Volume 3 Number 1

The OPCW Science & Technology Monitor

A sampling of Science & Technology
Relevant to the Chemical Weapons Convention

2 March 2016

In this Issue

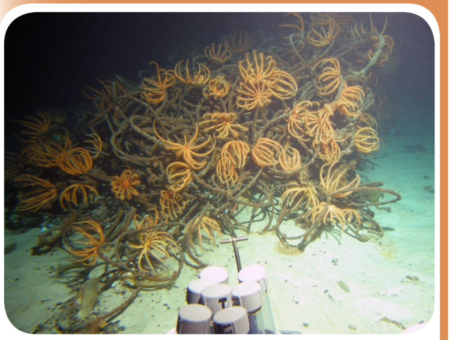

Photo by Christopher Mah

Sea Dumped Chemical Weapons

Image from Wikipedia

Precision Agriculture

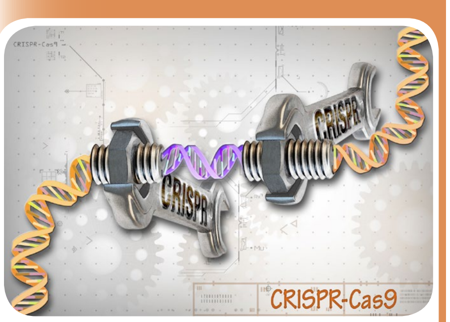

Image by Wikimedia

CRISPR/CAS-9

S&T Updates from the CWC Conference of States Parties and the BWC Meeting of States Parties

Welcome

Welcome to the OPCW Science and Technology Monitor, an occasional bulletin to provide updates on developments in science and technology across a broad spectrum of topics relevant to the CWC. Past issues are available from the [Science and Technology section of the OPCW website.]

The first issue of 2016 came to our editors on February 29, a day not seen again until 2020. This day, occurring every four years, corrects a discrepancy between the 365-day calendar and the 365.24219878 days required for the Earth to orbit the sun. [Things, however, are still not perfect; a tiny error remains in the Gregorian calendar, enough to recommend canceling leap year every 3,200 years – a change that would still give us a one day error every 100,000 years.] We mention this as a reminder that many seemingly simple and certain things hide more complex dimensions; dimensions we look to report on as our *Science and Technology Monitor* begins its third volume.

The S&T Puzzle

Congratulations go out to an OPCW laboratory staff member for solving last month's puzzle: using the sum of the numbers in each highlighted section of the completed Sudoko to identify the symbols of elements that can be arranged to spell the name of a Schedule 1 chemical (purple 17 = Cl; red 39 = Y; blue 53 = I; green 18 = Ar; violet 7 = N; pink 16 = S; yellow 8 = O; and orange 6 = C). The complete solution is shown below. With this win the Verification Division goes back to the top of the standings, which are now: VER 6, CTBTO 5, OSP 2, OCS 1, and INS 1.

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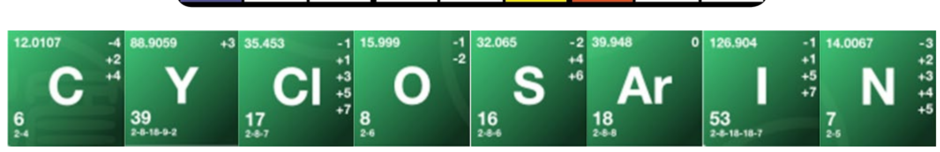
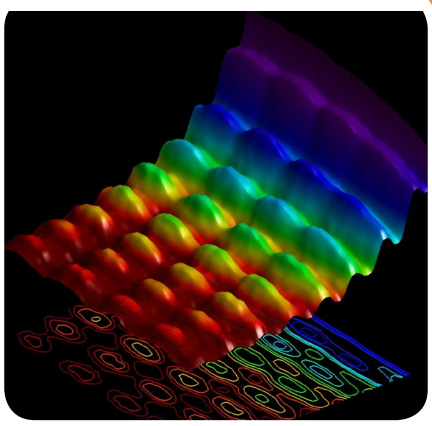


In this issue's edition of the puzzle (which can be found on the last page of this newsletter), we ask you to navigate a dangerous maze. Along the way, you must find and dispose of barrels of VX by transporting them to the correct location. Be Careful! The green area has been contaminated by VX and can only be entered if you have appropriate equipment (equipment that you can find along the way). You will receive Bonus Points for the correct identification of the chemicals in the barrels at locations 10-13, but you will Lose Points if you pick up things you don't need! The first person to successfully navigate the maze wins the prize: your choice of requesting a featured topic, designing a puzzle or receiving a beverage hand selected by the Science Policy Adviser. Send answers by email. Good luck!

Science Fun

It is often said that modern science and technology move forward at an ever increasing pace, burying anyone trying to keep up with it all under an avalanche of information. What this means in practical terms, is that we find ourselves continually asking, what did we miss? And this question, or more specifically "what did we miss in 2015" is the topic for this edition of *Science Fun*.



