OPCW

Organisation for the Prohibition of Chemical Weapons

Barriers and Opportunities: Science, Technology, Disarmament and Non-proliferation

2nd Annual Global Forum on Scientific Advances Important to the Biological and Toxins Weapons Convention
Palais de Nations, Geneva, Switzerland
2 December 2019

Jonathan E. Forman, Ph.D.
Science Policy Adviser and Secretary to the Scientific Advisory Board

Where Does Science Fit Into An International Disarmament and Non-Proliferation Treaty?

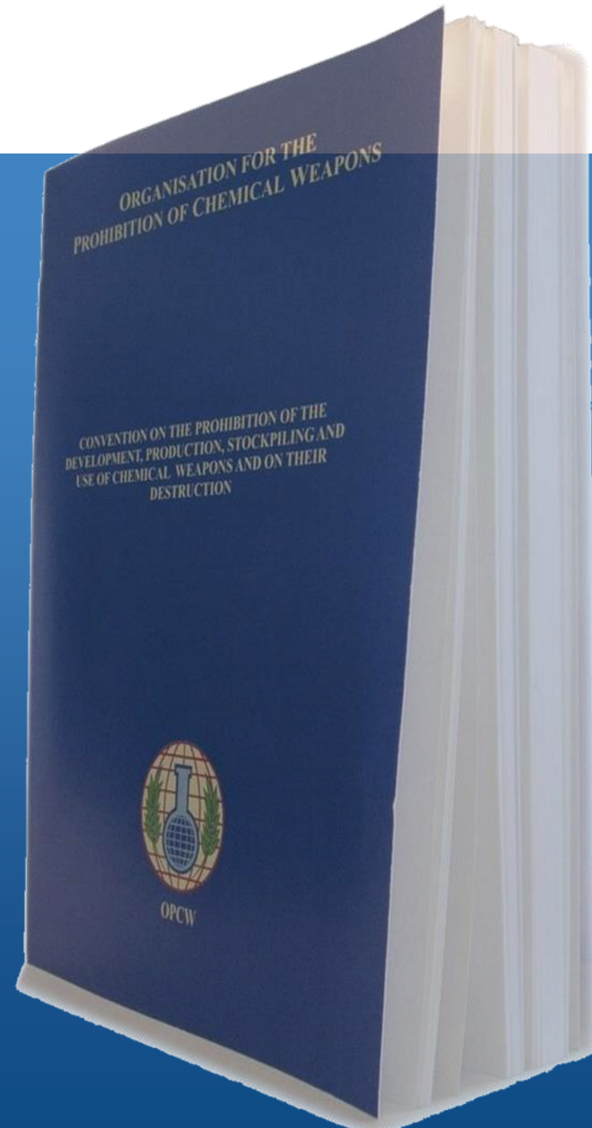

Where D
national
Disarm
Treaty?
INSIDE | North-South Summit Eases Korean Tensions
Arms Control TODAY
Volume 48 | Number 8
OCTOBER 2018
THE SOURCE ON NONPROLIFERATION AND GLOBAL SECURITY
'Everyone Has a Lot at Stake'
A Q&A with Fernando Arias, the new director-general of the Organisation for the Prohibition of Chemical Weapons
U.S. $7.00 Canada $8.00
A Publication of the Arms Control Association
www.armscontrol.org

The Conventions Mandate the States Parties to Discuss Science

The Conference of States Parties Shall:

“Review scientific and technological developments that could affect the operation of this Convention and, in this context, direct the Director General to establish a Scientific Advisory Board to enable him, in the performance of his functions, to render specialized advice in areas of science and technology relevant to this Convention, to the Conference, the Executive Council or States Parties.”

CWC Article VIII, Section B, paragraph 21(h)



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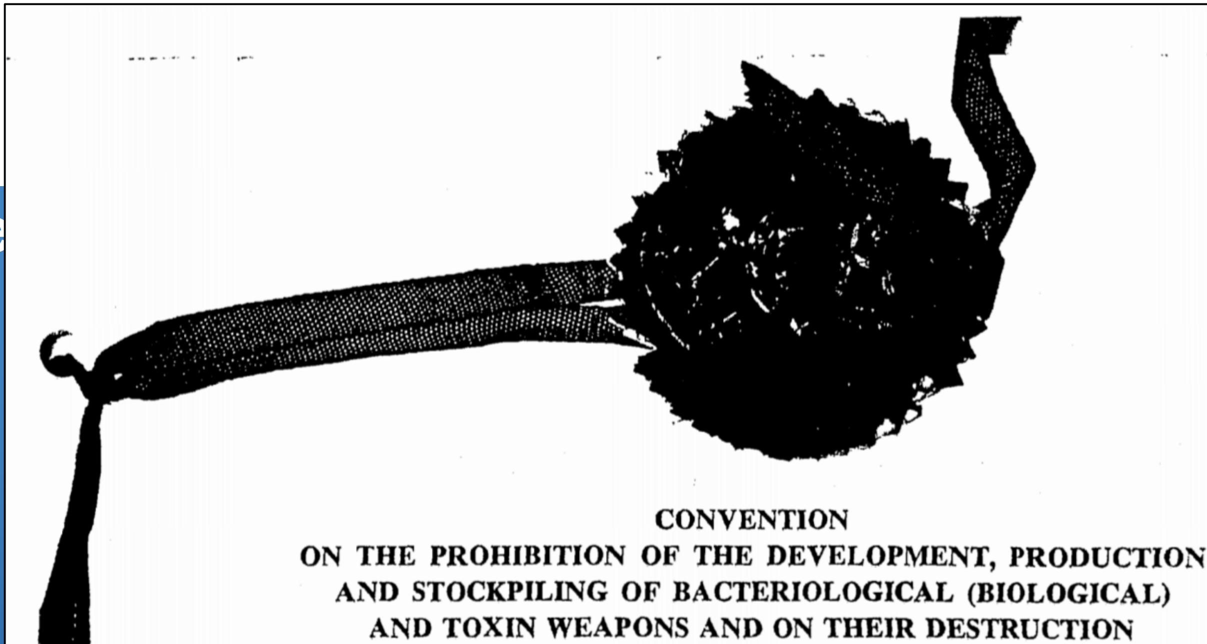
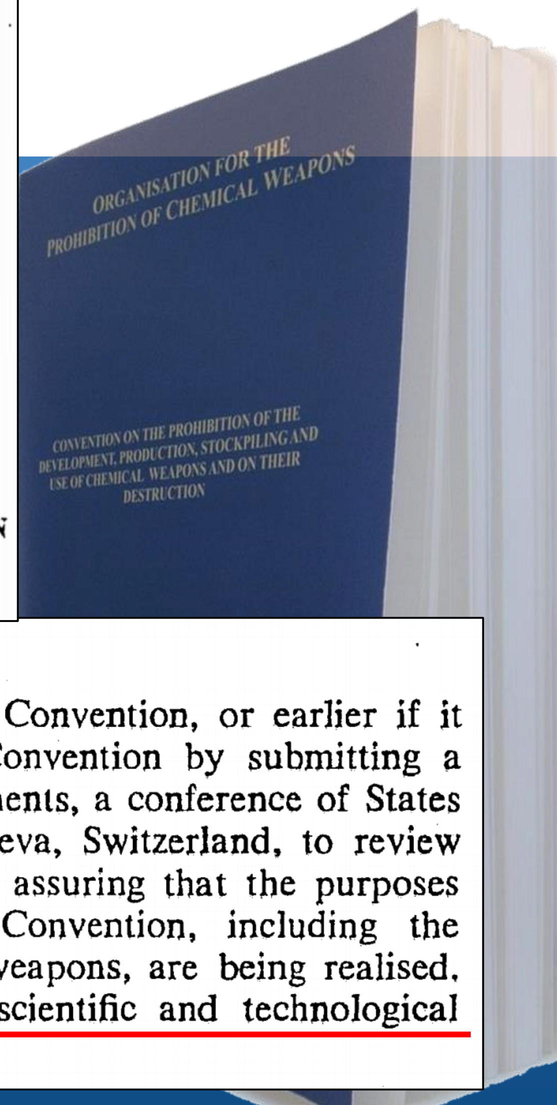
The Conventions Mandate the States Parties to Discuss Science



CONVENTION
ON THE PROHIBITION OF THE DEVELOPMENT, PRODUCTION
AND STOCKPILING OF BACTERIOLOGICAL (BIOLOGICAL)
AND TOXIN WEAPONS AND ON THEIR DESTRUCTION



The

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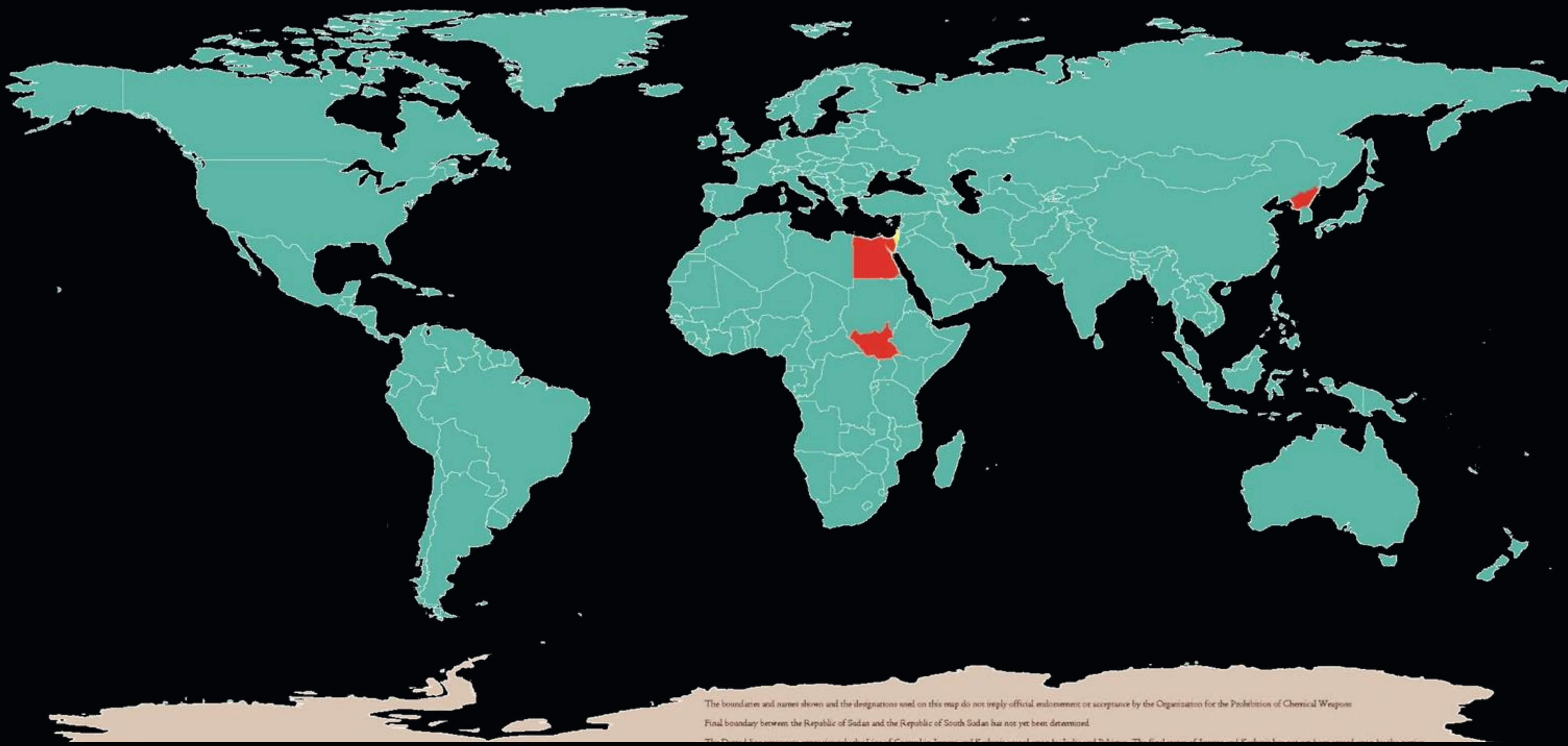
CWC Article VIII,

OPCW

ARTICLE XII

Five years after the entry into force of this Convention, or earlier if it is requested by a majority of Parties to the Convention by submitting a proposal to this effect to the Depositary Governments, a conference of States Parties to the Convention shall be held at Geneva, Switzerland, to review the operation of the Convention, with a view to assuring that the purposes of the preamble and the provisions of the Convention, including the provisions concerning negotiations on chemical weapons, are being realised. Such review shall take into account any new scientific and technological developments relevant to the Convention.

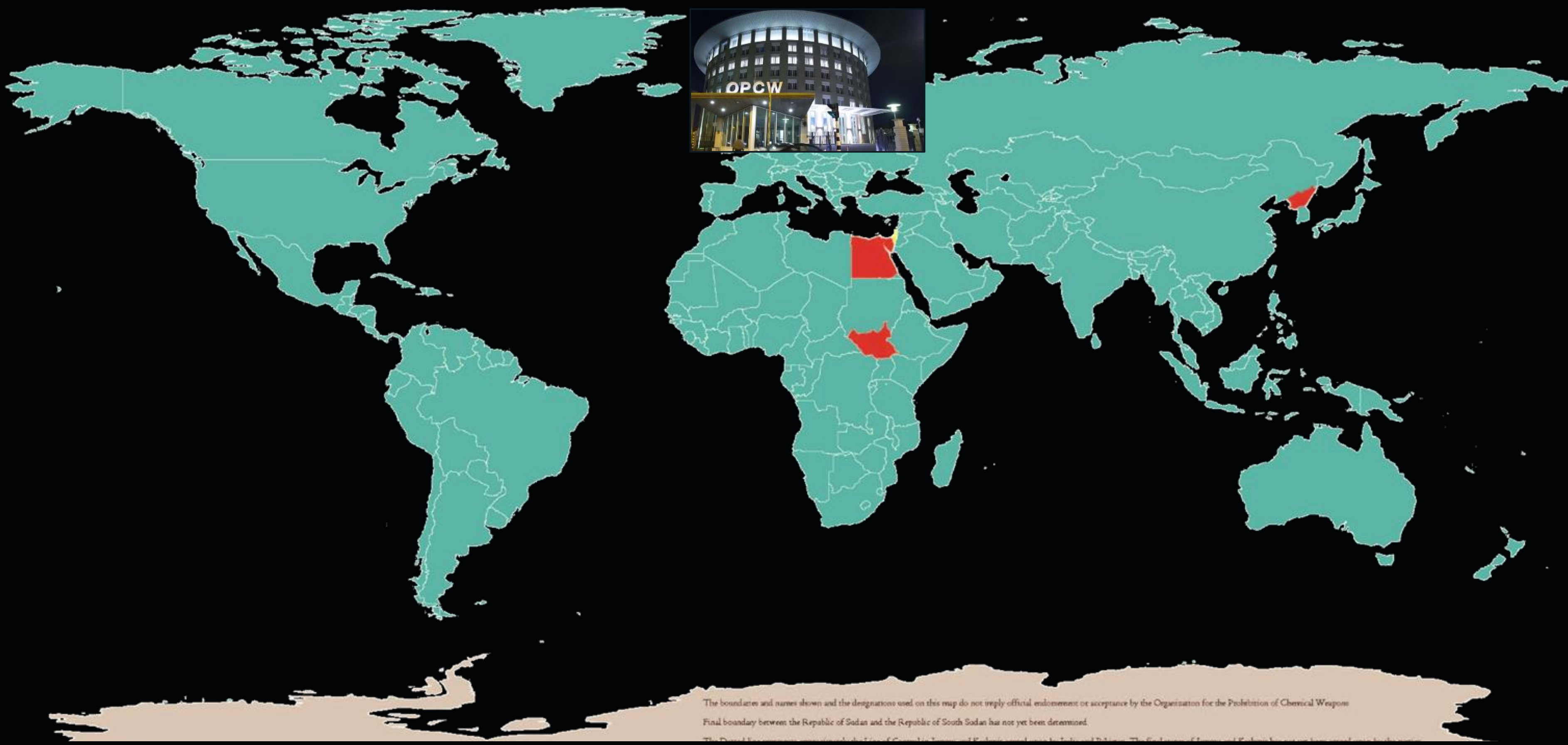
How Do 193 “States Parties” Discuss Science?



Signed Without Ratification

Non-Signatory

How Do 193 “States Parties” Discuss Science?



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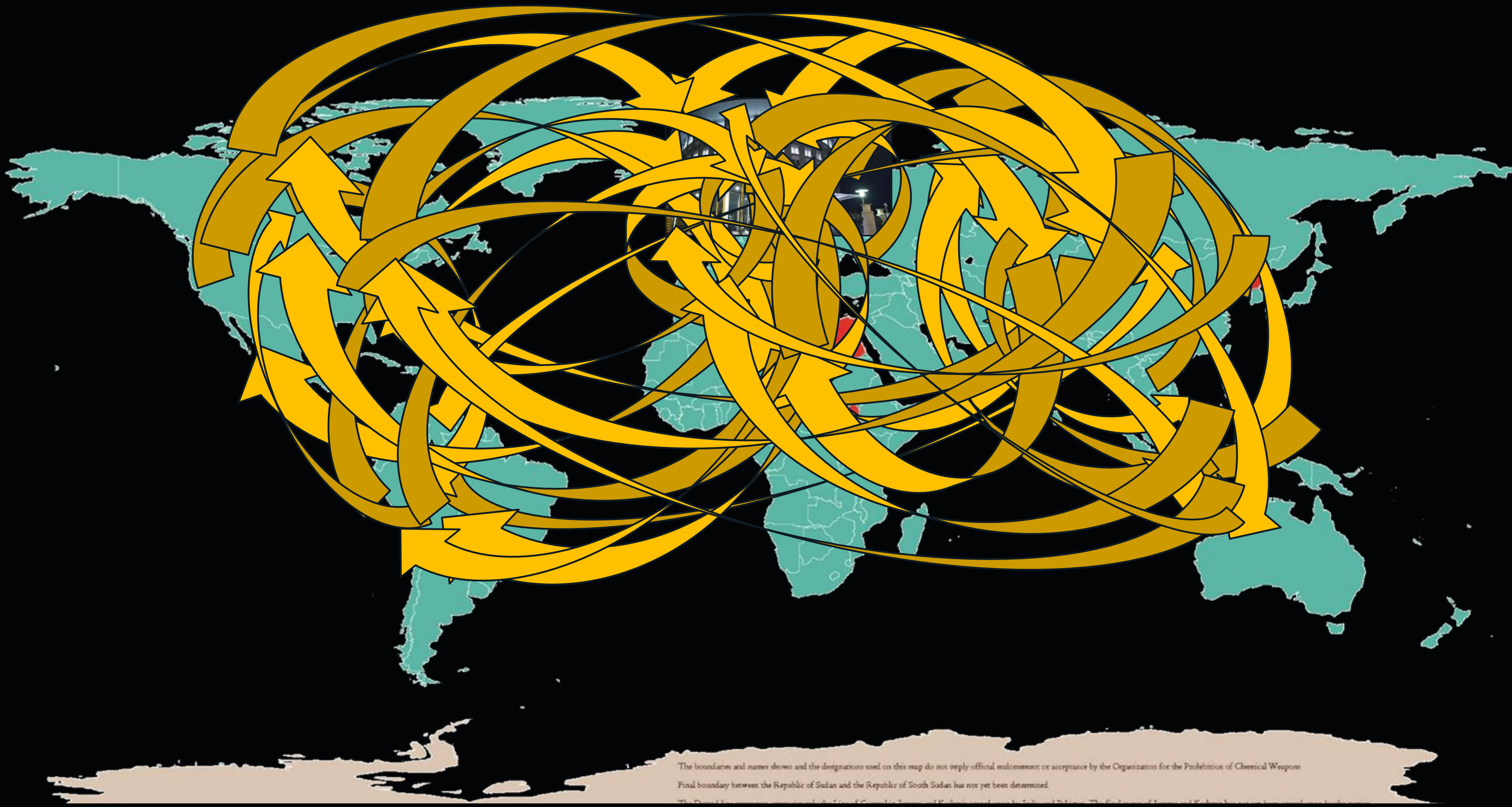


Signed Without Ratification

Non-Signatory

How Do 193 “States Parties” Discuss Science?

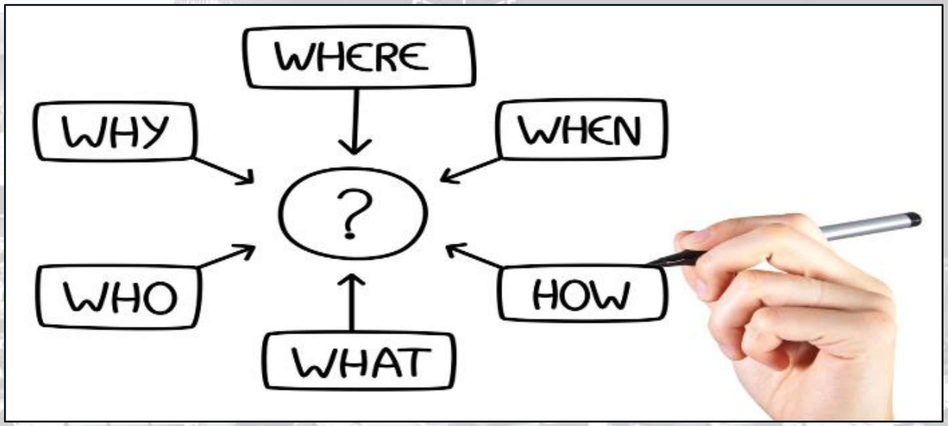
Signed Without Ratification

Non-Signatory

Can the Science Connect to Policy Priorities?

