates

### 2021

**9 February 2021 • IUPAC Global Breakfast • ONLINE**

Contact/International Coordinator Dr. Laura McConnell at <globalbreakfast@iupac.org>  
https://iupac.org/global-womens-breakfast/

**22-26 March 2021 • Chemistry and Climate • Irkutsk, Lake Baikal, Listvyanka, Russian Federation**

The 3rd Baikal International Scientific and Practical Conference “Snow cover, atmospheric precipitation, aerosols: chemistry and climate”  
Natalia Ianchenko, Chair of Local Organizing Committee, 83, Lermontov street, 664074 Irkutsk, Russian Federation, E-mail: fduecn@bk.ru, http://snow-baikal.tw1.ru/index-eng

**12-16 April 2021 • Polymer Characterization • Venice, Italy**

POLY-CHAR 2020 [Venice] – International Polymer Characterization Forum  
Valerio Causin, Chair of Local Organizing Committee, Università di Padova, E-mail: valerio.causin@unipd.it, or info@poly-char2020.org, www.poly-char2020.org

**9 June • 12 May 2021 • Biotechnology • Maastricht, Netherlands**

19th International Biotechnology Symposium, joint with the Congress of European Federation of Biotechnology and NBC-20, the annual Netherlands Biotechnology Conference  
Richard van Kranenburg, Corbion and Aldrik Velders, Wageningen University, Program Committee co-chairs, E-mail: ecb@tfigroup.com, www.ecb2021.com

**16-20 May 2021 • MACRO2020+ • Jeju Island, Korea**

48th World Polymer Congress  
Chair: Doo Sung Lee, ex-President, PSK; program chair: Jun Young Lee; secretary general: Dong June Ahn <ahn@korea.ac.kr>; E-mail: secretariat@macro2020.org; www.macro2020.org

**17-19 May 2021 • New Trends in Polymer Science • Turin, Italy**

Francesco Trotta, Pierangiola Bracco, Marco Zanetti, Co-chairs of Program Committee, E-mail: polymer-conference@mdpi.com, http://polymers2021.sciforum.net/

**9-11 June 2021 • CLEAR • London, United Kingdom**

5th International Conference on Contaminated Land, Ecological Assessment and Remediation – CLEAR  
Yong Sik Ok, Chair of Program Committee, and Diane Purchase, Chair of Local Organizing Committee:  
E-mail: clear2020@mdx.ac.uk, http://clear2020.mdx.ac.uk/

**27 June • 2 July 2021 • Coordination Chemistry • Rimini, Italy**

The 44th International Conference on Coordination Chemistry (ICCC2021)  
Maurizio Peruzzini <maurizio.peruzzini@iccom.cnr.it>, Chair and Giuliano Giambastiani <giuliano.giambastiani@iccom.cnr.it>, Scientific Secretary <iccc2021@iccom.cnr.it>, www.iccc2021.com

**18-22 July 2021 • Polymer Colloids • Prague, Czech Republic**

84th Prague Meeting on Macromolecules – Frontiers of Polymer Colloids: From Synthesis to Macro-Scale and Nano-Scale Applications  
Daniel Horák, Program Committee Chair, E-mail: horak@imc.cas.cz • Conference Office: Ms. Daniela Illnerová, E-mail: sympo@imc.cas.cz, www.imc.cas.cz/sympo/84pmm
19-23 July 2021 • Noncovalent Interactions • Strasbourg, France
2nd International Conference on Noncovalent Interactions (ICNI)
Chair of the Program Committee & Contact: Jean-Pierre Djukic, Université de Strasbourg,
E-mail: djukic@unistra.fr, http://icni2021.unistra.fr/

25-30 July 2021 • Theoretical and Computational Chemists • Vancouver, Canada
12th Triennial Congress of the World Association of Theoretical and Computational Chemists
Chair: Russell J. Boyd, Dalhousie University, E-mail russell.boyd@dal.ca; contact Chemical Institute of Canada

13-20 August 2021 • IUPAC World Chemistry Congress/General Assembly • Montréal, Québec, Canada

7-11 November 2021 • Bioanalytical and Environmental Analyses • Angkor Wat, Cambodia
Joint Meeting of the 18th Asia Pacific Symposium on Microscale Separation and Analysis and 17th
International Interdisciplinary Meeting on Bioanalysis (APCE & CECE 2020)
Doo Soo Chung (Chair of Local Organizing Committee), Department of Chemistry, Seoul National University,
E-mail: dschung@snu.ac.kr, www.apce-cece.org

7-11 November 2021 • Natural Products and Biodiversity • Naples, Italy
31st International Symposium on the Chemistry of Natural Products and 11th International Congress
on Biodiversity (ISCPN31 & ICOB11)
Conference chair: Raffaele Riccio <riccio@unisa.it>, Dipartimento di Farmacia, Università degli Studi di
Salerno; General Contact E-mail: info@iscnp31-icob11.org, www.iscnp31-icob11.org

2022

17-22 January 2022 • POLY-CHAR 2022 • Auckland, New Zealand
World Forum on Advanced Materials and “Short Course on Polymer Characterization”
Jianyong Jin, E-mail: j.jin@auckland.ac.nz or polychar2022@auckland.ac.nz, www.polychar2022.org

11-13 July 2022 • ECRICE • Rehovot, Israel
European Conference on Research in Chemical Education “Excellence and Innovation in Chemistry Teaching
and Learning”
Contact: Rachel Mamlok-Naaman <Rachel.mamlok@weizmann.ac.il>, http://www.weizmann.ac.il/
conferences/ECRICE2020/

17-22 July 2022 • MACRO2022 • Winnipeg Manitoba, Canada
49th World Polymer Congress
Chair of Local Organizing Committee, Lena Horne <Lena.Horne@umanitoba.ca>

18-22 July 2022 • Photochemistry • Amsterdam, The Netherlands
28th IUPAC Symposium on Photochemistry
A.M. (Fred) Brouwer, van ’t Hoff Institute for Molecular Sciences, University of Amsterdam, Program
Committee Chair, E-mail: a.m.brouwer@uva.nl, http://photoiupac2022.amsterdam

18-22 July 2022 • Chemistry Education • Cape Town, South Africa
26th IUPAC International Conference on Chemistry Education (ICCE 2020)
Contact/chair of the local organizing committee: Bette Davidowitz <Bette.Davidowitz@uct.ac.za> Chemistry
Department, University of Cape Town, Rondebosch, South Africa, E-mail: icce2022@allevents.co.za,
www.icce2022.org.za
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