Light as a wave and a particle. Image by Fabrizio Carbone/EPFL

The year 2015 was full of science (some quite attention grabbing), fun technologies, virtual reality and even innovations for social good! Did you know a new hominid species called *homo naledi* was discovered in South Africa? That light was simultaneously photographed in its wave and particle forms for the very first time? Or that a solar powered plane, Solar Impulse 2, flew from Abu Dhabi to Hawaii? Science even proved a few truisms, like the one about the brontosaurus existing only in popular culture, to be false!

Moving beyond the 52 weeks of chemistry, developments in the life and medical sciences included discovery of a new class of antibiotics and the long-sought 'missing link' between the immune system and the brain. Of course, in the life sciences, gene-editing took the spotlight (and we'll come back to that in this issue's feature on CRISPR/CAS9).

News and Updates

Recent reports and publications:

Forensic Science and Beyond, 2015 Annual Report from UK Government Chief Science Advisor.

Chemistry and Engineering News 2015 Pharma Year in Review.

Infectious disease control and elimination: Modelling the impact of improved diagnostics, a *Nature* Supplement.

Risk and Benefit Analysis of Gain of Function Research report from Gryphon Scientific.

Developments in automation and commercialization of synthetic biology from 2015.

Digital DNA: The Nagoya Protocol, Intellectual Property Treaties, and Synthetic Biology.

World Intellectual Property Indicators – 2015 Edition.

Global Innovation Index 2015.

A multilingual terminology portal of scientific and technical terms derived from patent documents, WIPO Pearl.

January 2016 issue of Dstl's *inSIGHT*.

Assessing Health Outcomes Among Veterans of Project SHAD (Shipboard Hazard and Defense).

Chemical weapons in Syria: The reports 2013–2016 and the first report of the OPCW-UN Joint Investigative Mechanism.

Use of Chemical, Biological, Radiological and Nuclear Weapons by Non-State Actors: Emerging Trends and Risk Factors.

Global Risks Report 2016.

A look at one second on the internet.

Visualising the Worlds Scientific Collaborations.

Science and education tools and resources:

Science Apps from the American Association for the Advancement of Science.

STEM activities, lessons, and resources for parents and educators from Science Friday.

Alternative metrics that allow researchers to gauge the impact and reach of their research in the social web from SciDev.net.

The 2015 Global Monitoring Report – Education for All 2000-2015: Achievements and Challenges.

Science and Engineering Indicators 2016 from the National Science Foundation.

A Changing Sector: Where is science communication now? A report on science communication from The British Science Association (BSA).

Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise.

Open Source Patent Analytics.

In neuroscience we saw the creation of fully-functioning artificial neurons, the development of injectable implants for studying brain function and the ability to transmit the sense of touch from a paralyzed patient's prosthetic hand directly to his brain. Physicists made progress toward quantum computing, achieving quantum entanglement on a silicon chip and proving that it is possible to write and manipulate a quantum computer code.

2015 was a transformative year in energy with plunging oil prices and breakthroughs in nuclear fusion technology and reactor design. It was a year that saw science fiction come to life, companies get serious about bringing internet access to the entire planet (and run into setbacks), new medical diagnostic codes to deal with the dark sides of new technologies and the use of 3D printing for preservation of endangered archaeological sites.

Science in 2015 was not without its ethical dilemmas and contentious issues. An agreement was reached at the Paris Climate talks, the war in Syria prompted the first retrieval of seeds from the Svalbard Global ("doomsday") Seed Vault and new technologies solved old problems by replacing them with new ones!

Moving into 2016, the analysists are already identifying what are sure to be the top break-through technologies and research trends; here is what is coming (think robots and virtual reality), what to look out for and a look ahead! What about the analyst's best picks of 2015? How many of them failed? How many of the predictions came true in 2015? How many of the 2015 technologies led to some unexpected outcomes? No matter what happens, we are looking forward to looking back at 2016 to see how it all turned out!