- **Science:** discovery, evidence, knowledge (running experiments)

- **Policy:** values and norms (defining outcomes)



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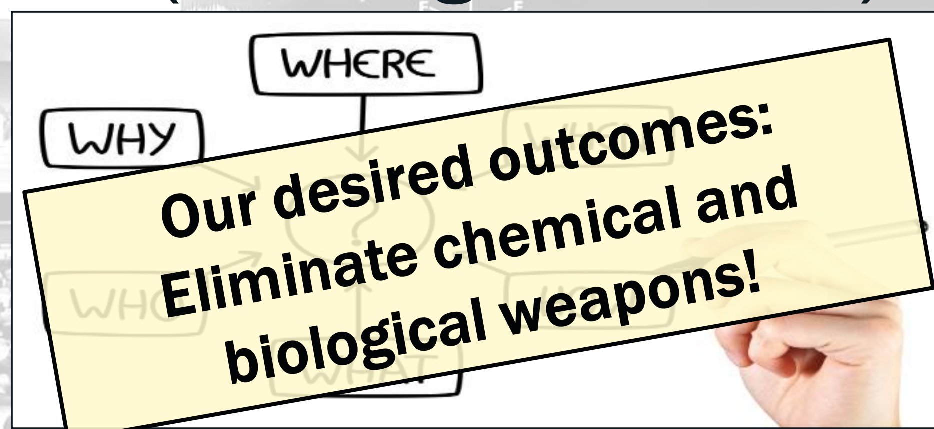

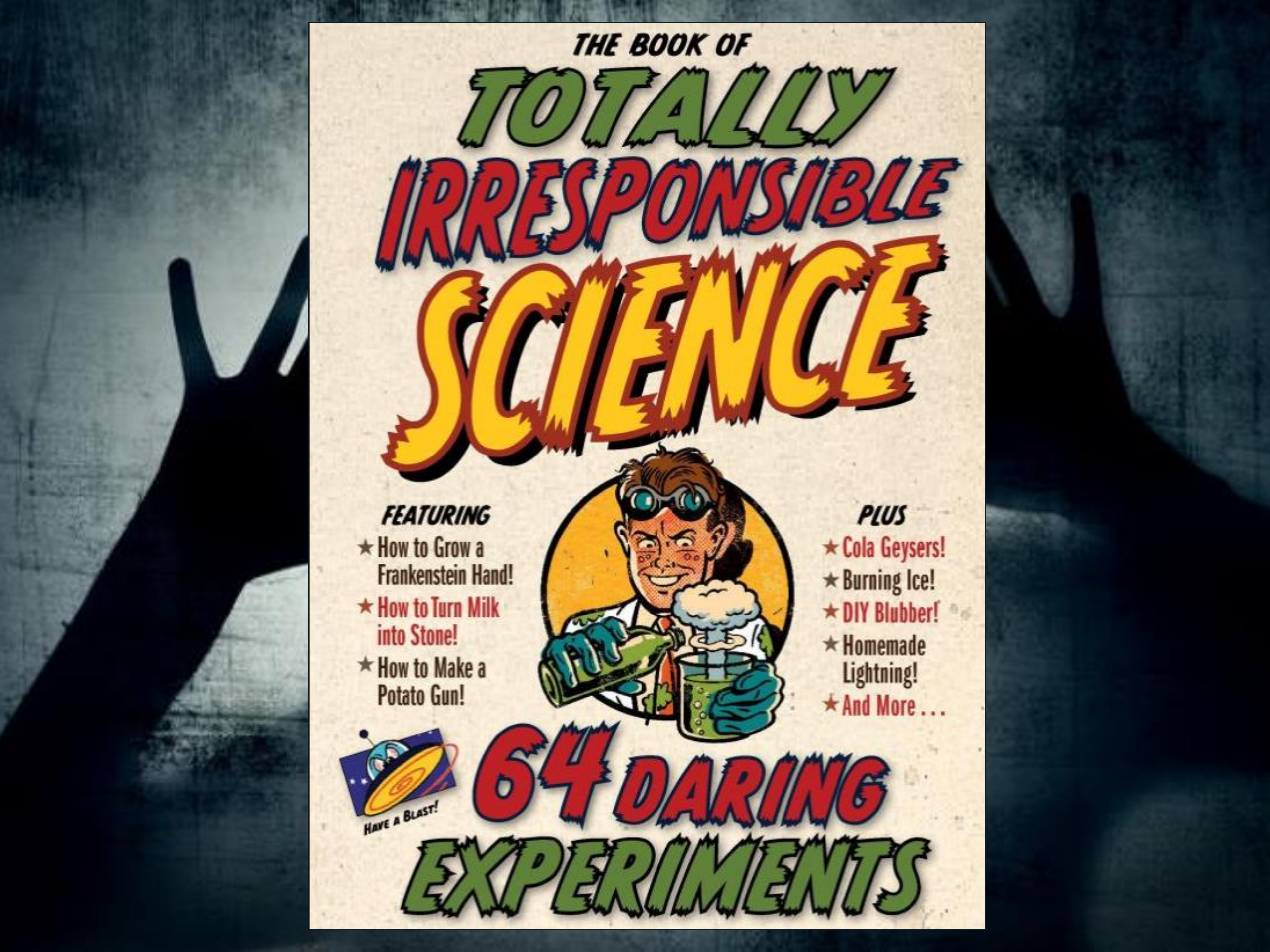
THE BOOK OF
TOTALLY
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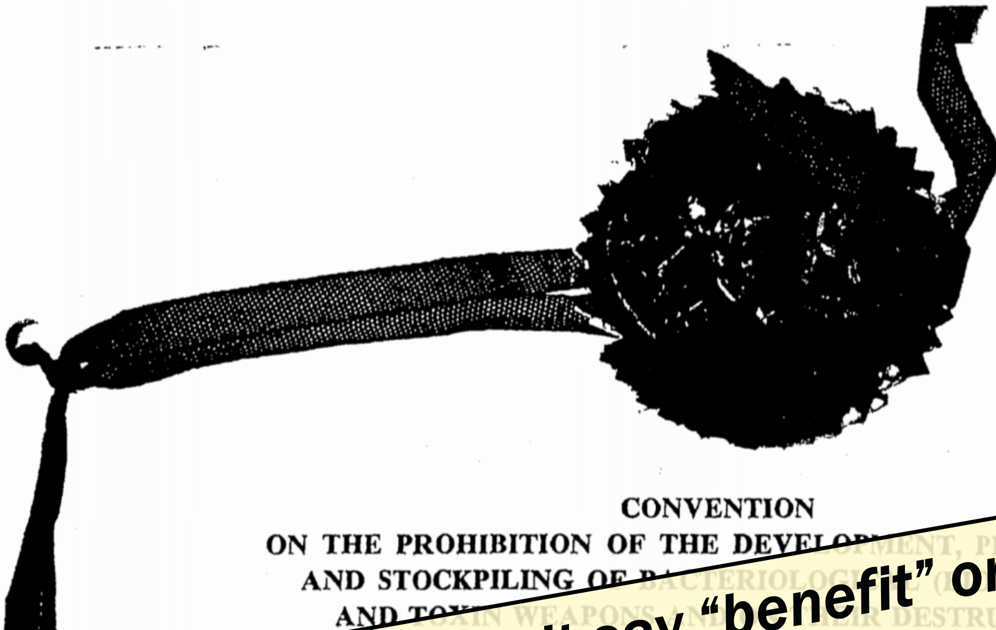
SCIENCE
FEATURING
★ How to Grow a Frankenstein Hand!
★ How to Turn Milk into Stone!
★ How to Make a Potato Gun!
PLUS
★ Cola Geysers!
★ Burning Ice!
★ DIY Blubber!
★ Homemade Lightning!
★ And More . . .
HAVE A BLAST!
64 DARING
EXPERIMENTS

The Conventions Mandate the States Parties to Discuss Science

The



CONVENTION
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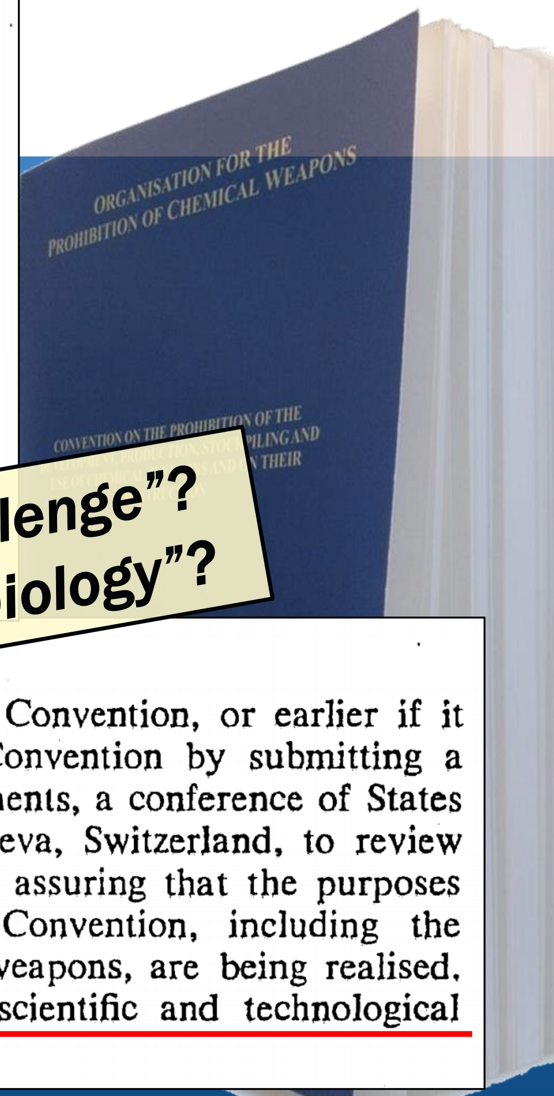

specialized a
technology re
Conference
Parties."

Where does it say "benefit" or "challenge"?
Where does it say "chemistry" or "biology"?

ARTICLE XII

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CWC Article VIII,

OPCW

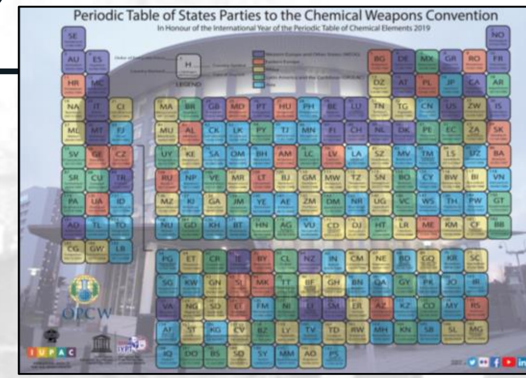
Treaty Implementation

"The Convention"

- Disarmament (Destruction and Verification)
- Non-proliferation (Verification)
- Assistance and Protection against CWs
- International Cooperation

Treaty Implementation

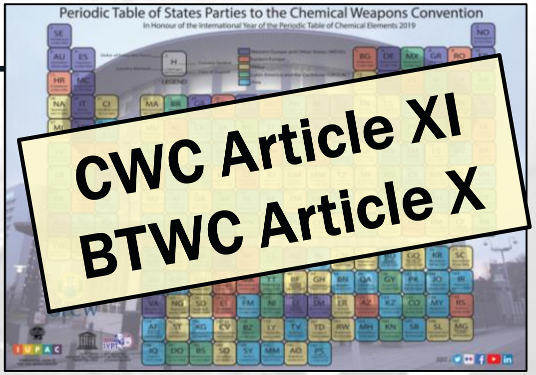
"The Convention"



Treaty Implementation

"The Convention"

Obligation of both CWC and BTWC

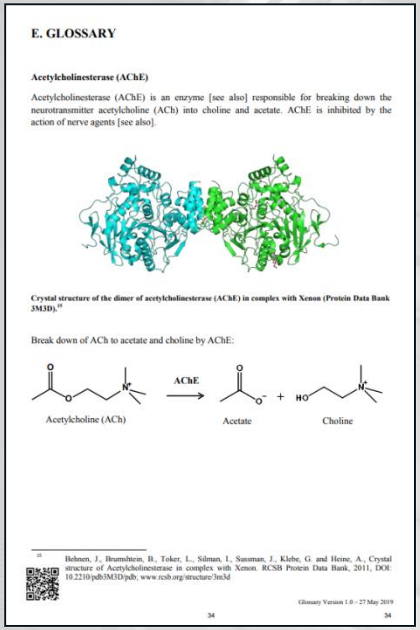


CWC Article XI
BTWC Article X

A more difficult discussion amongst CWC and BTWC communities!

CWC Article X
BTWC Article VII

Without a Sound Scientific Basis There is No Treaty Implementation!



E. GLOSSARY

Acetylcholinesterase (AChE)

Acetylcholinesterase (AChE) is an enzyme [see also] responsible for breaking down the neurotransmitter acetylcholine (ACh) into choline and acetate. AChE is inhibited by the action of nerve agents [see also].

Crystal structure of the dimer of acetylcholinesterase (AChE) in complex with Xenon (Protein Data Bank 3M3D).[15]

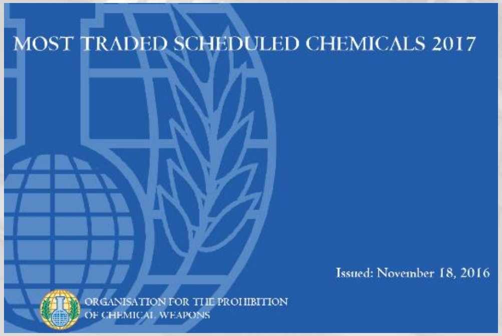
Break down of ACh to acetate and choline by AChE:

[15] Behnen, J., Brumshtein, B., Toker, L., Silman, I., Sussman, J., Klebe, G. and Heine, A., Crystal structure of Acetylcholinesterase in complex with Xenon. RCSB Protein Data Bank, 2011, DOI: 10.2210/pdb3M3D/pdb; www.rcsb.org/structure/3m3d

Glossary Version 1.0 – 27 May 2019

34 34

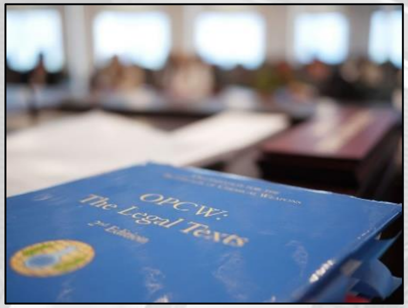
Article II



Article III

Articles IV and V

Article VI



Article VII

Article VIII

Articles IX and X

Article XI

OPCW

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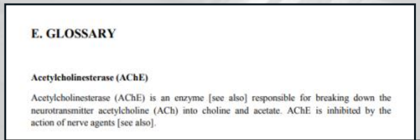
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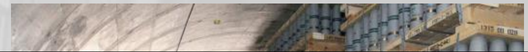
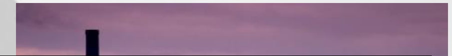




Article VII

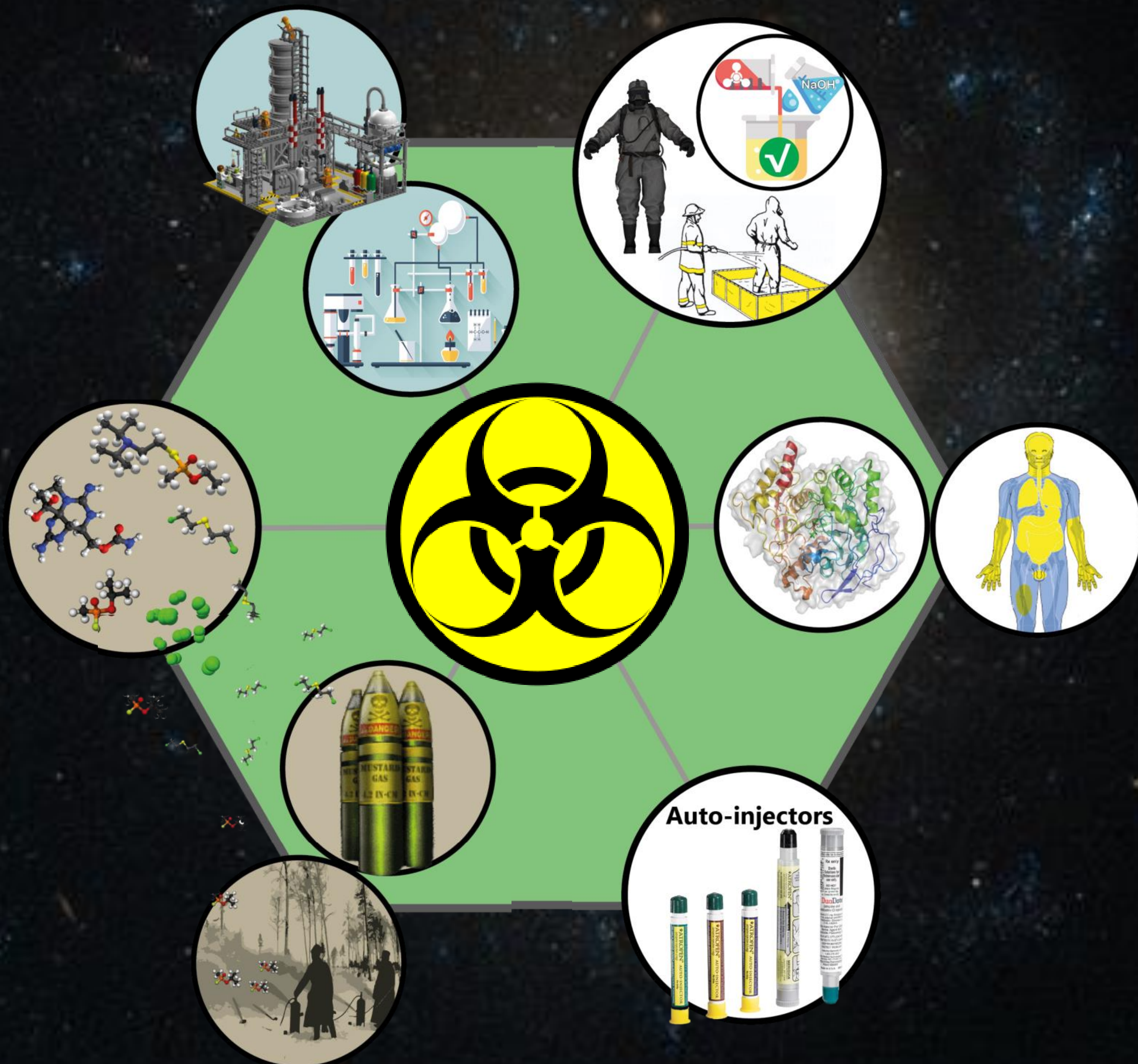
Article VIII

Articles IX and X

Article XI

OPCW

What Science Should be Our Priority?



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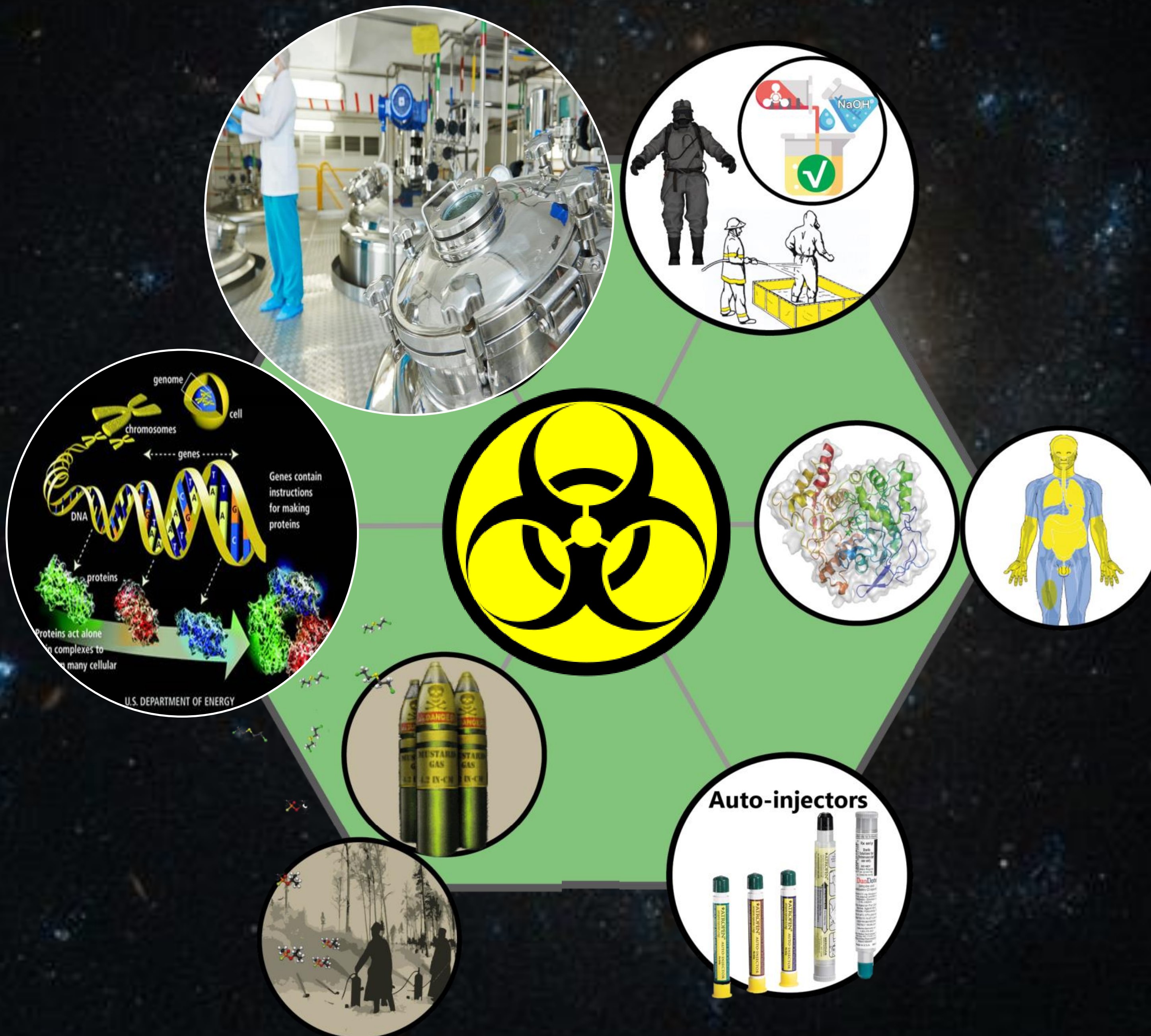