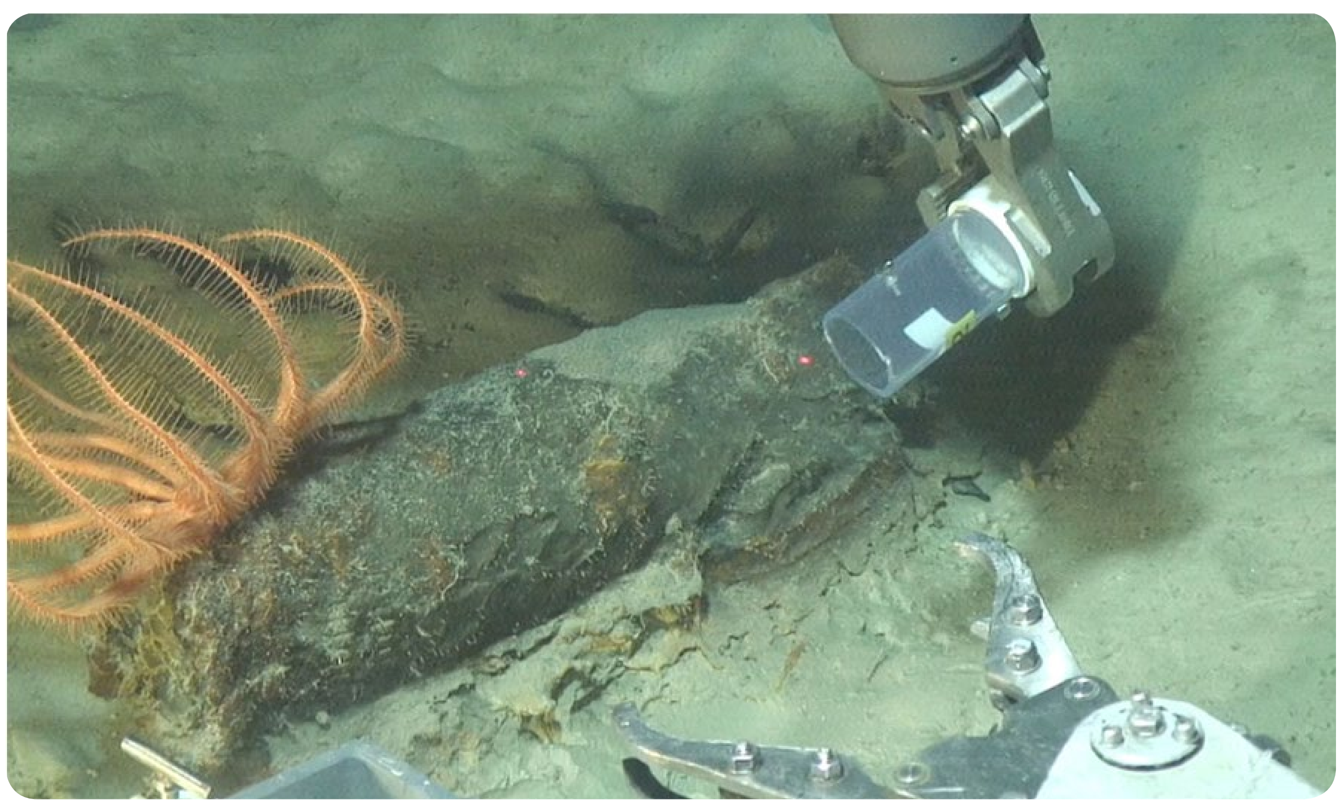
Some News from the World of Science & Technology:

From the weeks of 6 – 12 and 13 – 19 December 2015; 20 December 2015 – 2 January 2016; 3 - 9, 10 – 16, 17 – 23 and 24 – 30 January 2016; 31 January 2016 – 6 February 2016; and 7 – 13, 14 – 20 and 21 – 26 February 2016 in chemistry.

Sea Dumped Chemical Weapons

The need for suitable disposal methods for chemical munitions long predates the Chemical Weapons Convention. In the past, militaries looked to the vast oceans as a means for chemical warfare agents and munitions to lose their toxic properties through natural chemical decomposition. Between the two world wars and especially during the years following World War II, massive amounts of chemical munitions were dumped into the seas around the world. The dumped materials include chemical munitions, such as artillery shells, smoke candles, aircraft bombs, as well as bulk chemicals. It is estimated that several hundred-thousands of tonnes of chemical weapons have been disposed of at sea.

Although many disposal operations were carefully undertaken, munitions were sometimes jettisoned from ships as they travelled toward their selected dump sites and wooden casks containing munitions have occasionally washed up on-shore, scattering munitions well beyond the over one-hundred twenty-five known dump sites. Furthermore, chemical munitions have been caught by fishermen and munition related chemicals have been found in sea floor sediments beyond the boundaries of known dump sites.



Collecting samples near sea-dumped munitions off the coast of Hawaii. Image by University of Hawaii

Chemical munitions found in the dump sites raise serious concerns about risks to human health and the environment; especially where chemicals with high environmental persistence are involved. Activities such as laying of cables, trawling, dredging, and drilling can disturb dump sites (requiring appropriate risk assessments before undertaking such projects). Furthermore, corrosion of munitions and containers allows chemicals to leak into the marine environment. High levels of arsenic in sediments near lewisite dumpsites and blister agent exposure in species of fish near sulphur mustard dumpsites have been observed.

Much of the published work on environmental effects of sea dumped chemical weapons has focused on the Baltic Sea through the Chemical Munitions Search & Assessment (CHEMSEA) Project and the work of the Baltic Marine Environment Protection Commission - Helsinki Commission (HELCOM).

The environmental fate and transport of sea dumped chemical weapons is influenced by the marine environment itself (temperature, salinity, pH), the materials used to contain the chemicals and the physicochemical properties of individual chemical agents. As with all marine

Crowdsourcing

The Design by Biomedical Undergraduate Teams (DEBUT) challenge is a competition open to undergraduate student teams working on innovative solutions to unmet health and clinical problems.

The Air Liquide Essential Molecules Challenges: Sunny H_2 in a bottle, Pocketable small molecules, and CO_2, give back your O_2!

Interested in building a nuclear security innovation network? Take the N-Square Challenge!

Outcomes of crowdsourcing: how playing video games can lead to becoming an author on a peer-reviewed scientific paper. An example from the world of RNA structure prediction.

Upcoming S&T Related Events

OPCW Calendar of Events October to December 2015.

6 – 10 March 2016
Pittconn 2016
Atlanta, GA, USA

13 – 17 March 2016
251st American Chemical Society National Meeting & Exposition
San Diego, CA, USA

15 March 2016
Generic Integrated Forensic Toolbox (GIFT) Midway Conference
Brussels, Belgium

16 – 19 March 2016
16th Asian Chemical Congress
Dhaka, Bangladesh.

21 – 23 March 2016
Biomarker Summit 2016
San Diego, CA, USA.

4 – 5 April 2016
Global Chemists Code of Conduct Workshop
Kuala Lumpur, Malaysia

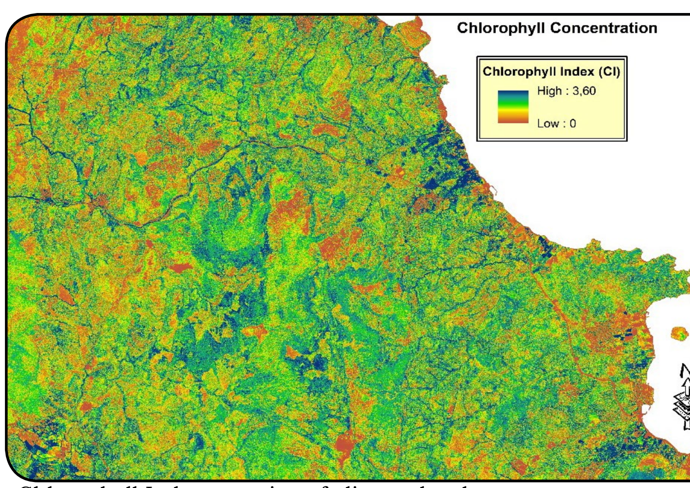
environments, the dumped chemicals and their containers become part of the ecosystem, influencing microbiota and benthic communities, acting as potential reefs (even when there is detectable leakage of chemicals) and increasing the risk of genotoxicity in fish (especially those found at known dumpsites). Integrated ecotoxicological studies of both sediments and marine-life are necessary to fully understand the ecological impact.

In regard to sampling and analysis, the large amounts of sulphur mustard munitions disposed of at sea and the high persistence of this chemical agent and its degradation products in deep-marine environments has yielded gas chromatography/mass spectrometry based methods for rapid analysis of sediments.

Disposal of chemical weapons at sea by some nations came to an end with the entry into force of the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter in 1975. Under the Chemical Weapons Convention, sea dumping is not allowed, however States Parties are not obligated to declare or destroy sea-dumped chemical weapons that had been disposed of before 1 January 1985 (see Article III paragraph 2 and Article IV paragraph 17). A number of Chemical Weapons Convention States Parties and the International Dialogue on Underwater Munitions (IDUM) have called for further action on the issue. For those interested, IDUM posts materials (including technical reports and presentations) from its conferences online.

Precision Agriculture

How much thought have you given to the potential of combining emerging and innovative technologies such as spectral sensors, cloud computing, artificial intelligence and unmanned automated systems to control chemical usage and delivery? Were you aware that this potential is being realised in the world of farming, where integrated technologies are handling chemicals such as fertilizers, herbicides and pesticides? We are, of course, talking about what is often referred to as "precision farming", "precision agriculture" or "site specific crop management."



Chlorophyll Index mapping of olive orchards.
Image from Wikipedia

A drone equipped with Near Infrared sensors and Cloud access.
Image by Cesar Harada

The precise management of crops involves combining positioning systems (GPS) with sensor and communication networks (including unmanned aerial vehicle mounted systems, that's right, farming drones) which collect and map data across the fields of a farm and even individual plants or trees. GPS has allowed tractors to be equipped with automated steering systems that reduce redundancy in planting, fertilizing and spraying. With the integration of sensor data, elevation, drainage and crop yield maps can be produced in real time. Hyperspectral imaging can measure chlorophyll and water content in the leaves of plants, measurements directly related to plant health; while a variety of other sensor technologies can provide actionable information on soil properties. Visible and infrared sensors can detect ripe fruit; these types of sensors in combination with other data inputs can be used to autonomously detect weeds or grow grapes that produce better wine (while consuming the least amount of resources).

With all the sensing technologies, the farm effectively becomes an "internet of things" where all collected data streams are wirelessly transmitted to a cloud server, integrated with other data sources (weather and meteorological data for example) and analysed. With data being collected and analysed in real-time, immediate decision making is possible; for example combining a sap flow measurement with wind speed and cloud cover information to pinpoint the exact time to provide water (and the exact amount to provide) at a precision vineyard.

6 – 8 April 2016
XXI IUPAC CHEMRAWN Conference
Solid Urban Waste Management
Rome, Italy.