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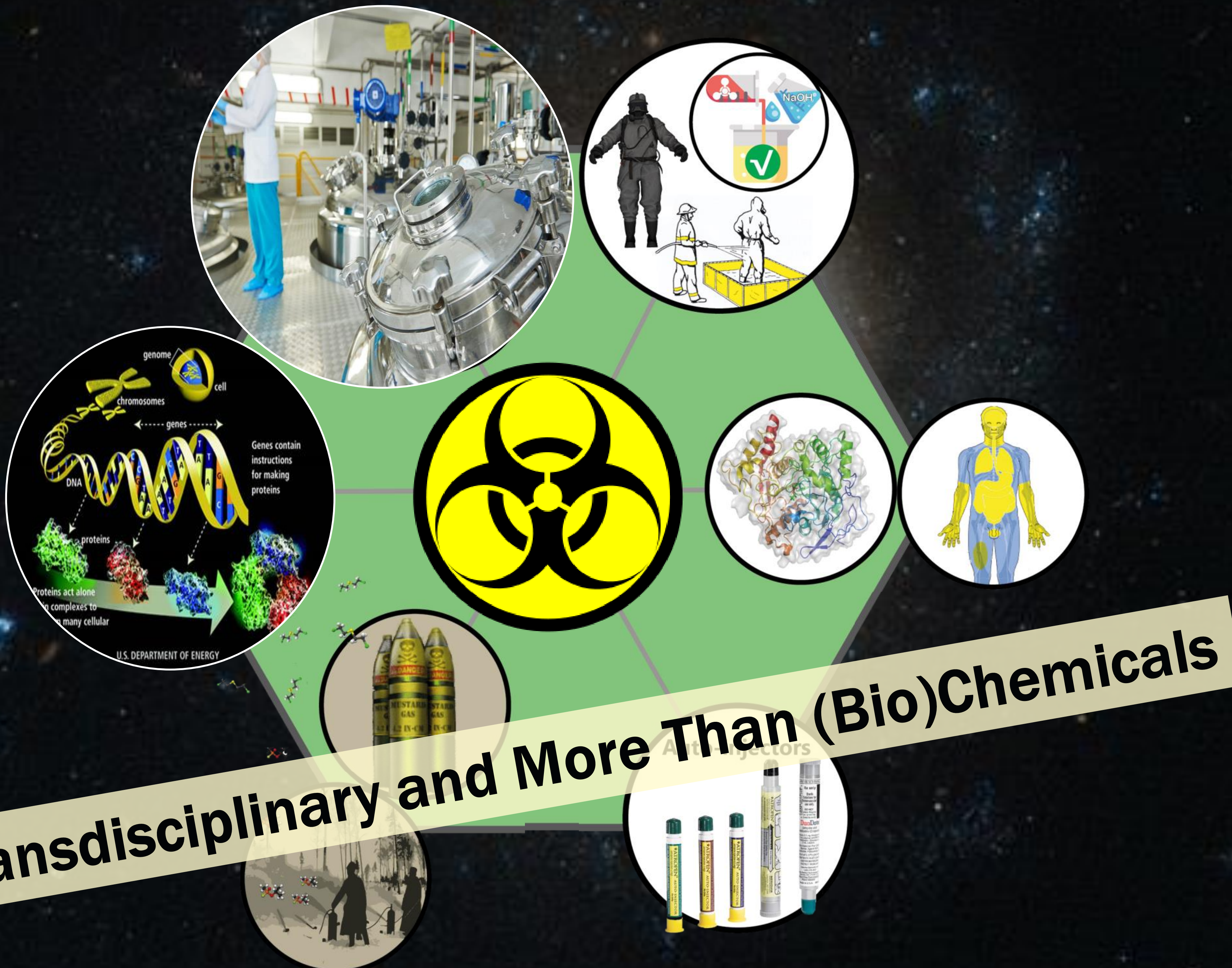

Transdisciplinary and More Than (Bio)Chemicals

There is always more to the Story..

Muir *et al. Genome Biology* (2016) 17:53
DOI 10.1186/s13059-016-0917-0

Genome Biology

OPINION — Open Access

The real cost of sequencing: scaling computation to keep pace with data generation

Paul Muir[1,2,3], Shantao Li[4], Shaoke Lou[4,5], Daifeng Wang[4,5], Daniel J Spakowicz[4,5], Leonidas Salichos[4,5], Jing Zhang[4,5], George M. Weinstock[6], Farren Isaacs[1,2], Joel Rozowsky[4,5] and Mark Gerstein[4,5,7*]

Abstract

As the cost of sequencing continues to decrease and the amount of sequence data generated grows, new paradigms for data storage and analysis are increasingly important. The relative scaling behavior of these evolving technologies will impact genomics research moving forward.

History from the 50s to next generation sequencing

In the 1950s, the contemporaneous development of biopolymer sequencing and the digital computer started a digital revolution in the biosciences. Then in the late 1970s, the advent of the personal computer (PC) and Sanger sequencing led to an appreciable amount of sequence data being generated, stored in databases, and conceptualized within a computational framework [1–4]. Communal sequence databases were developed in the 1980s [5, 6], but most investigators worked with data of a scale that allowed transfer to and processing on a local client. In the 1990s, the rise of the Internet facilitated increased data sharing, and analysis techniques began to shift to programs hosted on websites [7]. In the mid-2000s, the most recent big change occurred with the advent of cloud computing and next generation sequencing (NGS), which led to a dramatic increase in the scale of datasets (Fig 1) [4, 8]. This necessitated changes in the storage infrastructure; databases such as the European Nucleotide Archive [9] and the Sequence Read Archive (SRA) [10] were created to store and organize high-throughput sequencing data. The SRA has grown significantly since its creation in 2007, and it now contains almost four petabases (4×10^{15} bases), approximately half of which are open access [11]. These datasets present a challenge because they are too large for the old sharing and analysis paradigms, but recent innovations in computational technologies and approaches, especially the rise of cloud computing, provide promising avenues for handling the vast amounts of sequence data being generated.

Organizing principles for biocomputing history

There are a number of key concepts to keep in mind when considering the coevolution of sequencing and computing. First is the idea that scientific research and computing have progressed through a series of discrete paradigms driven by the technology and conceptual frameworks available at the time, a notion popularized by Jim Gray from Microsoft [12]. Gray organized his views into four paradigms of scientific research. The first two paradigms are empirical observation and attempts to identify general theories. Gray's third paradigm describes the original type of scientific computing, epitomized by large supercomputer-based calculations and modeling, for example, computing a rocket trajectory from a set of equations. This approach tends to favor differential equations and linear-algebraic types of computations.

The fourth paradigm is much more data intensive. Here the "capture, curation, and analysis" of large amounts of information fuels scientific research [12]. Researchers often try to find patterns in "big data" and a premium is placed on resource interoperability and statistical pattern finding. In order to realize fully the potential of this approach to science, significant investment must be made both in the computational infrastructure that supports data processing and sharing and in

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[4]Program in Computational Biology and Bioinformatics, Yale University, New Haven, CT 06520, USA
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Full list of author information is available at the end of the article

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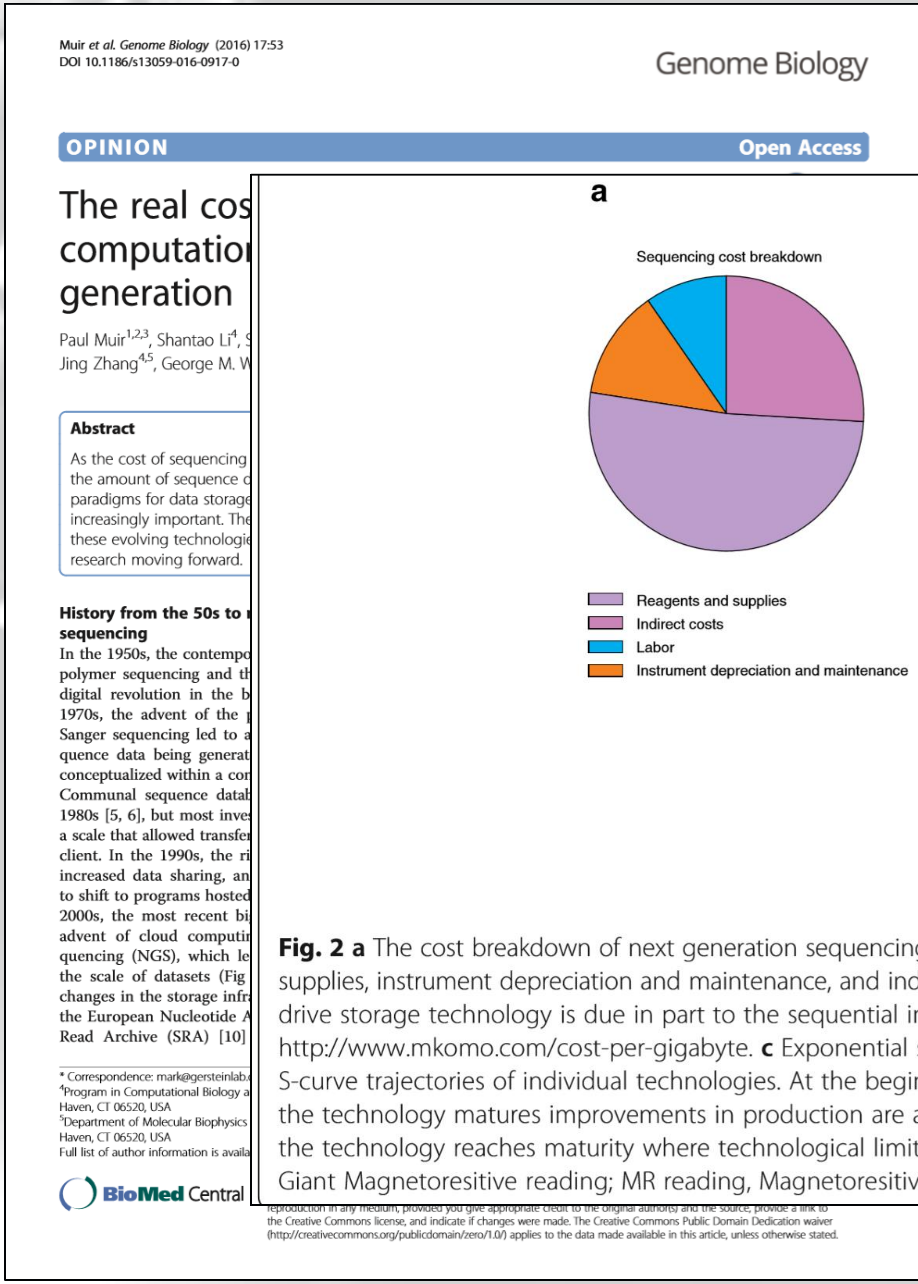
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Genome Biology

OPINION Open Access

The real cos
computation
generation

Paul Muir[1,2,3], Shantao Li[4], S
Jing Zhang[4,5], George M. W

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sequencing**

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* Correspondence: mark@gersteinlab.
[1]Program in Computational Biology a
Haven, CT 06520, USA
[5]Department of Molecular Biophysics
Haven, CT 06520, USA
Full list of author information is availa

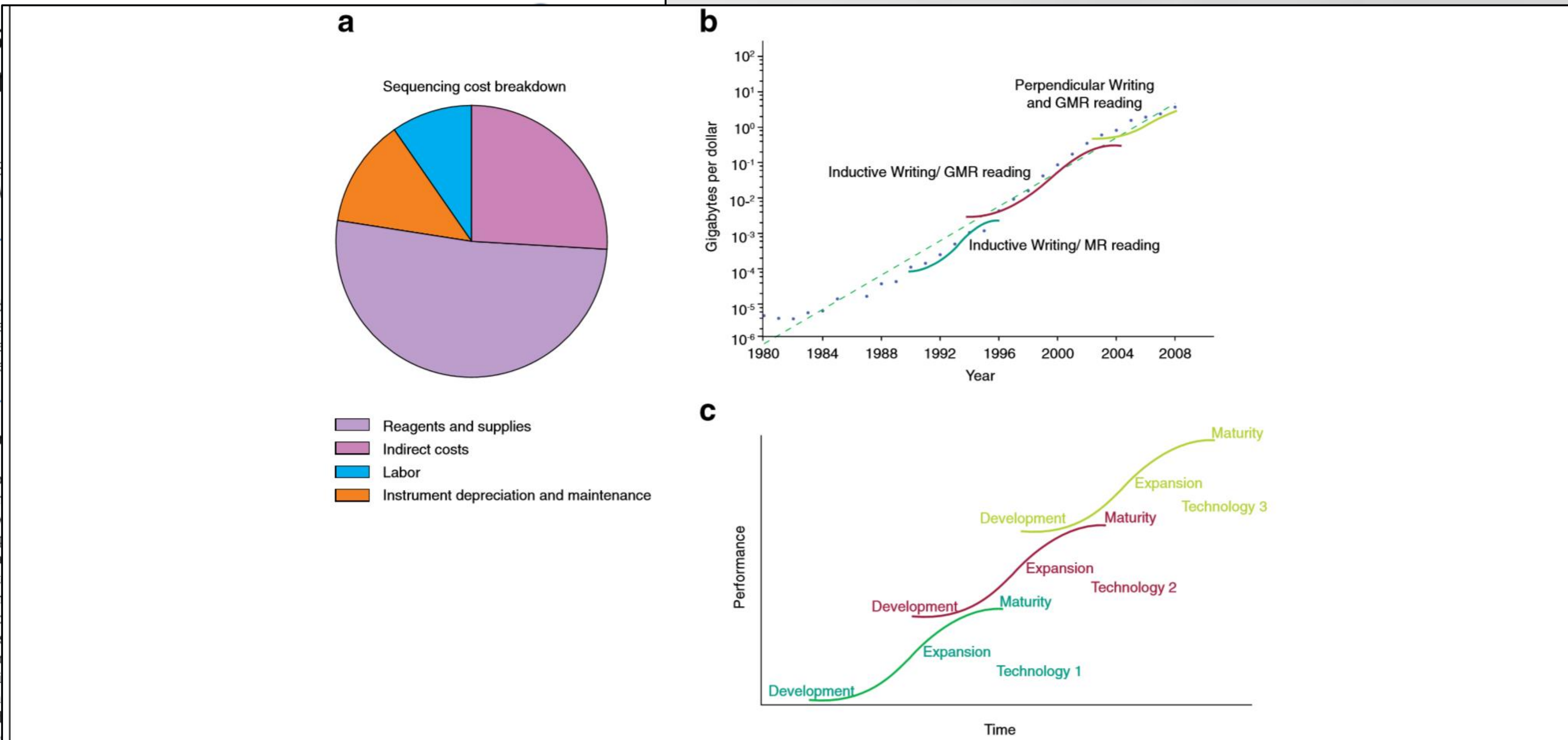
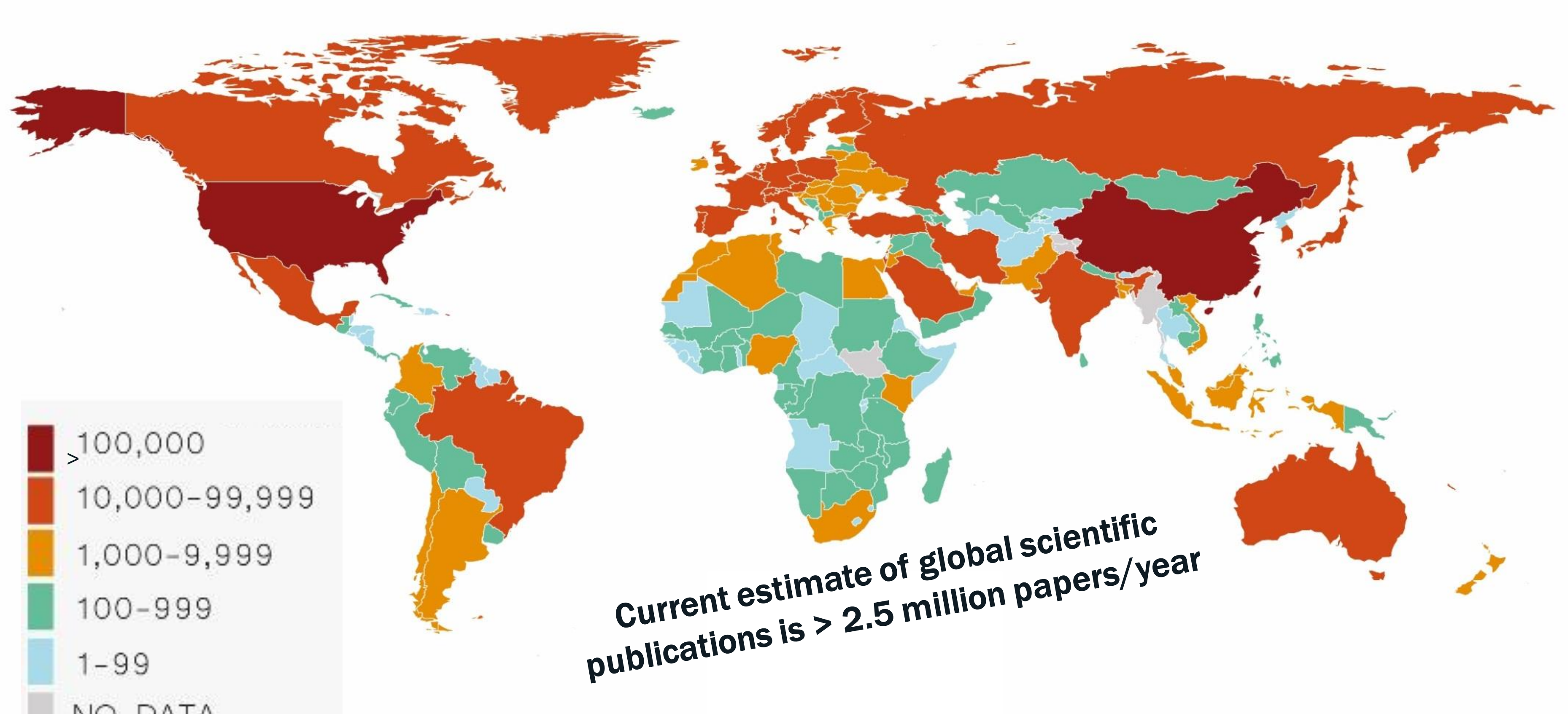


Fig. 2 a The cost breakdown of next generation sequencing projects. The total cost of these projects is split into the cost of labor, reagents and supplies, instrument depreciation and maintenance, and indirect fees. **b** The exponential increase in the number of gigabytes per dollar in hard drive storage technology is due in part to the sequential introduction and improvement of three technologies. Data were obtained from http://www.mkomo.com/cost-per-gigabyte. **c** Exponential scaling in technological cost improvement is often the superposition of multiple S-curve trajectories of individual technologies. At the beginning of a technology's life cycle, development costs keep cost reductions low. As the technology matures improvements in production are able to drive down per unit costs and establish an exponential regime. Eventually, the technology reaches maturity where technological limits are encountered and the cost improvements again slow down. GMR reading, Giant Magnetoresitive reading; MR reading, Magnetoresitive reading

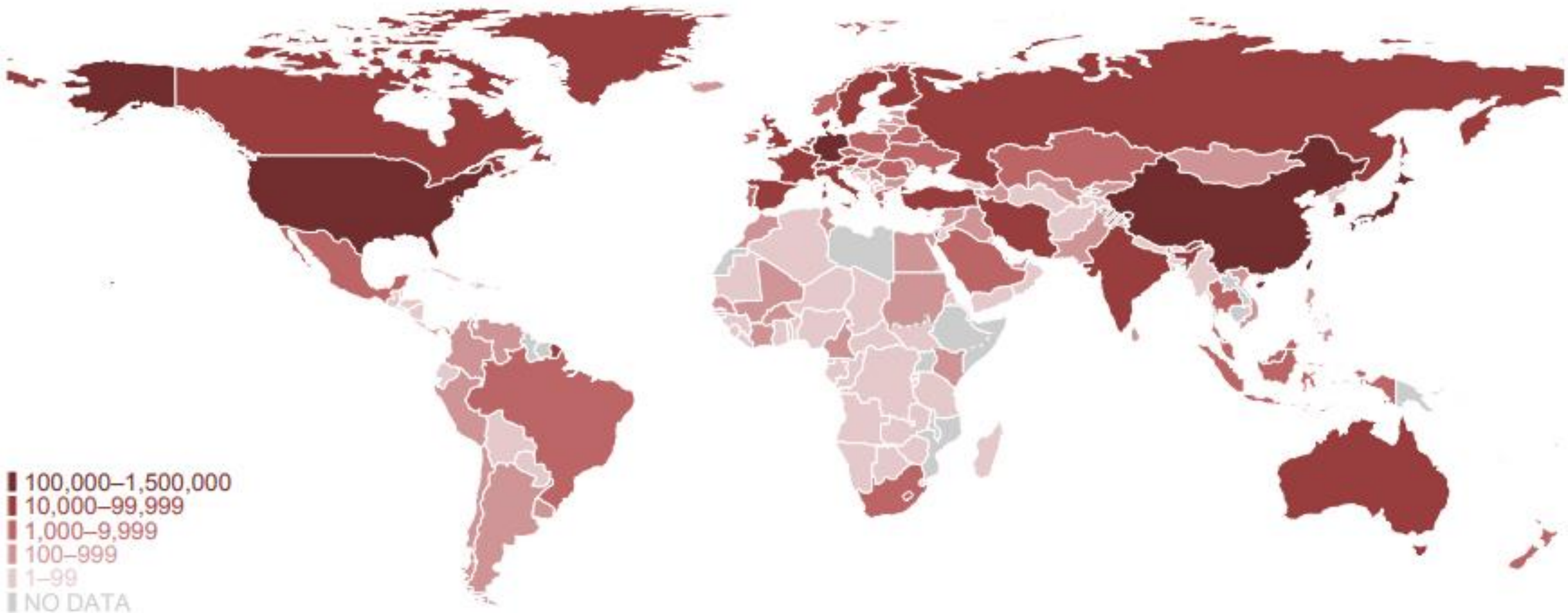
Where are the Rapid Advances in Science Happening?