15 April 2016
Meeting of the Expert Working Group on Green Chemistry
OPCW Headquarters
The Hague, The Netherlands

18 – 22 April 2016
23rd Session of OPCW SAB
OPCW Headquarters
The Hague, The Netherlands

26 – 27 April 2016
BWC Preparatory Committee for the Eighth Review Conference
Geneva, Switzerland

2 May – 10 June 2016
2016 Spring ConfChem: Science, Disarmament, and Diplomacy in Chemical Education: The Example of the Organisation for the Prohibition of Chemical Weapons.
A virtual Conference
Papers will be posted on a weekly basis followed by online questions and comments.

2 – 4 May 2016
International Day for the Foundation of the Organisation for the Prohibition of Chemical Weapons ("Chemical Safety and Security in a Technologically Evolving World")
OPCW Headquarters
The Hague, The Netherlands

5 May 2016
Science Diplomacy 2016
Washington DC, USA

26 – 28 May 2016
23rd Symposium on Chemical and Science Education
TU Dortmund, Germany

30 May – 3 June 2016
European Space Solutions
The Hague, The Netherlands

1 – 2 June 2016
CBRNeConvergenceAsia
Tokyo, Japan

Examples of what is possible include: the use of moisture and salinity probes to help manage valuable water resources; smart flytraps that can give farmers early warnings about pest infestations; wasp larvae-delivering drones for biological pest control; smart greenhouses; fluorescent seed coatings that can aid in the development of fully automated weed management systems (a further use of unmanned technologies); and apps for wearable devices (Google Glass) that can quantify chlorophyll levels in real time (details here). The future will see technologies employed for improved plant virus epidemiology and the continued development of big data analytics for enhancing crop yields.

The large-scale applications of precision farming may be expensive, yet the low cost nature of sensors and the ability to share data across mobile networks still provide affordable technological solutions for smaller farms and developing regions. For example, open-source farming machines; and the combination of hand-held crop sensors and mobile apps for tailoring plant nutrient management directly to the type of crop, soil and weather conditions on any individual farm.

What is the driver behind technology integration into farming? There are of course cost savings, the efficient use of resources and environmental management; and at the same time a realization that Earth's human population will rise from today's 7.3 billion people to about 9.5 billion by 2050. Agricultural production will need to keep up with a higher demand for food, especially in developing regions of the world. With such an increase in scale, farming practices will need to cope with resource constraints and the effects of climate change. Precision farming based technological solutions are but one dimension of meeting these challenges, ecologically and environmentally sound farming practices, new types of (urban) farms, microbial biotechnology and nanotechnologies may also play a role.

CRISPR/CAS9

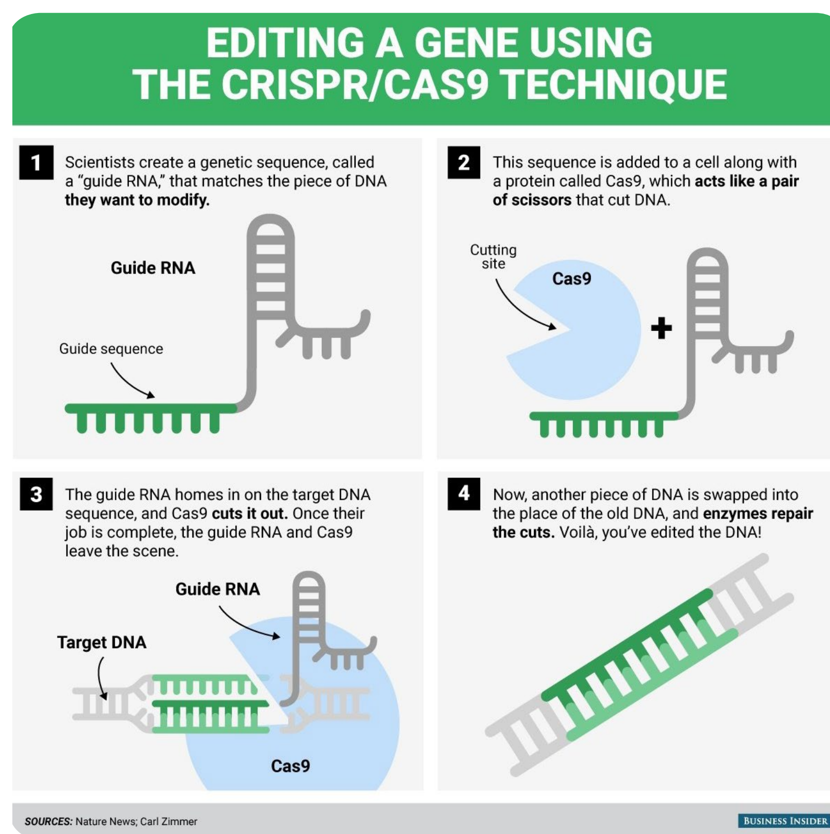


Image from Business Insider

Gene-editing technologies, while not new, made headlines in 2015 as CRISPR/CAS9 captured the attention of the science world and beyond! Gene-editing is transforming life science research and the sectors where it finds application (medicine, agriculture, industrial biotechnology and more) and some believe that it could even transform the future of our species, generating much discussion on bioethics and biosecurity. The headlines continue with on-going patent lawsuits; a top US official calling gene editing a WMD threat; disputes over the history of CRISPR/CAS9; the United Kingdom granting a team of scientists working on early development research a license to edit human embryos; visualization of CRISPR/CAS9 in action at the molecular level (details here); and the first IPO for a CRISPR/CAS9 based therapeutic company, Editas Medicine, raising $94.4 million (for those interested in the SEC filing click here) all in the first two months of 2016!