Scientific Publications in 2014 (from UNESCO Science Report)

Where are the Rapid Advances in Science Happening?

Patent Application by origin 2017

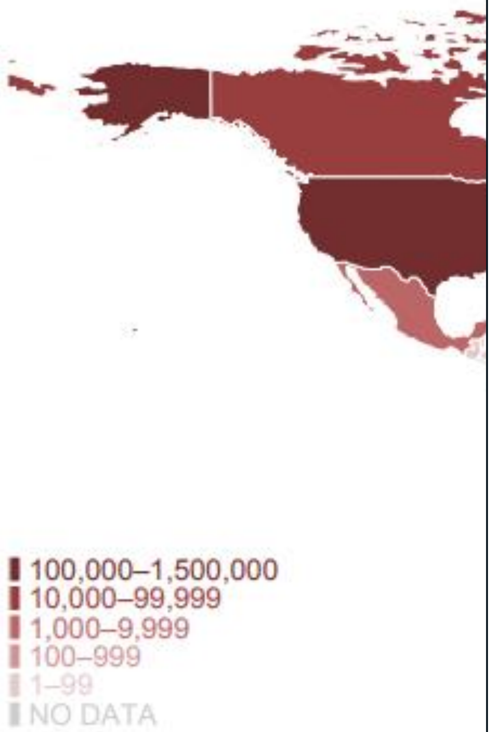


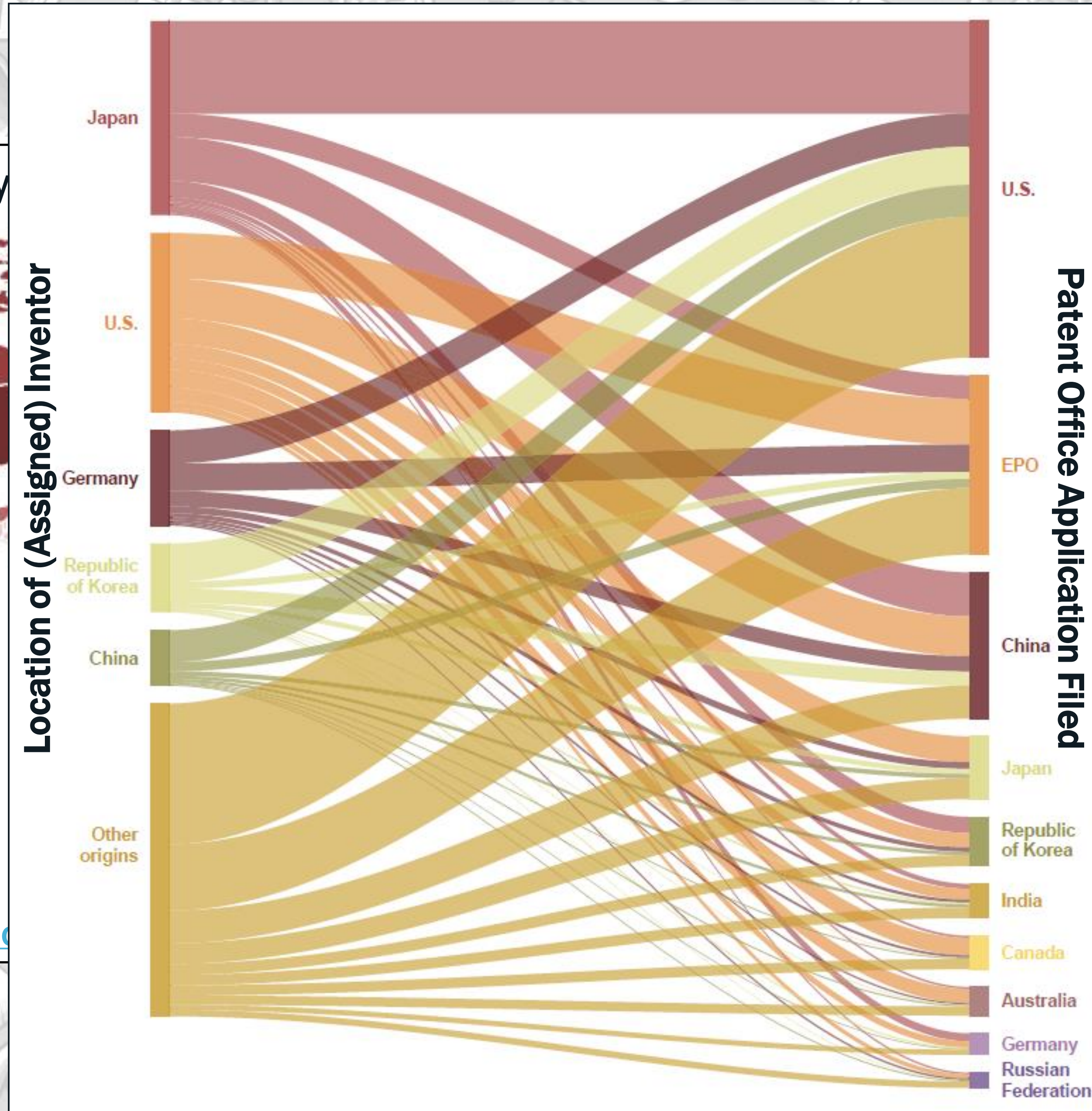
https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2018.pdf

Current estimate of global patent applications is > 3 million/year

Where are the Rapid Advances in Science Happening?

Patent Application by





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Where are the Rapid Advances in Science Happening?

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https://www.wipo.int/edoc

Regulated markets and sectors –commonly operating beyond the borders of the traditional non-proliferation communities

Continuation of driving forces reported in 2016 by OECD

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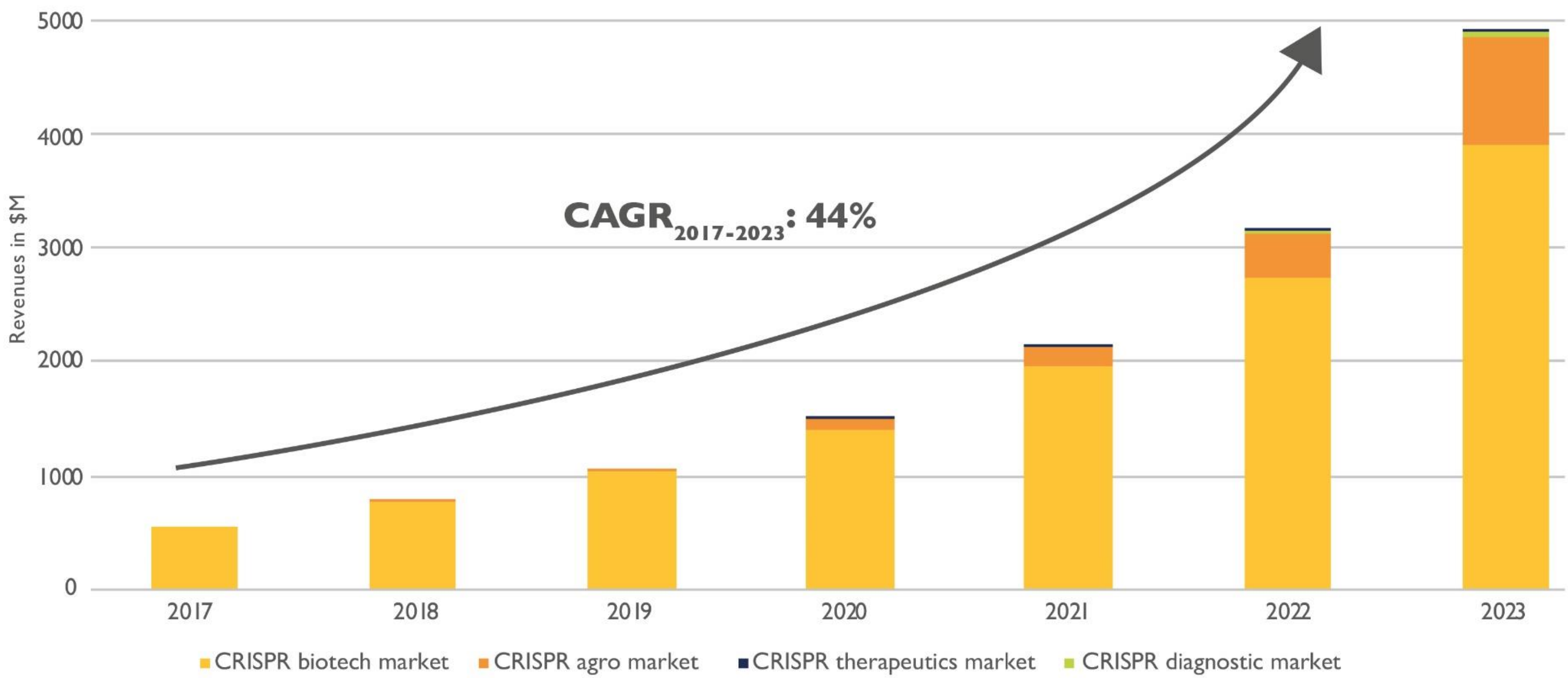
ear

Commercial/Private Sector Driving Forces are Significant

Yole Développement

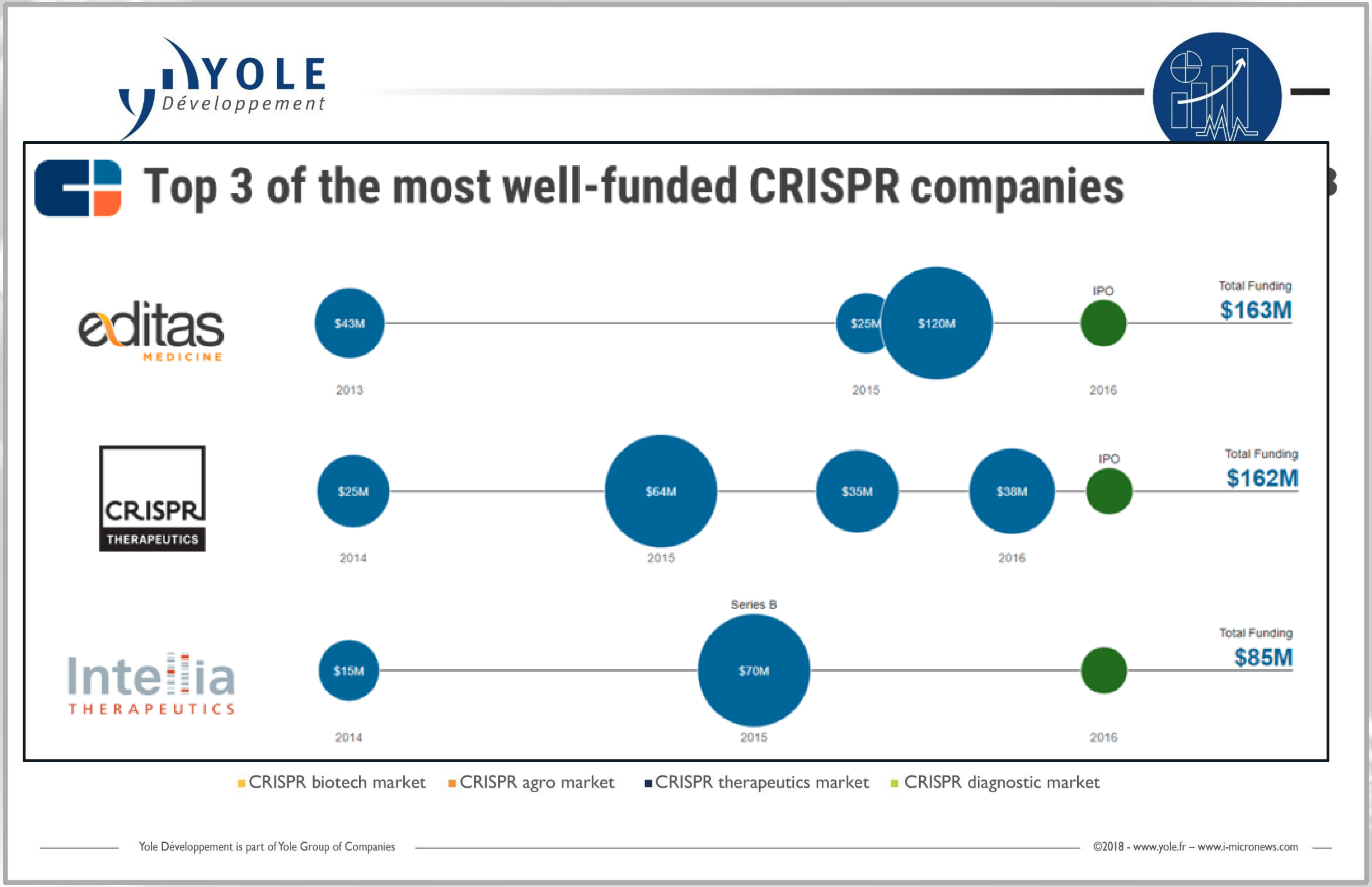
CRISPR technology: global market forecasts from 2017 to 2023

(Source: CRISPR Technology & Market Overview: from Lab to Industry 2018 report, Yole Développement, October 2018)



(CAGR = compound annual growth rate)

Commercial/Private Sector Driving Forces are Significant



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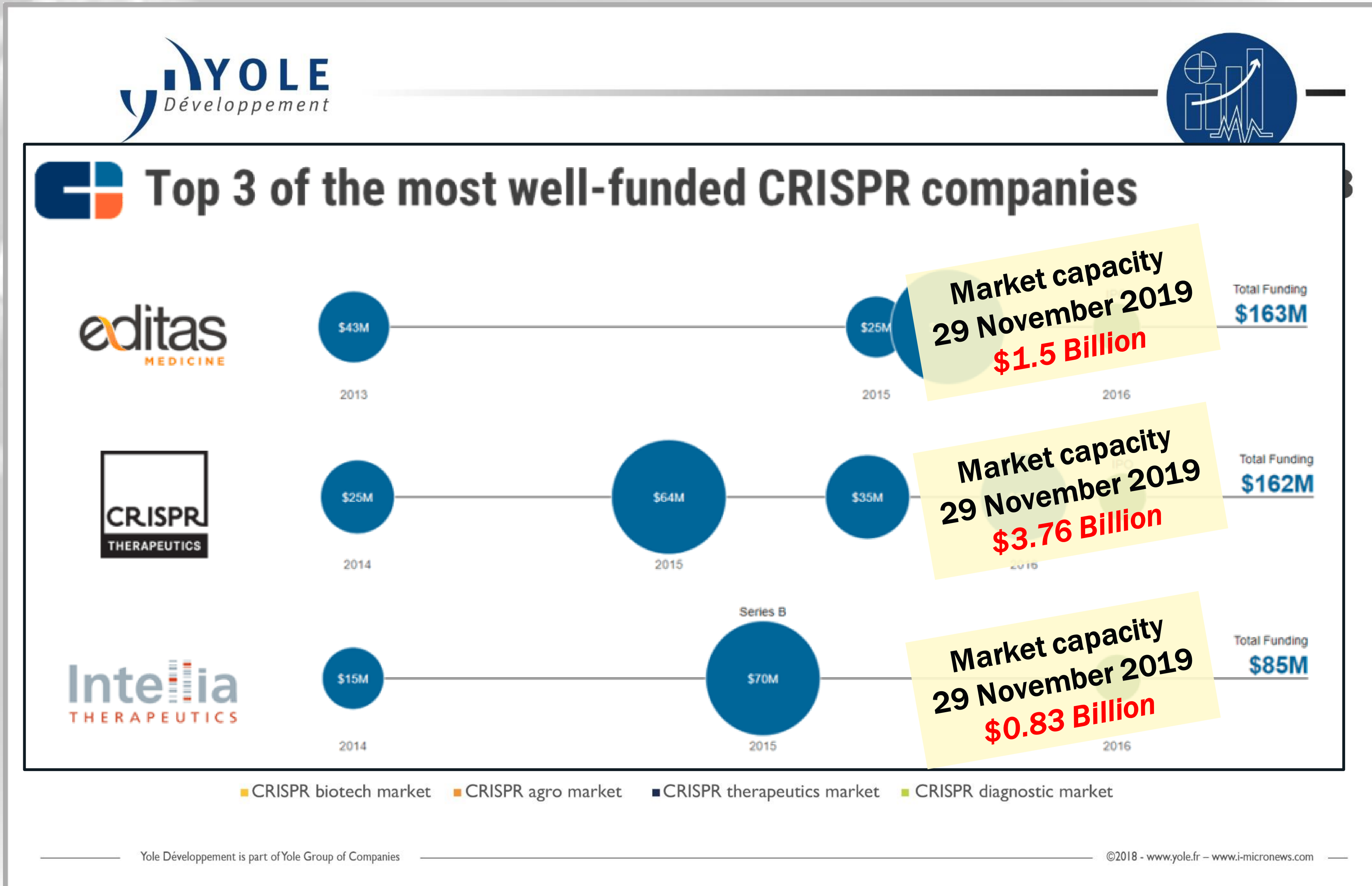

(CAGR = compound annual growth rate)

Commercial/Private Sector Driving Forces are Significant

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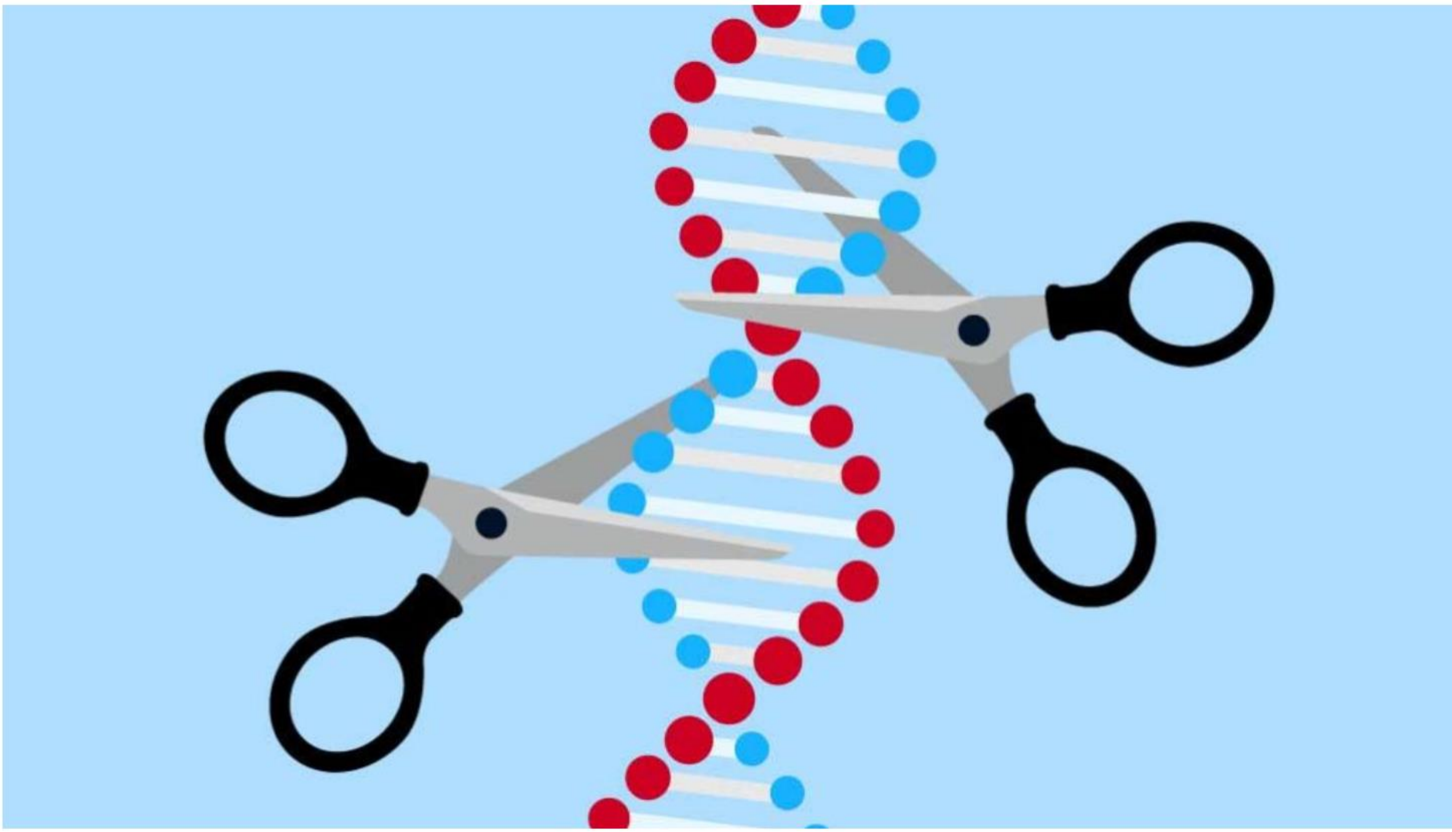
CRISPR enters its first human clinical trials

The gene editor targets cancer, blood disorders and blindness



CUTTING ROOM Scientists will soon wield the molecular scissors CRISPR/Cas9 in the human body. Some people with a form of inherited blindness will have the gene editor injected into their eyes, where researchers hope it will snip out a mutation. Two other trials are CRISPR editing cells outside of the body to treat cancer or blood disorders.

TRAFFIC_ANALYZER/GETTY IMAGES PLUS

Funding
63M

Funding
62M

Funding
35M

(CAGR = compound annual growth rate)

Commercial/Private Sector Driving Forces are Significant

NEWS LIFE

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CRISPR enters its first human clinical trials

The gene editor targets cancer, blood disorders and blindness

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Technology

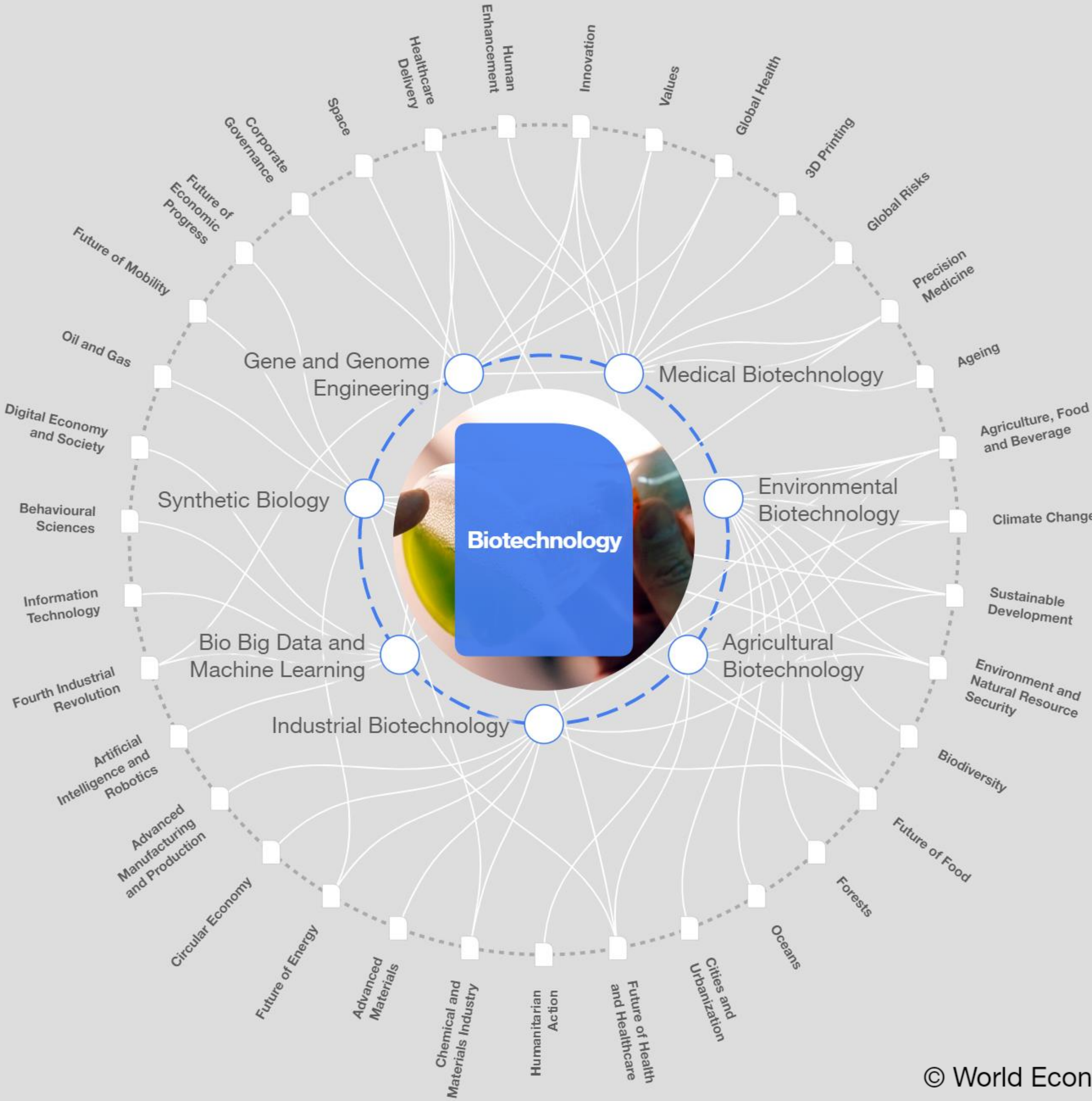
Crispr's Next Frontier Is In-Human Treatment, Co-Inventor Says

By Tatiana Darie
October 19, 2019, 4:00 AM PDT

CUTTING ROOM Scientists will soon wield the molecular scissors CRISPR/Cas9 in the human body. Some people with a form of inherited blindness will have the gene editor injected into their eyes, where researchers hope it will snip out a mutation. Two other trials are CRISPR editing cells outside of the body to treat cancer or blood disorders.

TRAFFIC_ANALYZER/GETTY IMAGES PLUS

(CAGR – compound annual growth rate)

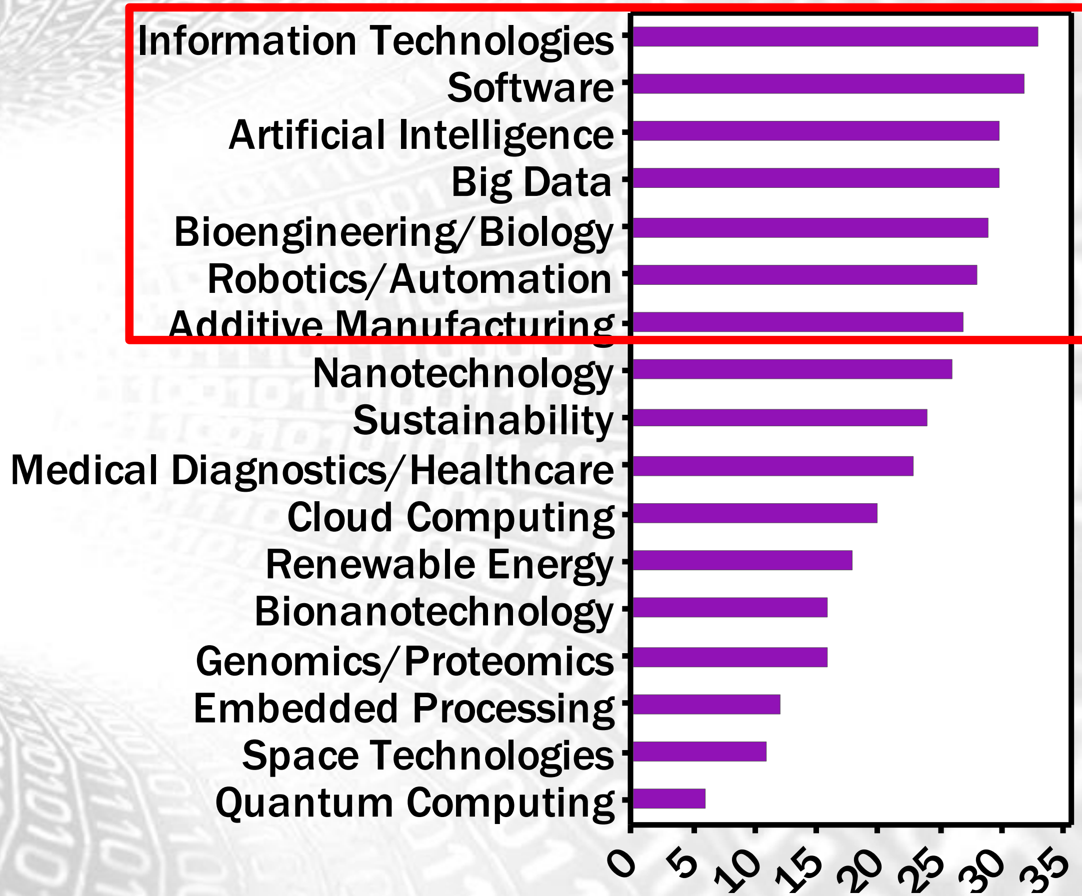


Biotechnology
Gene and Genome Engineering
Medical Biotechnology
Synthetic Biology
Environmental Biotechnology
Bio Big Data and Machine Learning
Agricultural Biotechnology
Industrial Biotechnology
Healthcare Delivery
Human Enhancement
Innovation
Values
Global Health
3D Printing
Global Risks
Precision Medicine
Ageing
Agriculture, Food and Beverage
Climate Change
Sustainable Development
Environment and Natural Resource Security
Biodiversity
Future of Food
Forests
Oceans
Cities and Urbanization
Future of Health and Healthcare
Humanitarian Action
Chemical and Materials Industry
Advanced Materials
Future of Energy
Circular Economy
Advanced Manufacturing and Production
Artificial Intelligence and Robotics
Fourth Industrial Revolution
Information Technology
Behavioural Sciences
Digital Economy and Society
Oil and Gas
Future of Mobility
Future of Economic Progress
Corporate Governance
Space

Technological Change is More Than (Bio)Chemistry

Most important technologies by 2022

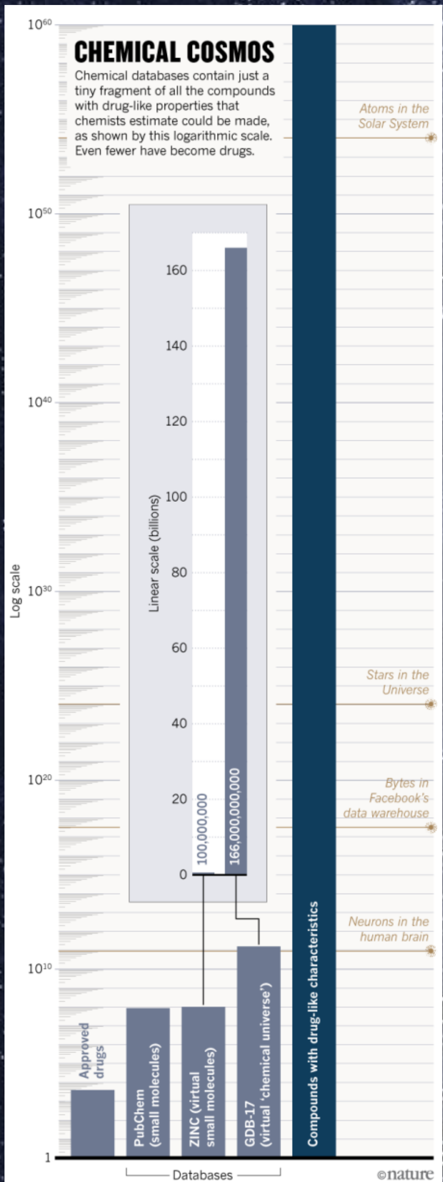
Emerging Technologies?

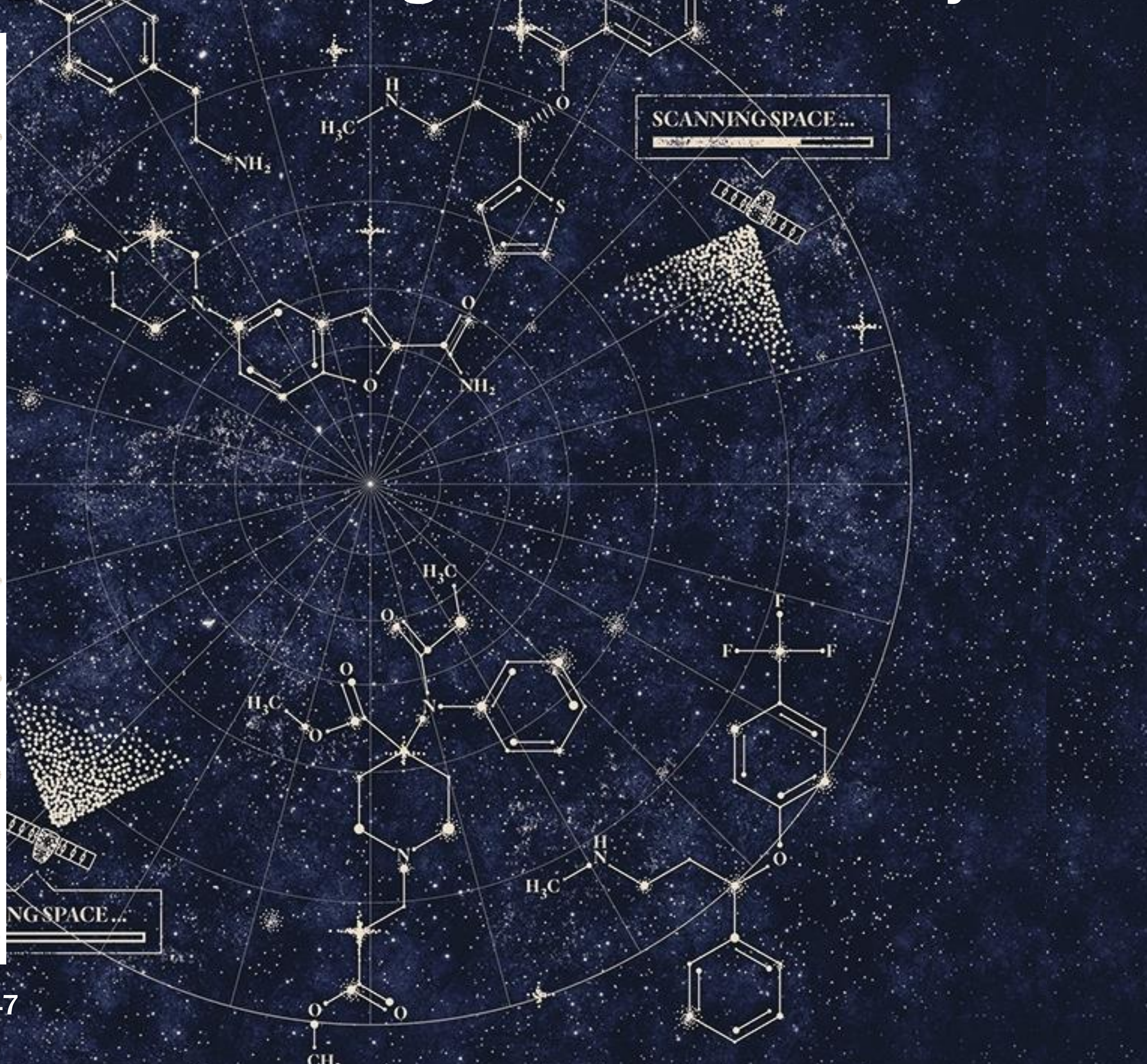


These are technologies NOT applications!

OPCW

"Important Technologies" and Chemistry





Nature 2017, *549*, 445–447
DOI: 10.1038/549445a

"Important Technologies" and Chemistry

Perspective | Published: 15 January 2019

How to explore chemical space using algorithms and automation

Piotr S. Gromski, Alon B. Henson, Jarosław M. Granda & Leroy Cronin

Nature Reviews Chemistry 3, 119–128 (2019) | Download Citation

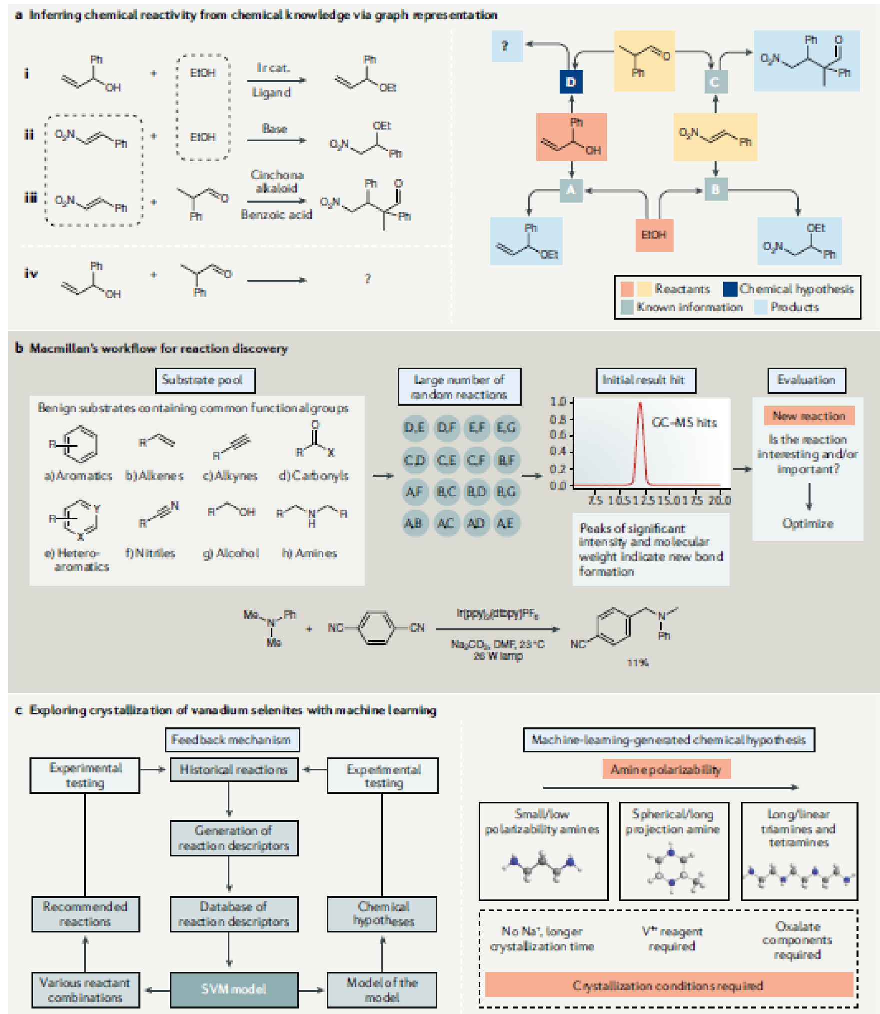
Abstract

Although extending the reactivity of a given class of molecules is relatively straightforward, the discovery of genuinely new reactivity and the molecules that result is a wholly more challenging problem. If new reactions can be considered unpredictable using current chemical knowledge, then we suggest that they are not merely new but also novel. Such a classification, however, requires an expert judge to have access to all current chemical knowledge or risks a lack of information being interpreted as unpredictability. Here, we describe how searching chemical space using automation and algorithms improves the probability of discovery. The former enables routine chemical tasks to be performed more quickly and consistently, while the latter uses algorithms to facilitate the searching of chemical knowledge databases. Experimental systems can also be developed to discover novel molecules, reactions and mechanisms by augmenting the intuition of the human expert. In order to find new chemical laws, we must seek to question current assumptions and biases. Accomplishing that involves using two areas of algorithmic approaches: algorithms to perform searches, and more general machine learning and statistical modelling algorithms to predict the chemistry under investigation. We propose that such a chemical intelligence approach is already being used and that, in the not-too-distant future, the automated chemical reactor systems controlled by these algorithms and monitored by a sensor array will be capable of navigating and searching chemical space more quickly, efficiently and, importantly, without bias. This approach promises to yield not only new molecules but also unpredictable and thus novel reactivity

A new approach to materials design for organic light-emitting diodes was demonstrated by Aspuru-Guzik and co-workers using high-throughput virtual screening. By combining theoretical computations, chemoinformatics with machine learning and organic synthesis, it was possible to successfully narrow down the space of 1.6 million possible molecules to thousands of promising novel organic light-emitting diode molecules and then to successfully synthesize new organic light-emitting diodes[38].

Searching chemical space

Chemical space can be searched for specific molecules or specific goals such as optimized yield or a biological function. This search can be performed through two different avenues: theoretical and experimental. Theoretical searches are an important use



“Important Technologies” and Chemistry

Perspective | Published: 15 January 2019

How to explore chemical space using algorithms and autom[ation]

Piotr S. Gromski, Alon B. Henson, Jarosław M. Gra[...]

Nature Reviews Chemistry **3**, 119–128 (2019) | Do[...]

Abstract

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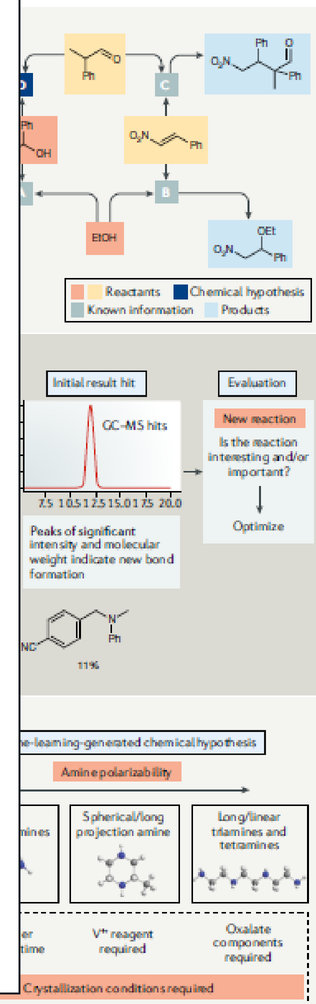
PERSPECTIVES

Searching chemical space
Chemical space can be searched for specific molecules or specific goals such as optimized yield or a biological function. This search can be performed through two different avenues: theoretical and experimental. Theoretical searches are an important use

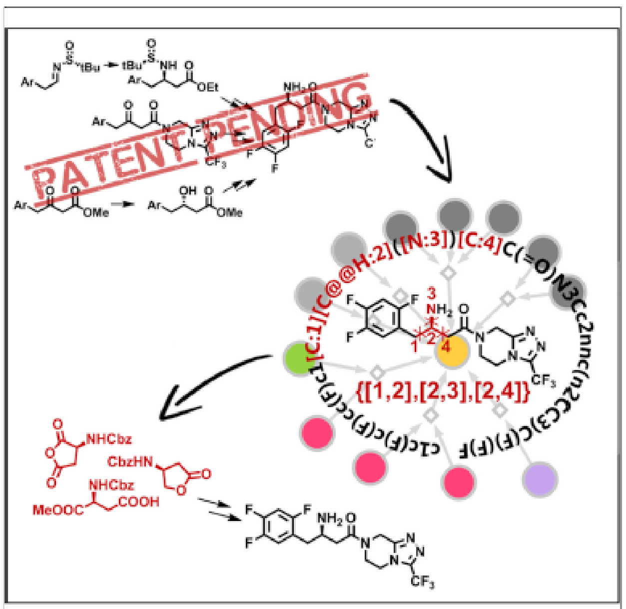


Chem

CellPress

Article

Navigating around Patented Routes by Preserving Specific Motifs along Computer-Planned Retrosynthetic Pathways



Karol Molga, Piotr Dittwald, Bartosz A. Grzybowski

piotr.dittwald@gmail.com (P.D.)
nanogrzybowski@gmail.com (B.A.G.)