The genome-editing tool CRISPR/CAS9 represents a step forward from zinc finger nucleases (ZFN) and transcription activator-like effector nucleases (TALEN); especially in regard to cost, ease of use and predictability of results compared to the earlier technologies (as described in the linked articles). The cost has been especially relevant in the diffusion of this technology away from only well-funded organisations and into the hands of researchers in smaller laboratories (there are even kits available for Do-It-Yourself Biologists; however, there is more to using the technology than just buying a kit).

6 – 9 June 2016
2016 BIO International Convention
San Francisco, CA, USA

7 – 8 June 2016
5th Internet of Things Event
High Tech Campus Eindhoven, The Netherlands

8 – 10 June 2016
12th International Symposium on Protection against Chemical and Biological Warfare Agents
Stockholm, Sweden

9 – 11 June 2016
ECSITE Annual Conference 2016
Graz, Austria

20 – 22 June 2016
OPCW SAB Workshop on Chemical Forensics
Helsinki, Finland

22 – 24 June 2016
Industrial Technologies 2016
Amsterdam, The Netherlands

11 – 16 July 2016
AAAS-TWAS Course on Science Diplomacy 2016
Trieste, Italy

18 – 22 July 2016
The International Conference on Pure and Applied Chemistry (ICPAC 2016)
"Emerging Trends in Chemical Sciences"
Flic en Flac, Mauritius

8–12 August 2016
BWC Preparatory Committee for the Eighth Review Conference (continued)
Geneva, Switzerland

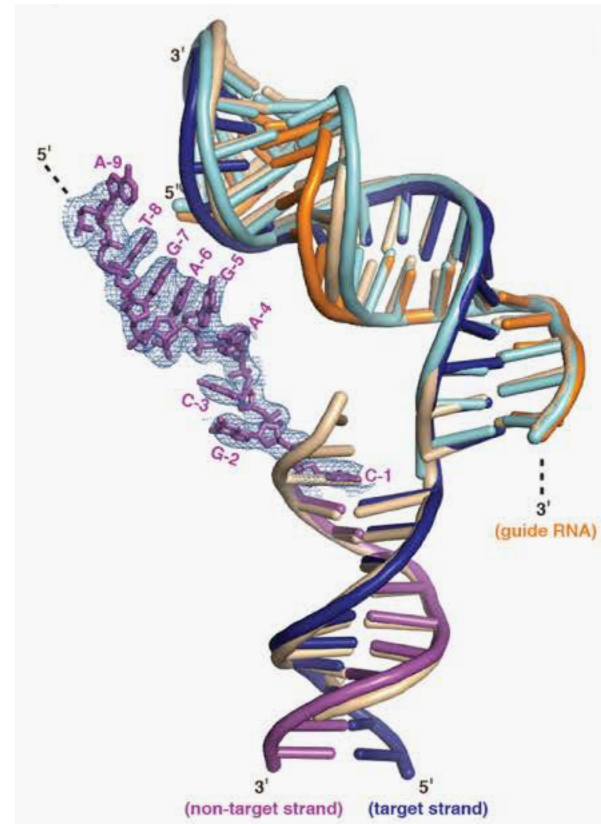
15 – 20 August 2016
24th IUPAC International Conference on Chemistry Education (ICCE 2016)
Kuching, Malaysia.

21 – 25 August 2016
252nd American Chemical Society National Meeting & Exposition
Philadelphia, PA, USA

4 – 7 September 2016
52nd Congress of the European Societies of Toxicology (EUROTOX2016)
Istanbul, Turkey

4 – 8 September 2016
6th International IUPAC Conference On Green Chemistry
Venice, Italy

Despite how easy it all sounds, gene-editing still has hurdles to overcome; hurdles that include reducing off-target effects, identifying which diseases are suitable targets, accurately predicting phenotypic and the ethical implications of the use of this technology.



Distorted conformation of sgRNA-DNA complexes interacting with the CAS9 protein. Image from ScienceMag

In regard to addressing the technical limitations, researchers are continuing to look for ways to improve the performance and the ability to deliver CRISPR/CAS9 into target cells (an area of active research). Alternate enzymes (including modified CAS9 or multi-component enzymatic systems, Cpf1 for example) can be used in place of CAS9; offering the possibility for more flexibility in locations of the genome that can be targeted for editing. Other developments include the testing of new methods for delivering CAS9 and synthesising guide RNA (gRNA) to overcome current limitations in overall efficiency and ease of use, the use of asymmetric donor DNA to improve the efficiency of precise sequence replacement, light activated on/off switching, and the use of nanotechnologies and microfluidics for delivery into cells.