HIGHLIGHTS

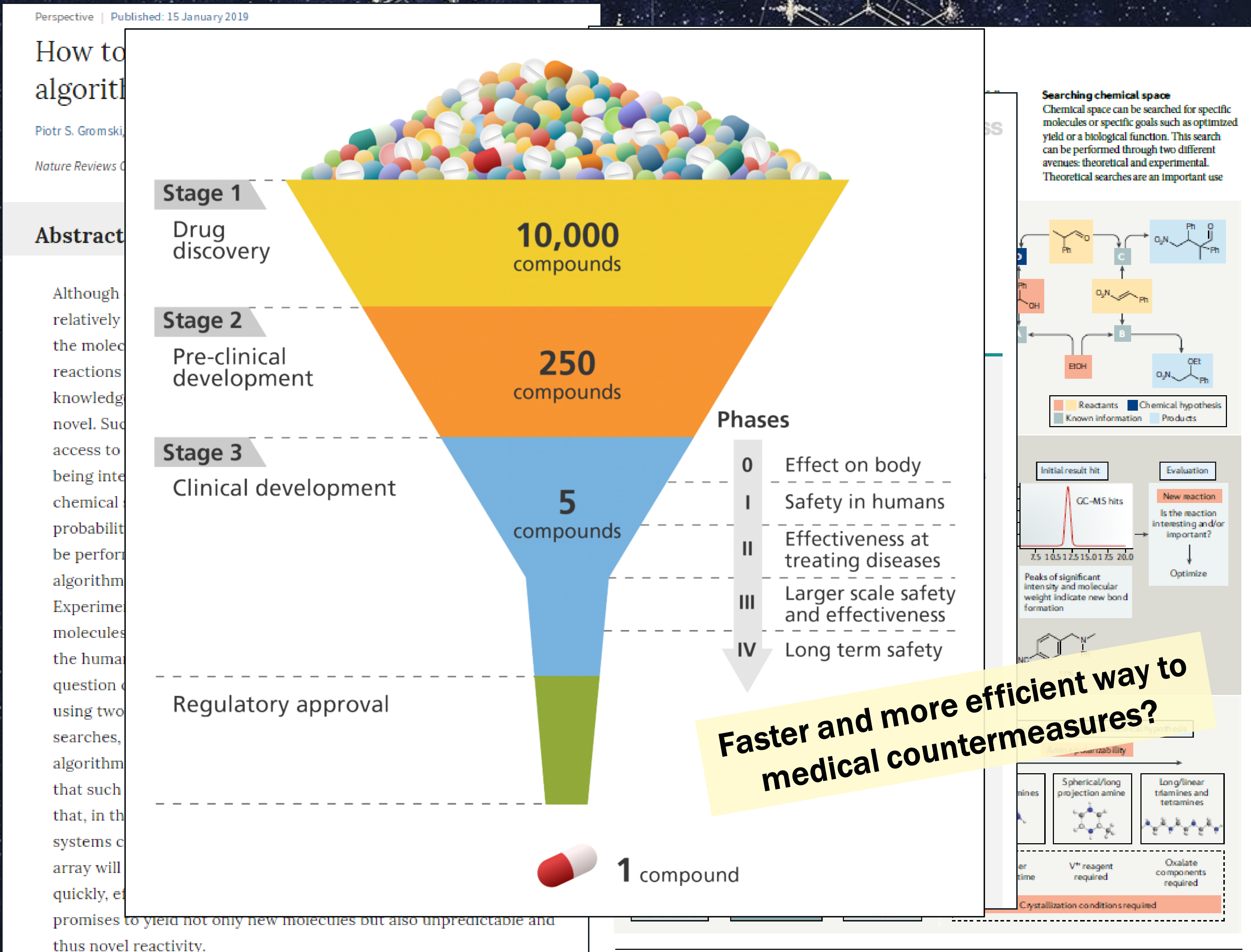
Computer autonomously designs syntheses avoiding desired key disconnections

By doing so, it navigates around patent-protected syntheses of blockbuster drugs

The algorithm can be useful to both identify and prevent such patent “bypasses”

Chem 5, 2019, 1–14
DOI: 10.1016/j.chempr.2018.12.004

"Important Technologies" and Chemistry



Central Nervous System (CNS)-Acting Chemicals

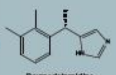
OPCW

by Sofia Sola Sancho, Maria Hemme and Ayah wafi
Office of the Science Policy Advisor

Toxic chemicals that target the central nervous system (CNS). These chemicals can act as anaesthetics, sedatives, and analgesics. Specific CNS-acting chemicals discussed in the context of the Chemical Weapons Convention have included α2-adrenergic receptor agonists, inhaled anaesthetics, fentanils and the Schedule 2A.03* chemical BZ.

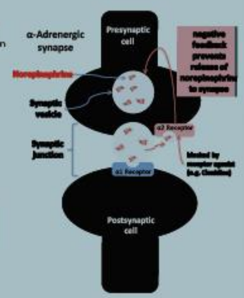
α2-adrenergic receptor agonist examples

Dexmedetomidine


Dexmedetomidine

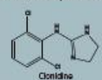
Mechanism of action:

- Presynaptic activation of the α2-adrenoceptor, inhibiting norepinephrine release, preventing entry of the neurotransmitter into the synaptic junction (negative feedback).
- Postsynaptic activation of the α1-adrenoceptor
- inhibiting sympathetic activity. This results in decreased blood pressure and heart rate.
- Produces analgesic, sedative, and anxiolytic effects.
- Occupational exposure band (OEB) 5: control exposure to < 1 μg/m³.



Mechanism of action of Dexmetomidine and Clonidine.

Clonidine


Clonidine

Mechanism of action:

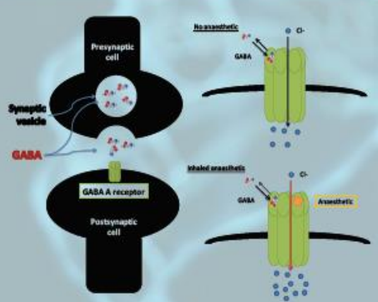
- Reduces release of noradrenaline at both central and peripheral sympathetic nerve terminals.
- Produces dose-related sedation, analgesia and anxiolysis.
- A reduction in the effective dose of other anaesthetic agents and opioids is also observed.
- LC_{50} (rat inh): 19.7 mg/m³/4 Hours
- LD_{50} (rat i.v.): 29 mg/kg

Download the poster:

Inhaled anaesthetic examples

Mechanism of action:

- Enhances γ-aminobutyric acid (GABA) binding to its chloride ion-channel receptor.
- The increase in intra-cellular chloride levels produces an inhibitory effect (anaesthesia).

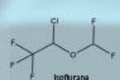


Mechanism of action of Inhaled anaesthetics.

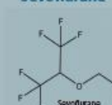
Halothane


Halothane

Isoflurane


Isoflurane

Sevoflurane


Sevoflurane

Toxicity Data	Oral LD_{Lo} (Human) [μL/kg]	Oral LD_{50} (rat)	Inhalation LC_{50} (rat) [ppm]	Oral LD_{50} (mouse) [μL/kg]	Inhalation LC_{50} (mouse) [ppm (3 hrs)]
Halothane	-	5680 mg/kg	29000 (1h)	-	-
Isoflurane	1071	4770 μL/kg	15300 (3h)	5080	16800
Sevoflurane	-	10800 μL/kg	28800 (3h)	18200	28300

LD_{Lo}: the lowest dosage of a substance observed to cause a fatality within a specific subject population under a specific set of exposure conditions. LD_{50}: the median value of all the observed dosages of a substance resulting in a fatality within a specific subject population under a specific set of exposure conditions. LC_{50}: the median value of all the observed concentrations (based on an exposure time) of a substance resulting in a fatality within a specific subject population under a specific set of exposure conditions. Lethal dose and lethal concentration values are statistics derived from specific populations and exposure conditions (typically controlled animal studies), they may not be representative of alternate populations and/or exposure conditions.

Fentanils

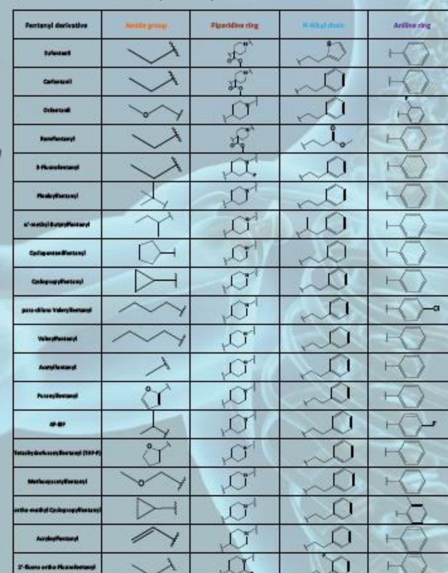
- Fentanils are a highly potent family of opioid narcotic analgesic drugs.
- The family includes fentanyl, a narcotic linked to an increased risk of overdose amongst opioid addicts.
- As of May 2018, there were 20 fentanil derivatives scheduled under the Single Convention on Narcotic Drugs

Properties

- Fentanyl and its analogues are solids that require aerosolisation for weaponisation purposes.
- Routes of exposure for fentanils include inhalation (aerosolized form), oral exposure or ingestion. Transdermal absorption is possible (for example, the use of transdermal patches), however as the process is slow, such that brief incidental exposures may not cause significant opioid toxicity.

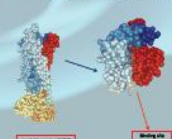
- Fentanyl and its analogues have higher potency than morphine and heroin.
- Poor drug dosage, poly-drug use and addiction are all contributors to the high rates of overdose, respiratory depres-

Structure and substitution positions for fentanyl and derivatives.



Mechanism of action:

- In the CNS, fentanils bind to opioid receptors, specifically μ-receptors. These receptors are found predominantly in the brain and spinal cord
- They act to depress CNS function.
- Bioavailbility from inhalation exposure can range from 12-100%.


Crystal structure of the μ-opioid receptor bound to a morphinan antagonist (Protein Data Bank Structure 4DKL)

Effects:

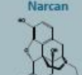
- Loss of pain sensation
- Miosis
- Decreased intestinal paristalsis (constipation)
- Nausea and vomiting
- Dose-dependent respiratory depression (which can lead to death)
- Diminished mental alertness resulting in a feeling of drowsiness, euphoria, sleepiness, and unconsciousness

Time Weighted Average – Occupational Exposure Limits (OEL-TWA)	
Alfentanil	1 μg/m³
Fentanyl	0.1 μg/m³
Sufentanil	0.032 μg/m³

Antidotes: Naloxone hydrochloride (Narcan) or Naltrexone

- Opioid receptor antagonists.
- Bind to the opioid receptors more strongly than a fentanyl derivative, but do not activate the receptor.
- Quickly reverse signs and symptoms, especially life-threatening respiratory depression.
- Short half-life, symptoms may return in an apparently stabilized patient and antidotes might need to be readministered.
- 0.4 mg is the standard starting dose but for some fentanyl derivatives doses up to 2 mg have been required.

Narcan



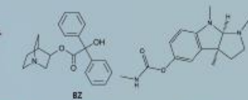
Naltrexone

BZ (3-quinuclidinyl benzilate)

BZ is a glycolate anticholinergic compound and is a only "CNS-acting chemical" found in the Annex of Chemicals of the Chemical Weapons Convention (Schedule 2A.03*).

Properties

- Odourless crystalline powder with bitter taste.
- Persistent in soil and water and on most surfaces.
- Half-life in moist air ~ 3-4 weeks.


BZ

Antidote: Physostigmine

- Temporarily raises acetylcholine concentrations by binding reversibly to anticholinesterase.

Safety Ratio of BZ

Dose in [mg.min/m³]

The large difference between the median lethal concentration (LC_{50}) and the median incapacitating concentration (IC_{50}) allows for the onset of CNS-acting symptoms to appear at a dosage much lower than a lethal dose.

Mechanism of action:

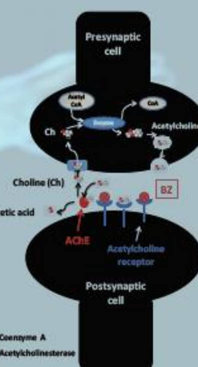
- Acts as a competitive inhibitor of the neurotransmitter acetylcholine (ACh) in postsynaptic ACh receptors.
- As the concentration of BZ at these sites increases, the proportion of receptors available for binding to acetylcholine decreases, resulting in an understimulation of nerve signal transduction.
- When administered by inhalation (in aerosolised form), absorption to the bloodstream is more pronounced than with oral administration.

CNS effects:

- Stupor, ataxia, confusion, and confabulation. Induces concrete and panoramic illusions and hallucinations.

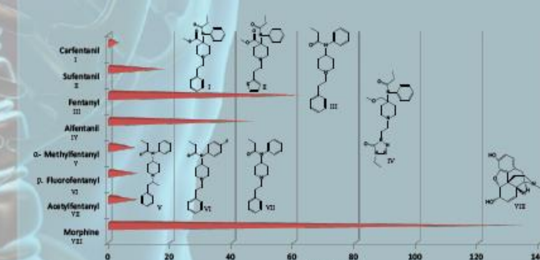
Peripheral effects:

- Mydriasis, blurred vision, dry mouth and skin, initially rapid heart rate; later, normal or slow heart rate.



Mechanism of action of BZ.

Toxicity



Industry 4.0 and the chemicals industry

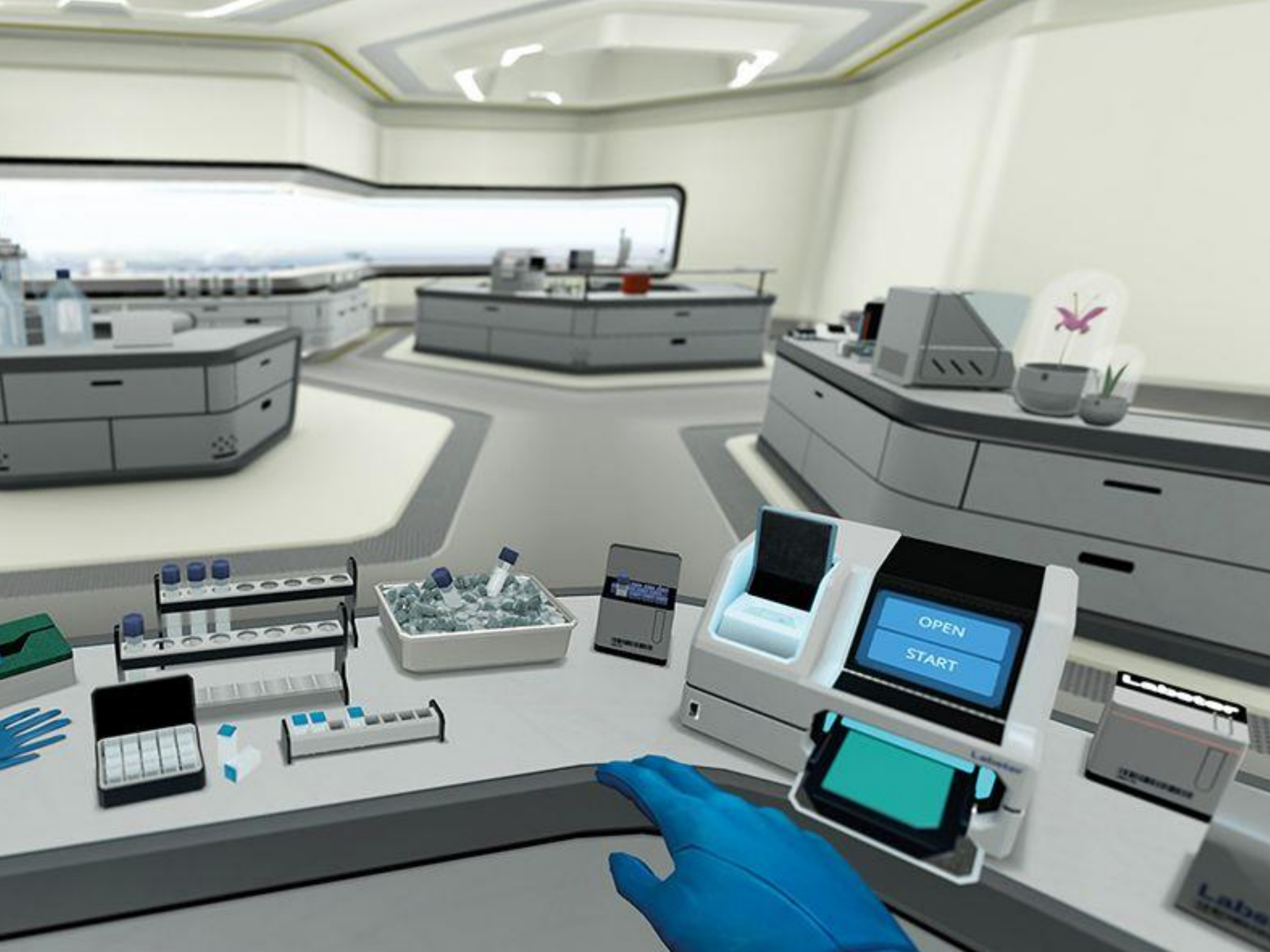
READY TO BE DEPLOYED NOW

- Virtual assistants (natural language based)
- AI-based pricing engines
- AI-based next best actions in marketing
- AI-based augmentation of control room operators
- AI-based experiment prediction & evaluation
- Datascience-based maintenance
- Blockchain-based supply chain track & trace
- Virtual assistant-based internal administration
- Robotic process automation in administration

...and so much more...

Press


New ways to approach problem solving
and change organizational cultures!


OPEN
START

POWERING ON-DEMAND DISCOVERY BIOLOGY

ACCELERATING DRUG DISCOVERY AND SYNTHETIC BIOLOGY RESEARCH

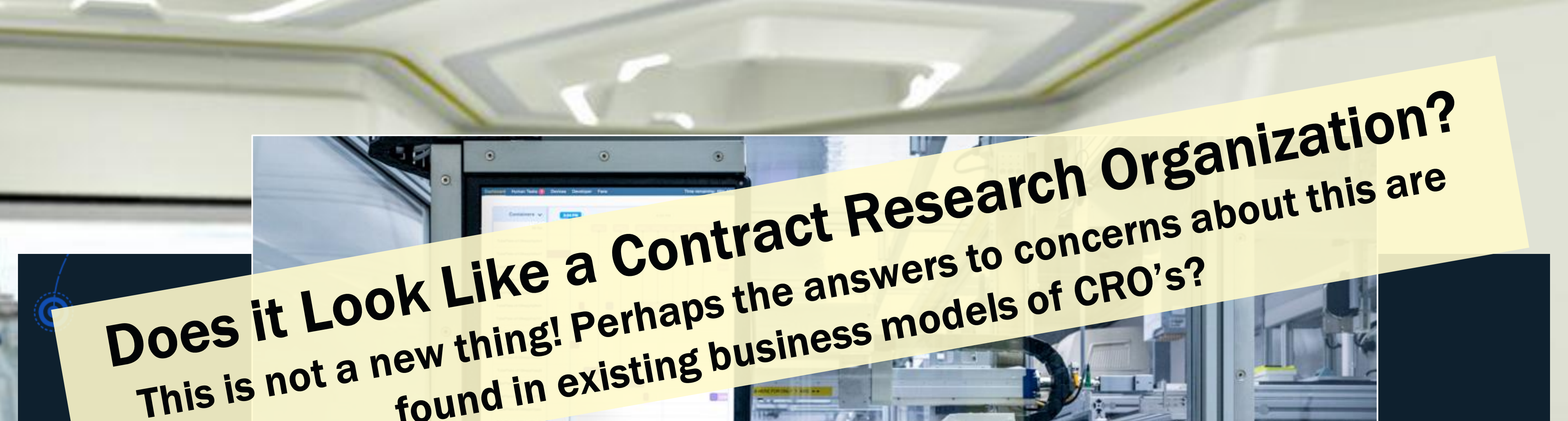
The Transcriptic Common Lab Environment (TCLE) coordinates scientific processes, instruments, and robotics to create a programmatically addressable lab environment that enables unparalleled scale, efficiency, and accuracy for the discovery process.

https://www.transcriptic.com/

"A Cloud Laboratory Research Service"

https://www.transcriptic.com/

With a "physical" location and real equipment and people to maintain it!

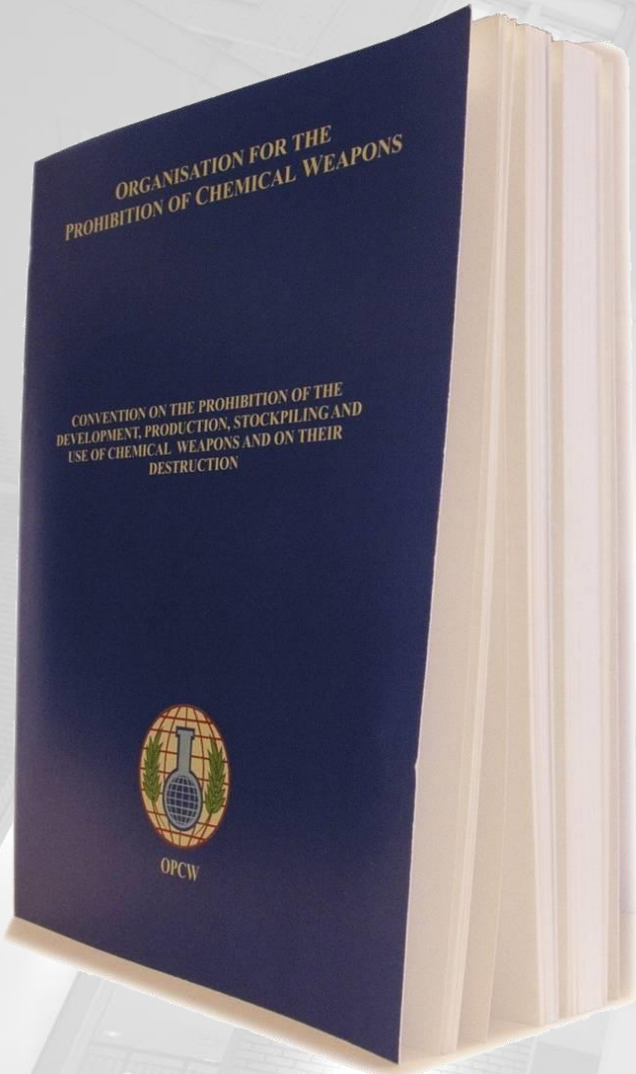


Does it Look Like a Contract Research Organization?

This is not a new thing! Perhaps the answers to concerns about this are found in existing business models of CRO's?

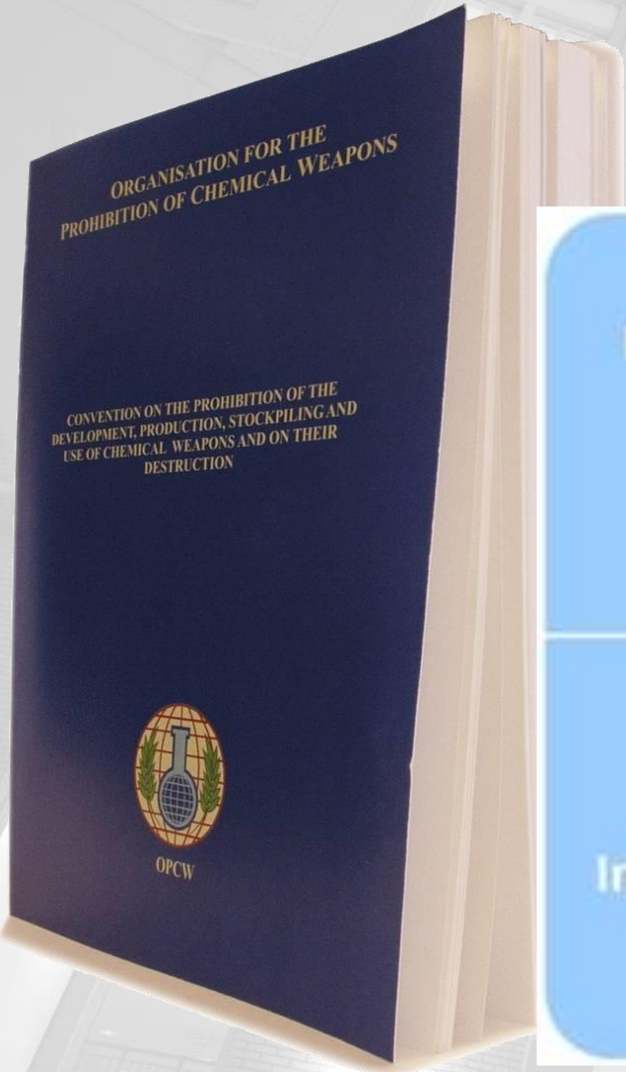
Policy, Regulation and/or Oversight for Science?

International Obligations and Member State Compliance



- **Treaty = Agreement between states**
- **National Compliance = laws and regulations**
  - **States Parties must establish a “National Authority”**
  - **National legislation**
  - **Criminal laws, trade monitoring, reporting and enforcement**

International Obligations and Member State Compliance



- **Treaty = Agreement between states**

ty”

Bioeconomy Policies around the World

- dedicated bioeconomy strategy
- bioeconomy-related strategy
- be-related strategy; dedicated be-strategy is under development
- dedicated be-strategy is under development

As of May 2017


We Cannot Afford to Fear Science!

All of this Advanced Science and…

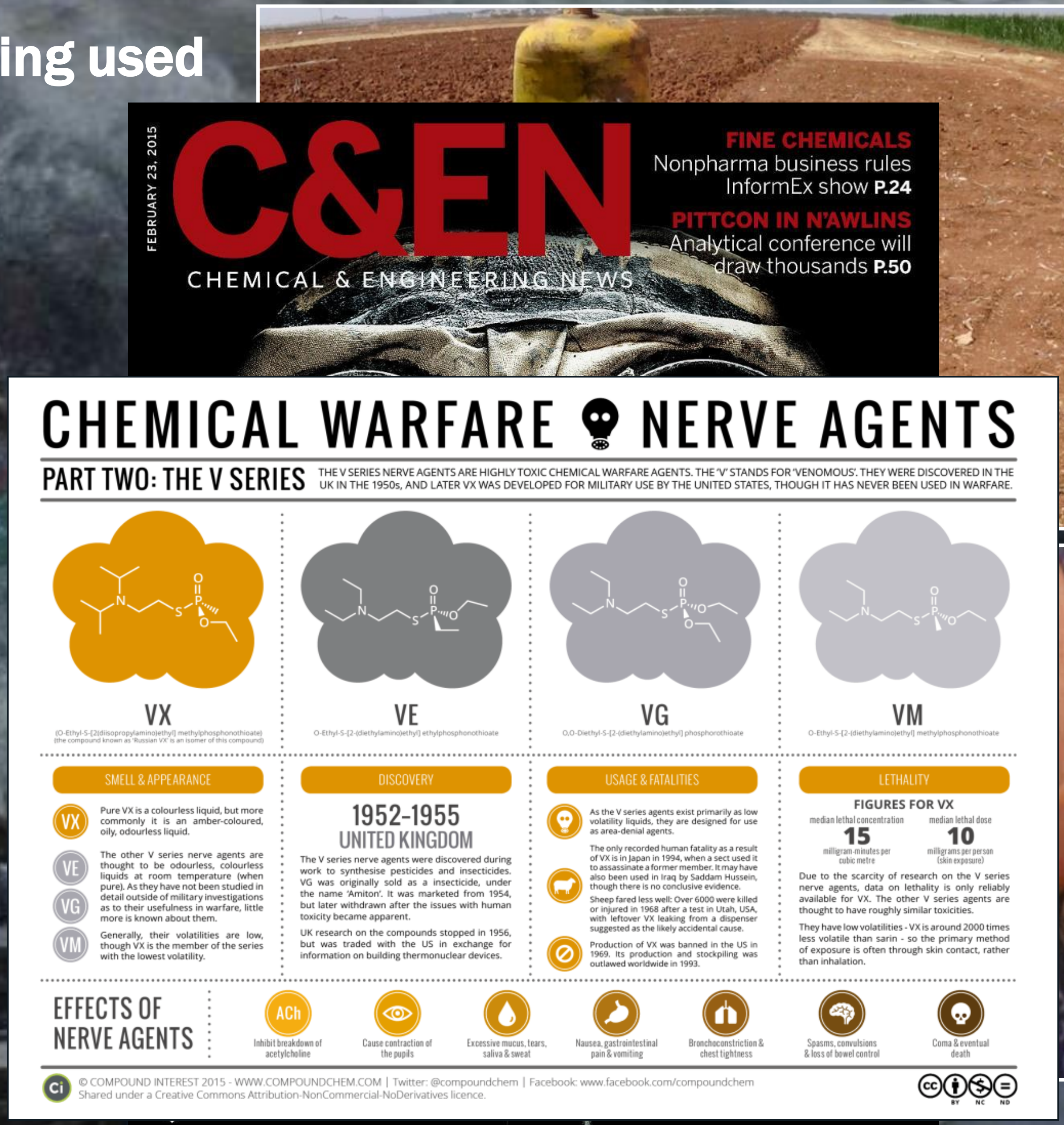
- Chemical weapons being used

All of this Advanced Science and…

- **Chemical weapons being used**

All of this Advanced Science and...

- Chemical weapons being used
- Biological weapons being used?

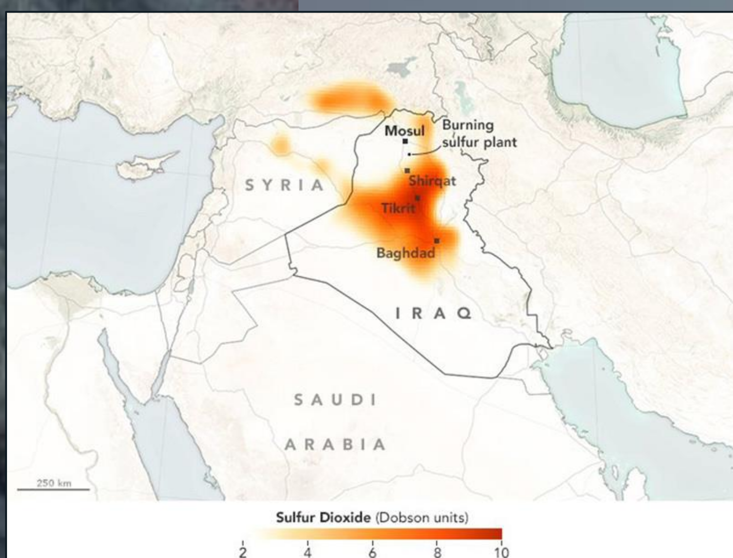


All of this Advanced Science and…

- Chemical weapons being used
- Biological weapons being used?

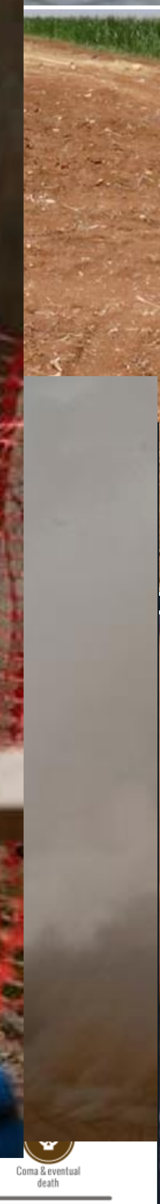
All of this Advanced Science and…

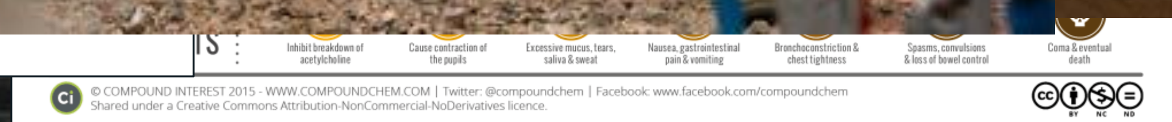
- Chemical weapons being used
- Biological weapons being used?

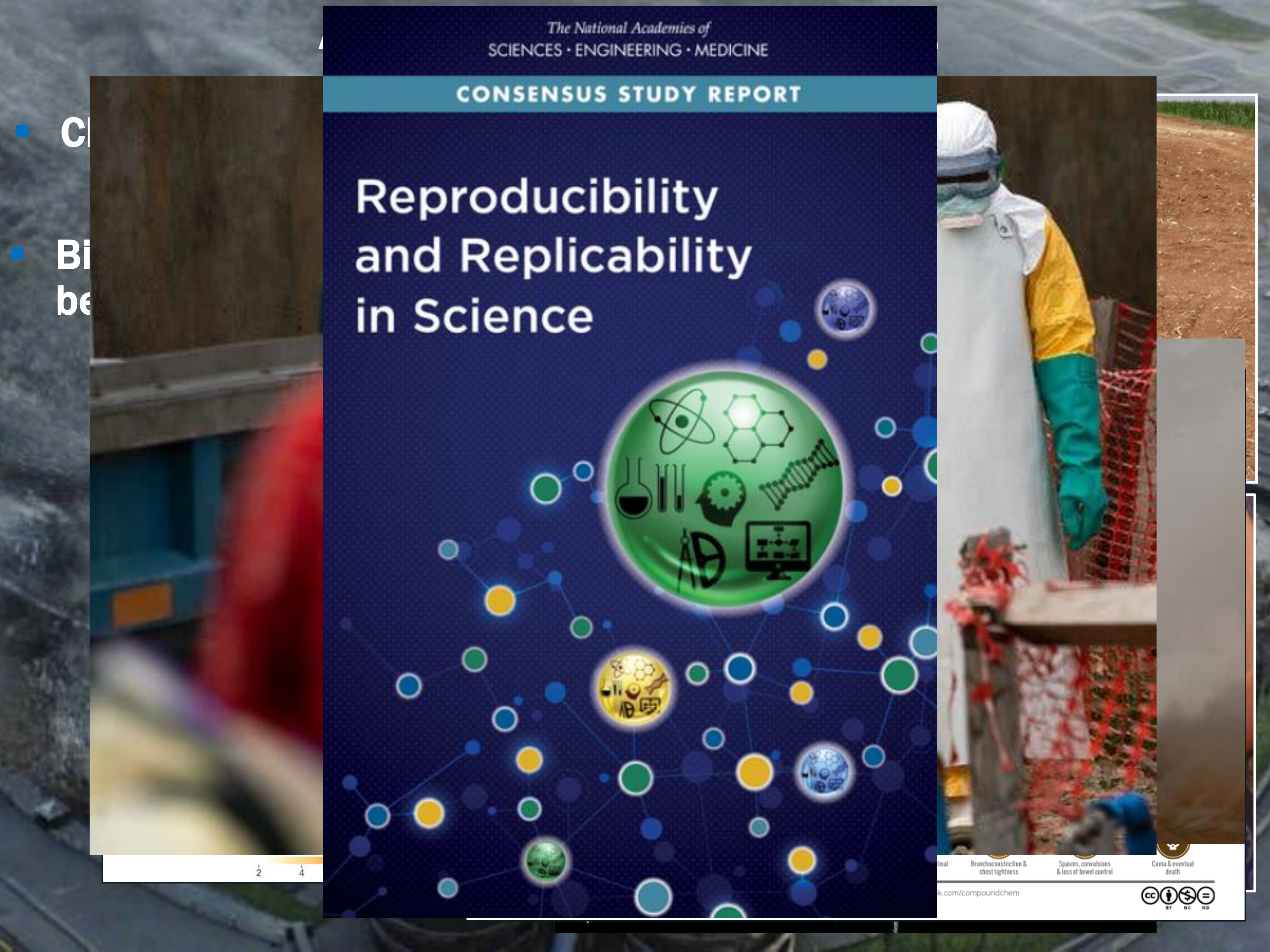


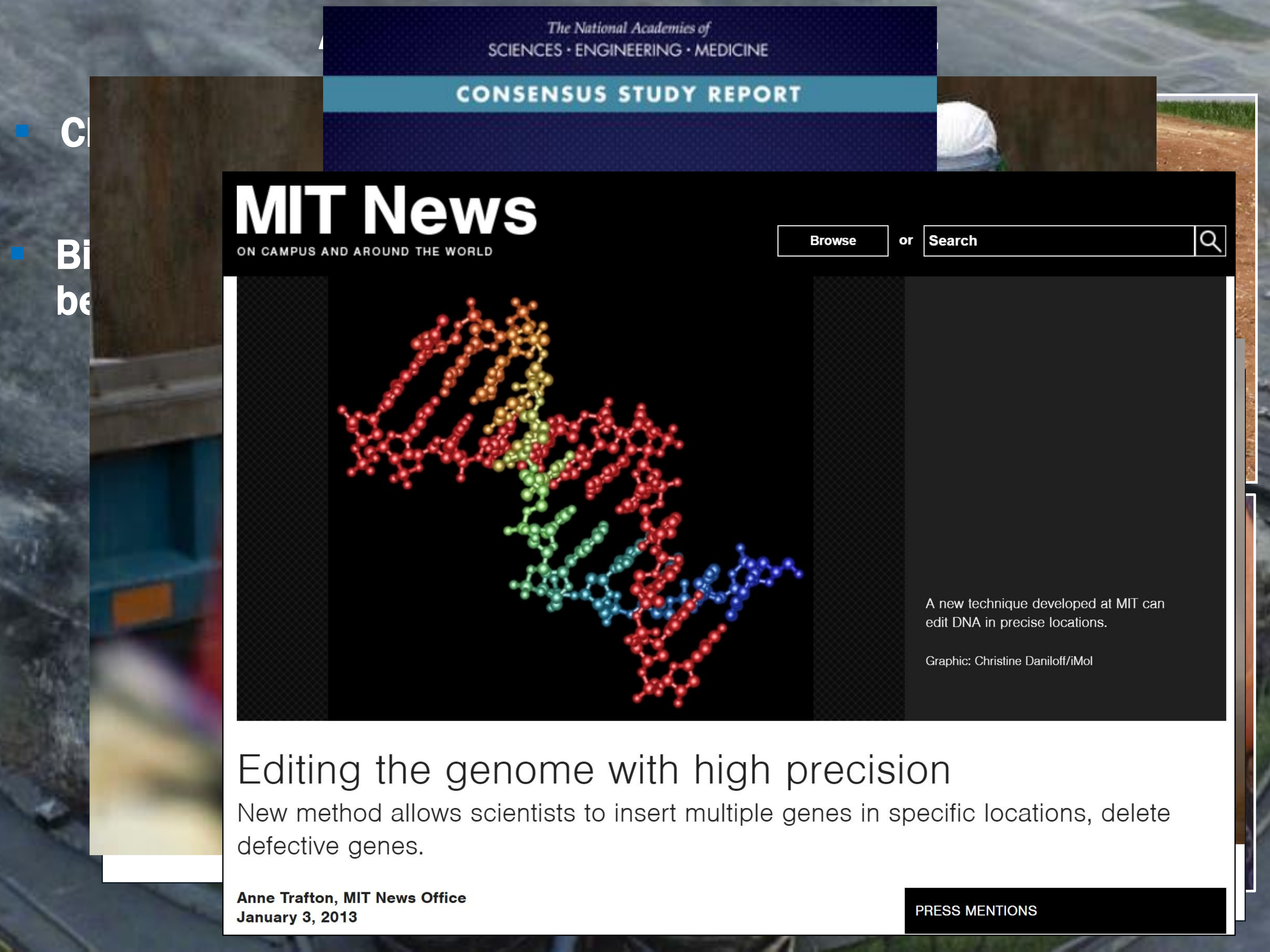
All of this Advanced Science and...

- Cl
- Bi
  be



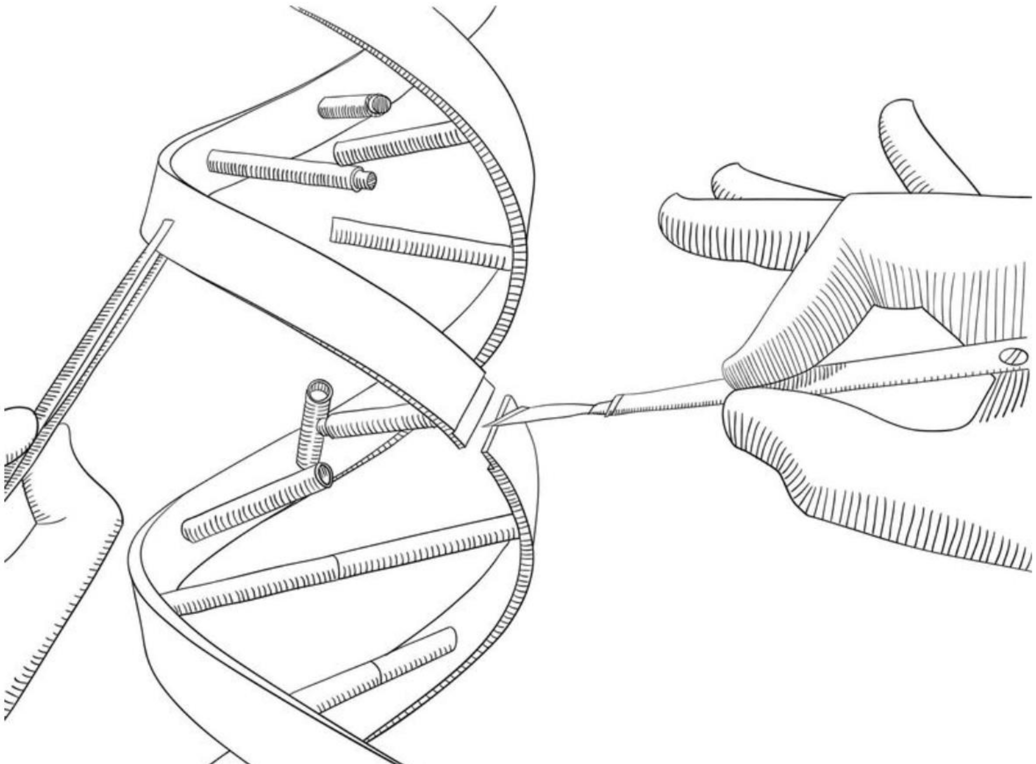



The National Academies of
SCIENCES · ENGINEERING · MEDICINE
CONSENSUS STUDY REPORT
Reproducibility and Replicability in Science
Bronchoconstriction & chest tightness
Spasms, convulsions & loss of bowel control
Coma & eventual death


The National Academies of
SCIENCES · ENGINEERING · MEDICINE
CONSENSUS STUDY REPORT
MIT News
ON CAMPUS AND AROUND THE WORLD
Browse
or
Search
A new technique developed at MIT can edit DNA in precise locations.
Graphic: Christine Daniloff/iMol
Editing the genome with high precision
New method allows scientists to insert multiple genes in specific locations, delete defective genes.
Anne Trafton, MIT News Office
January 3, 2013
PRESS MENTIONS

A New Gene Editing Tool Could Make CRISPR More Precise

Prime editing offers a new way to make changes to DNA while avoiding some of the drawbacks and clunkiness of traditional CRISPR



Unlike classic CRISPR-based editing, which fully cleaves DNA in two, prime editing starts with a cut to only one strand of the double helix. (Perception7 / iStock)

By **Lila Thulin**
SMITHSONIAN.COM
OCTOBER 21, 2019

The National Academies of
NE
ORT

Browse or Search

A new technique developed at MIT can edit DNA in precise locations.

Graphic: Christine Daniloff/iMol

h precision

ble genes in specific locations, delete

PRESS MENTIONS

Uncertainty…

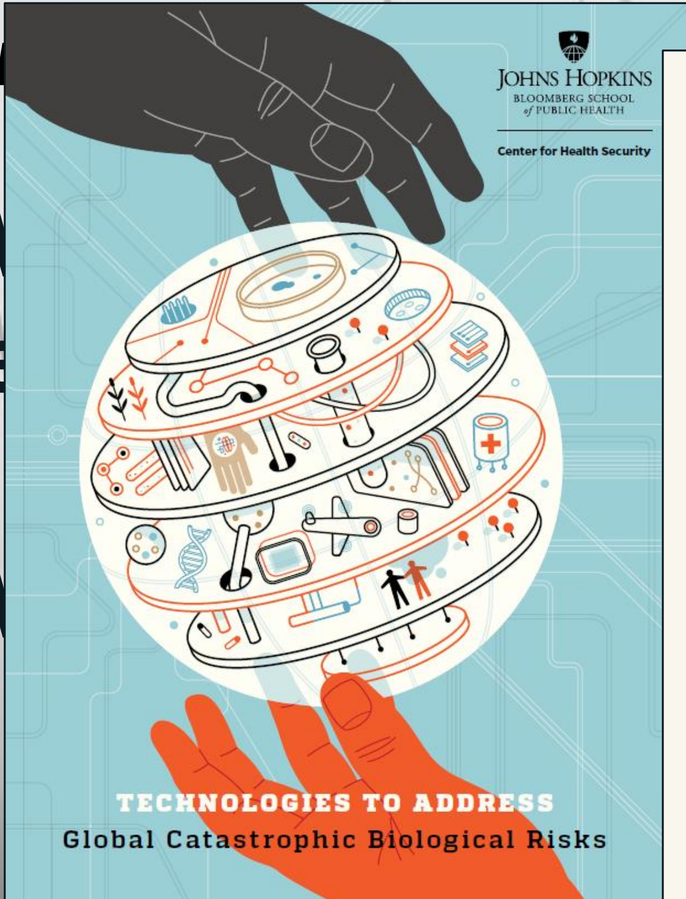
What are the capabilities (independent of technology) we need?