Scientists are finding potential applications for the technology in areas that include metabolic engineering, cancer biology, genomic regulation and interrogation, defence against HIV-1, *in-vivo* interrogation of gene function in the brain and gene therapy. Demonstrations of what can be done with CRISPR/CAS9 include genetic screening in human cells and targeted DNA degradation.

Commercially, the use of CRISPR/CAS9 might show up on your dinner plate as agricultural biotechnology companies are already studying gene-edited food crops; this has also raised questions in regard to GMO crop regulations. Does deleting a gene from a plant instead of modifying (or replacing) a gene, still make that plant a GMO?

There is also commercial interest in the use of CRISPR/CAS9 for genetic treatments in human healthcare and for drug development, as exemplified by companies such as CRISPR Therapeutics, Editas Medicine and Intellia Therapeutics.

In regard to the ethical issues, the National Academy of Sciences in Washington DC hosted a Human Gene Editing Summit last December, where rules and guidelines for use of the technology were discussed (presentations and a report are available online). The Royal Society is engaging in further dialogue on gene editing bioethics (which includes considerations for the Biological Weapons Convention). Many ethical discussions focus on editing the human germline, as exemplified by the reaction to the first (and only) reported editing of a human embryo in 2015.

We don't expect any slowdown in new developments (and controversies) in the discussion of CRISPR/CAS9, if anything it will give us much to consider over the coming years!

4 – 9 September
Asser Institute Summer Programme on Disarmament and Non-Proliferation of Weapons of Mass Destruction in a Changing World
The Hague, The Netherlands

25 – 28 October 2016
24th Session of OPCW SAB
OPCW Headquarters
The Hague, The Netherlands

7 – 25 November 2016
BWC Eighth Review Conference
Geneva, Switzerland

6 – 8 December 2016
CHAINS 2016, the Dutch chemistry conference
The Netherlands

Science and Technology Updates from the CWC Conference of States Parties and the BWC Meeting of States Parties

With all the science and technology discussed in our offices, the question often comes up, what issues and topics are the States Parties interested in? To answer, we highlight the science and technology that featured in the Chemical Weapons Convention Twentieth Conference of States Parties (CSP-20) and Biological Weapons Convention Meeting of States Parties (BWC MSP) both held in December of 2015.

At CSP-20, of the seventy-nine General Debate Statements from States Parties, fifty-four made mention of science and technology in relation to the Chemical Weapons Convention; a paper on "Aerosolisation of Central Nervous System-Acting Chemicals for Law Enforcement Purposes" was introduced by Australia (jointly with twenty-one other States Parties); and the CSP adopted decisions on additional guidelines on the designation of laboratories for the analysis of authentic samples, the designation of laboratories for the analysis of authentic biomedical samples and guidelines for the conduct of biomedical proficiency tests and the establishment of an advisory board on education and outreach (ABEO).

Royal Society & IAP Side-event at the BWC MSP. Image by Elizabeth Bohm

Science and technology related side events at CSP-20 covered topics that included autonomous systems and artificial intelligence (hosted by The Hague Security Delta, OPCW and UNICRI); the book launch for The Practical Guide for Medical Management of Chemical Warfare Casualties; aerosolisation of central nervous system-acting chemicals, detection of chlorine gas poisoning (with presentations from OPCW, the Swedish Defence Research Agency and the Center for Disease Control); The Hague Ethical Guidelines; and Science for Diplomats presentations on chemical forensics (from OPCW and Verifin).

At the BWC MSP, States Parties submitted papers on dedicated processes for reviewing science and technology (Switzerland); challenges for politics and science in biosafety and biosecurity (Austria); a proposal for the development of a template for a biological scientist code of conduct (China); and the application of dual use to science and technology advances (Iran).

Under the standing item on the review of developments in the field of science and technology, statements and presentations were made by Australia, China, Canada, Cuba, Finland, France, Georgia, Iran (on behalf of NAM and Others Group), India, Japan, The Netherlands, OPCW, The Russian Federation, Switzerland (a science and technology review, and a CRISPR/CAS9 update), the United Kingdom, and the United States.

The Royal Society and the International Academy Panel presented reports from their workshop on trends in science and technology that impact the BWC. The side event included additional presentations on microbial forensics and synthetic biology. The role of open source information in compliance, the United Nations Secretary General's Mechanism Designated Laboratories and Ebola (lessons learned from response, biosecurity and capacity, and a survivors speech) were discussed in other technical focused side events.

Biosafety and biosecurity topics were addressed in side events on contributions of ASEAN scientists and scientific organizations to the BWC (presentations provided an overview and looked at current implementation); effective biological security education (presentations included introductory remarks, a look at preventing biological threats, a biological security handbook and the IFBA Certification Programme); assessing the biothreat and proceeding safely (presentations included a Delphi study on biothreat assessment, safely pursuing biological advances and biological threat perceptions among experts); and laboratory procedures and personnel ethics in developing countries (presentations included an overview and reports from Latin American, Central Asian and African regions).

An advanced version of the BWC MSP report is available.

Did You Know?

Some Baltic Sea bacteria can use sulphur mustard degradation products as their sole source of carbon and energy?

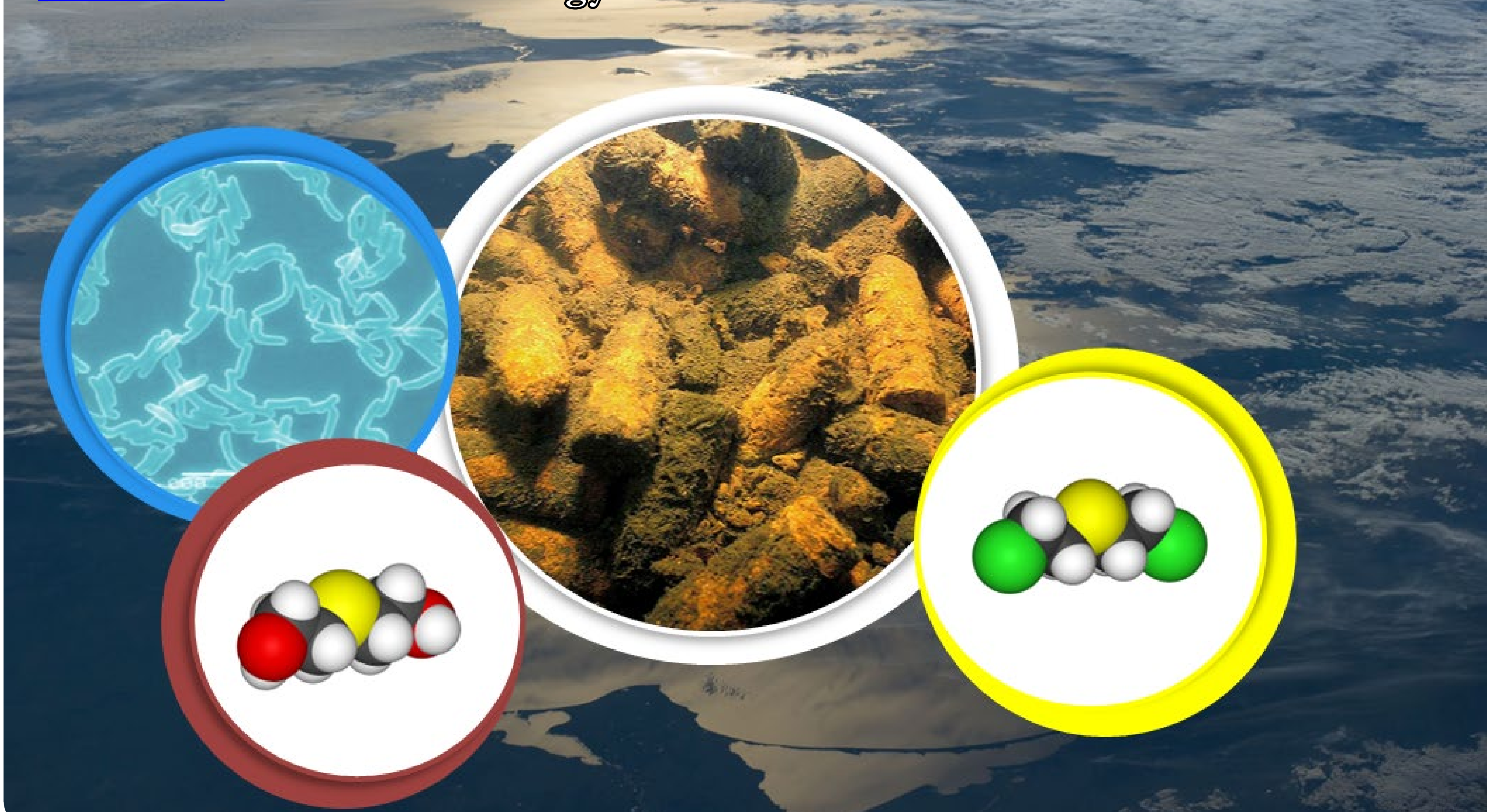


Image of Baltic sea by NASA, Underwater Munitions by IDUM and Bacteria by Wang et al.

Contact Us

Questions, ideas, comments, suggestions, want to make a contribution, or be added to the mailing list?
Please contact us through the OPCW Office of Strategy and Policy (OSP).
For more frequent updates, Visit us on the web or follow us on Twitter at @OPCW_ST.

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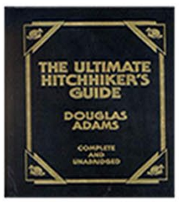

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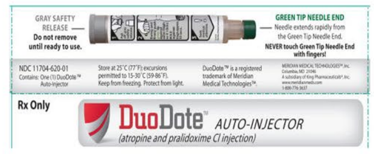

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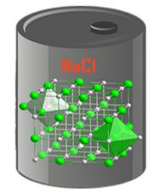

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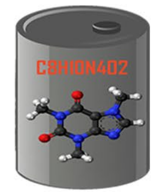

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