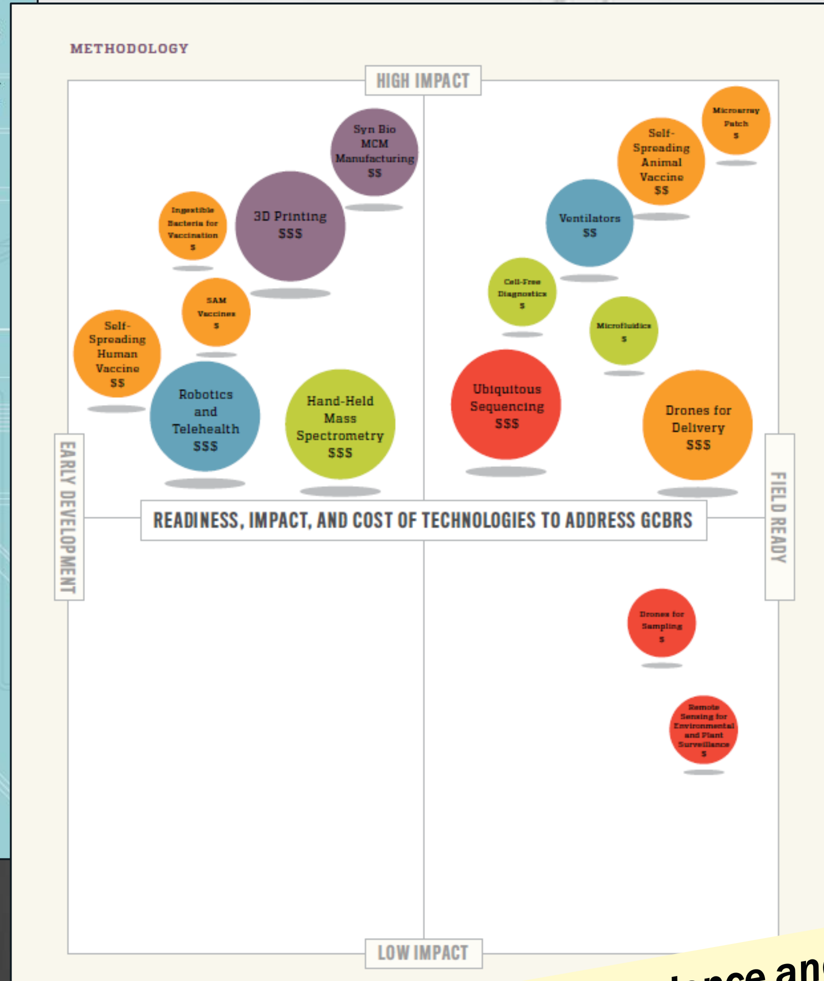
What Scenarios Do We Need to be Prepared for?

Ul

W ndent of te

W ared for?



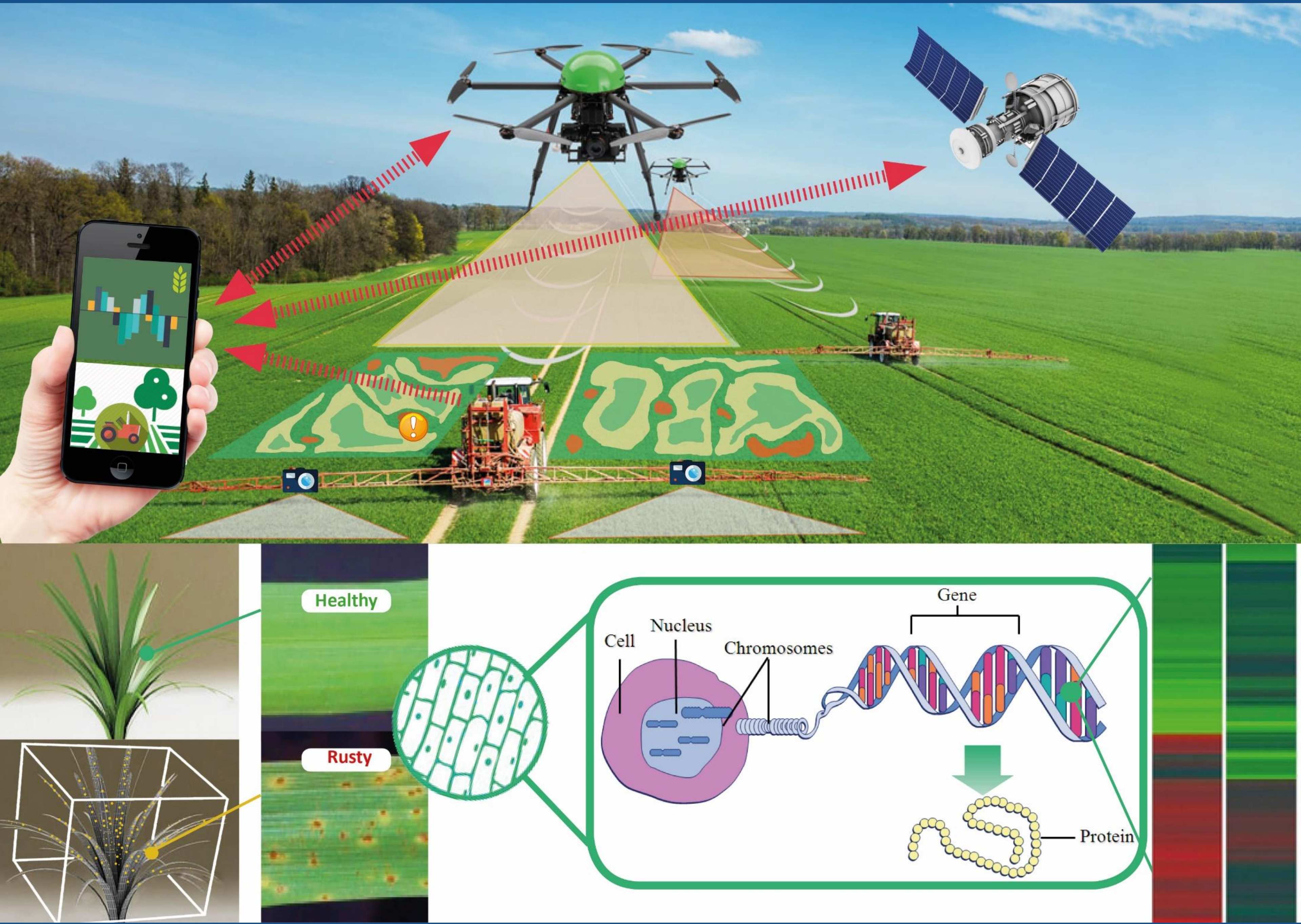


Once you answer these questions, you can talk about scuience and technology…

New technology vs. old technology?

What do we need? What works reliably?

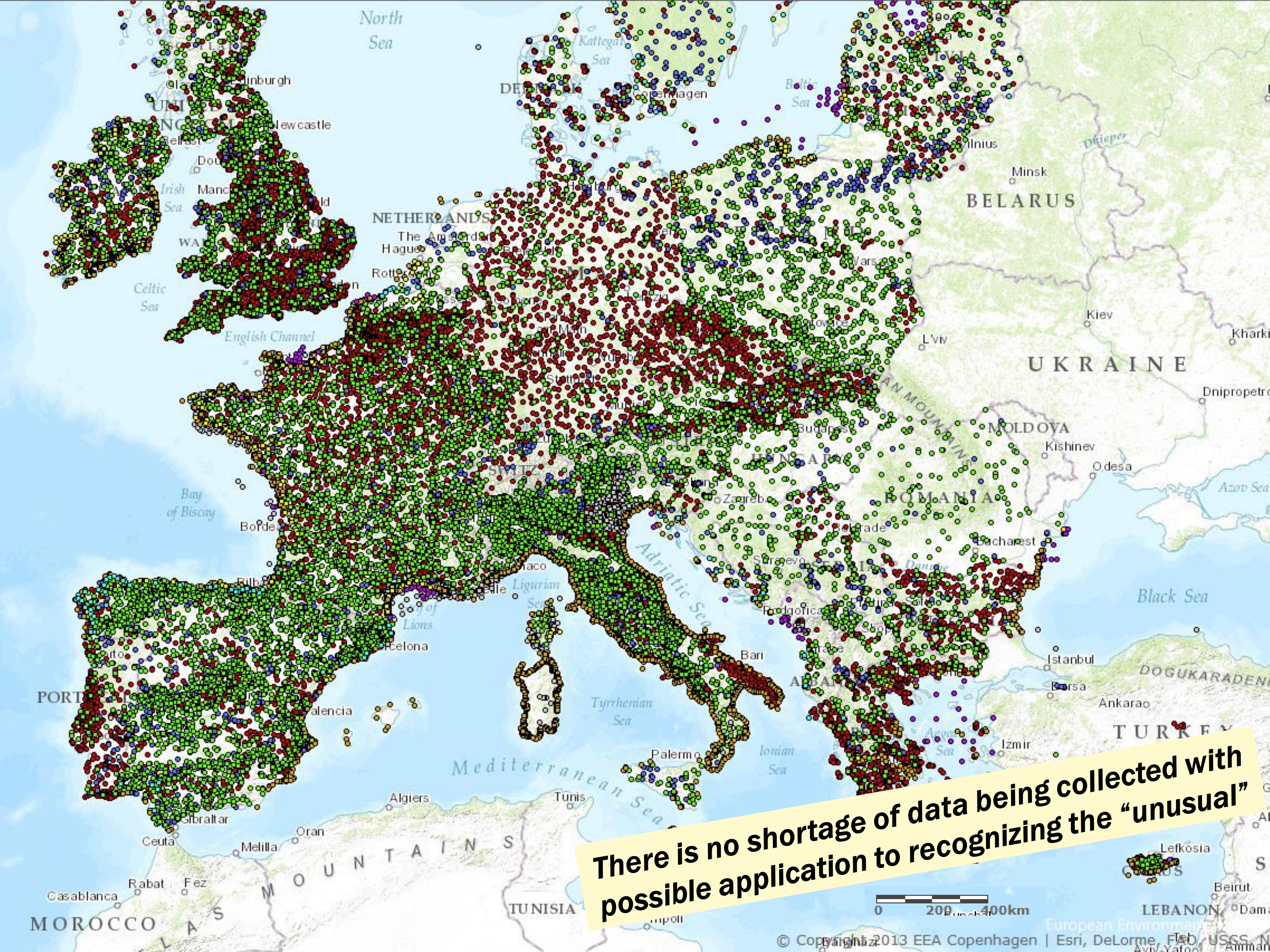
Focus on needs and capability requirements


Healthy
Rusty
Gene
Nucleus
Cell
Chromosomes
Protein

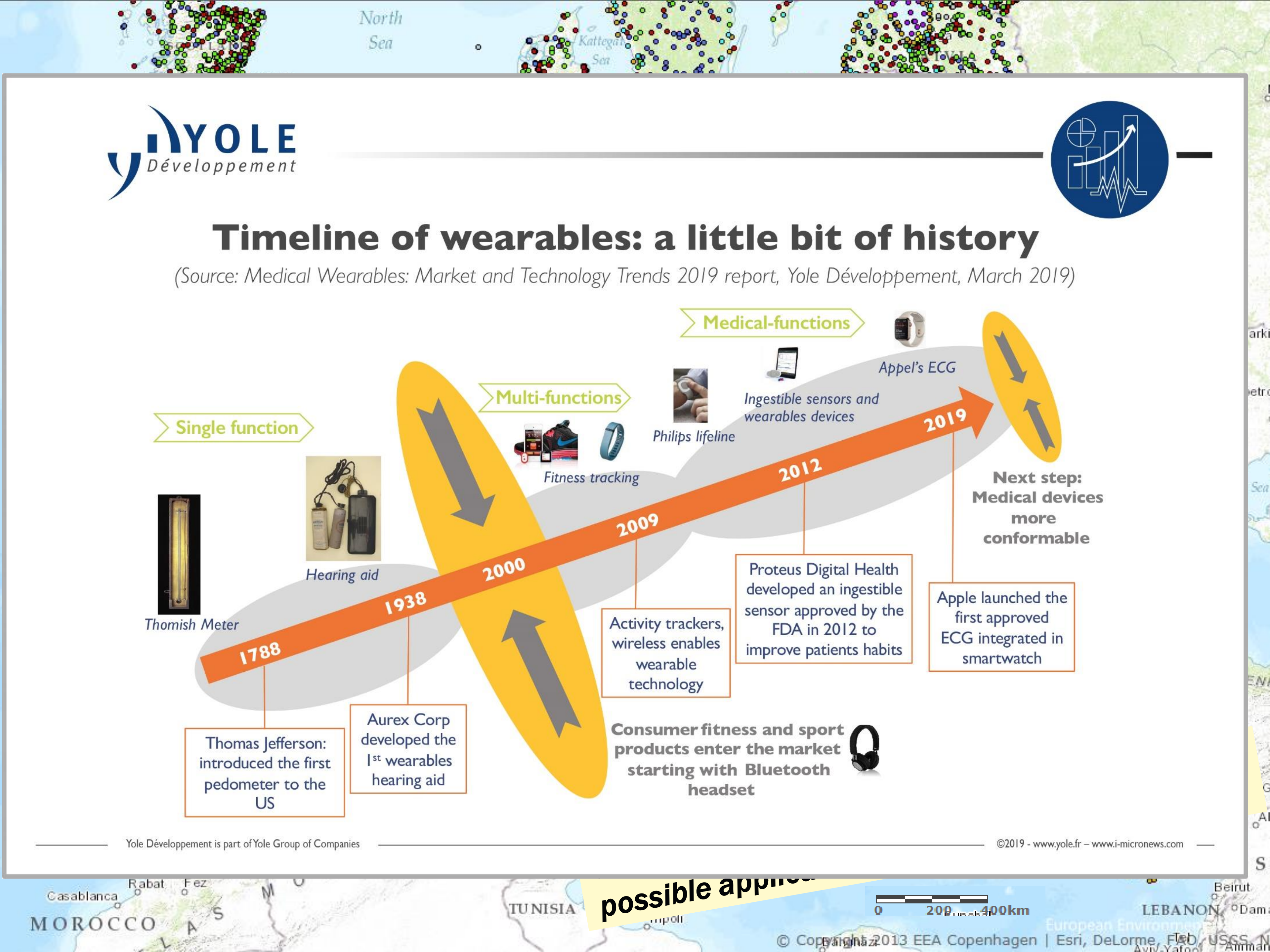

Recognize when something is “not right”
Healthy
Rusty
Gene
Nucleus
Cell
Chromosomes
Protein
Further investigate as needed

If Plants Could Talk…

"The signs are that the bombs were made with the windows open but the net curtains taped to the walls to avoid being seen. The fumes had killed off the tops of plants just outside the windows"
- Report of the Official Account of the Bombings in London on 7th July 2005



There is no shortage of data being collected with possible application to recognizing the "unusual"


YOLE Développement
Timeline of wearables: a little bit of history
(Source: Medical Wearables: Market and Technology Trends 2019 report, Yole Développement, March 2019)
Single function
Multi-functions
Medical-functions
Thomish Meter
Hearing aid
Fitness tracking
Philips lifeline
Ingestible sensors and wearables devices
Appel's ECG
1788
1938
2000
2009
2012
2019
Next step: Medical devices more conformable
Thomas Jefferson: introduced the first pedometer to the US
Aurex Corp developed the 1st wearables hearing aid
Consumer fitness and sport products enter the market starting with Bluetooth headset
Activity trackers, wireless enables wearable technology
Proteus Digital Health developed an ingestible sensor approved by the FDA in 2012 to improve patients habits
Apple launched the first approved ECG integrated in smartwatch
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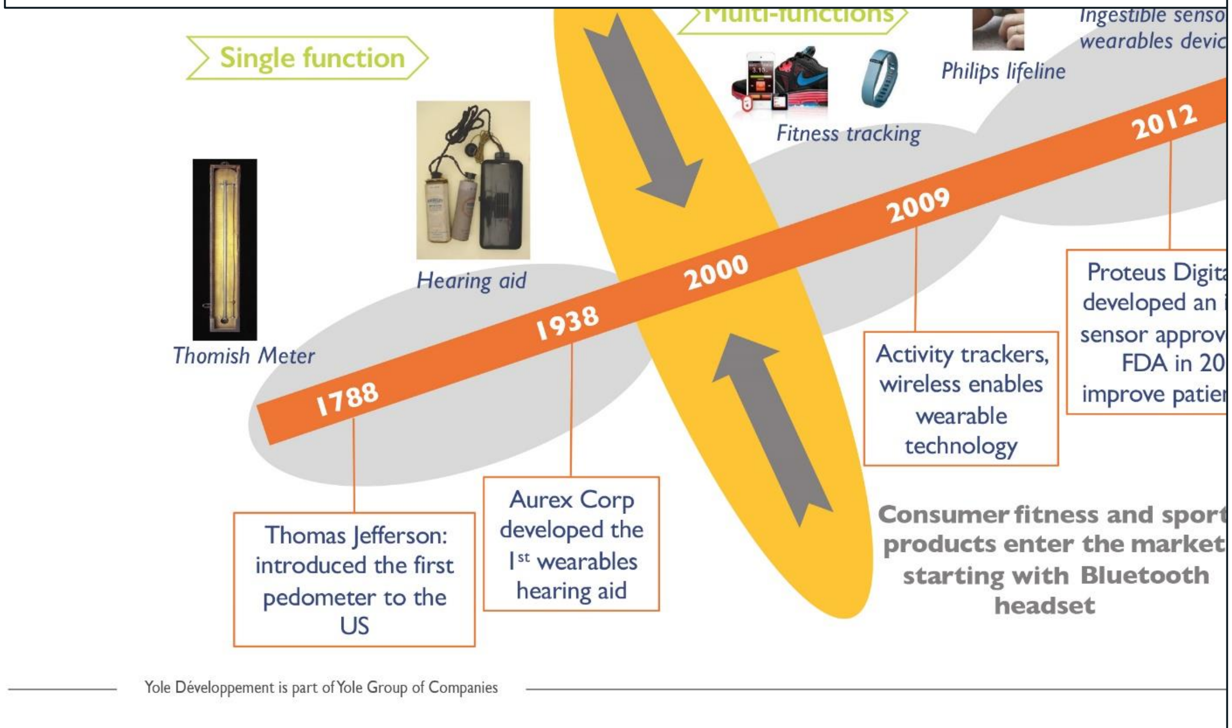
possible applic
TUNISIA
MOROCCO
Rabat
Fez
Casablanca
LEBANON
Beirut
0 200 400km
© Copyright 2013 EEA Copenhagen | Esri, DeLorme, FAO, USGS

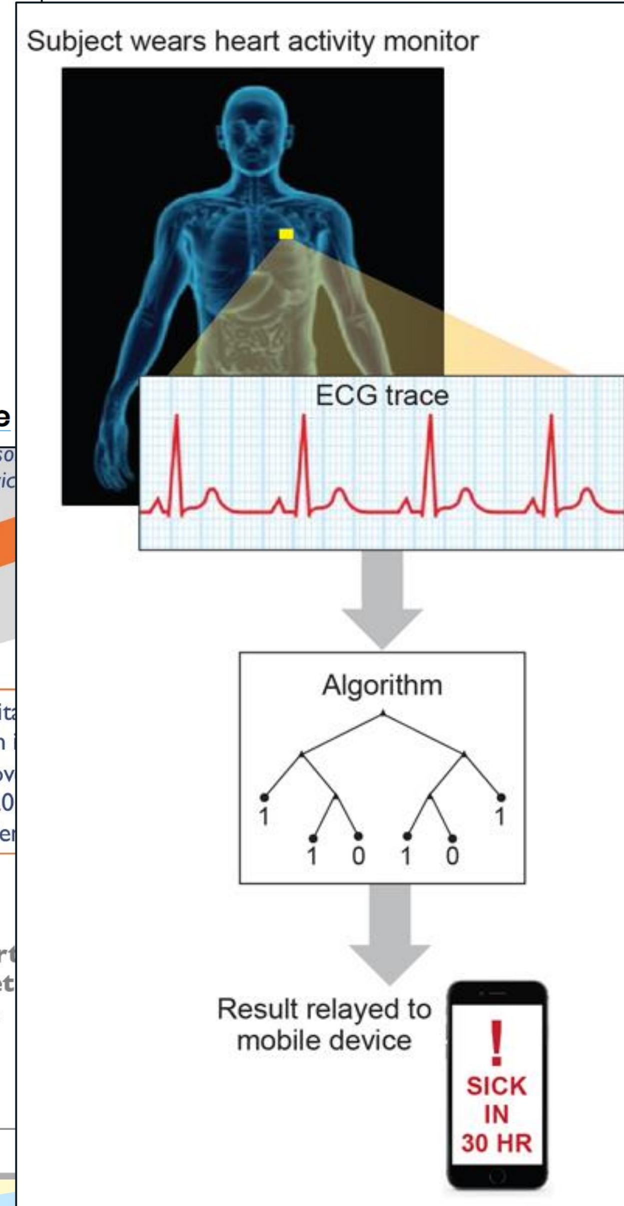
New technology gives early warning of exposure to disease-causing pathogens

The enabling algorithm uses non-invasive physiological data to predict the probability of viral or bacterial exposures.

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

DECEMBER 5, 2017 | **Dorothy Ryan | Communications & Community Outreach Office**

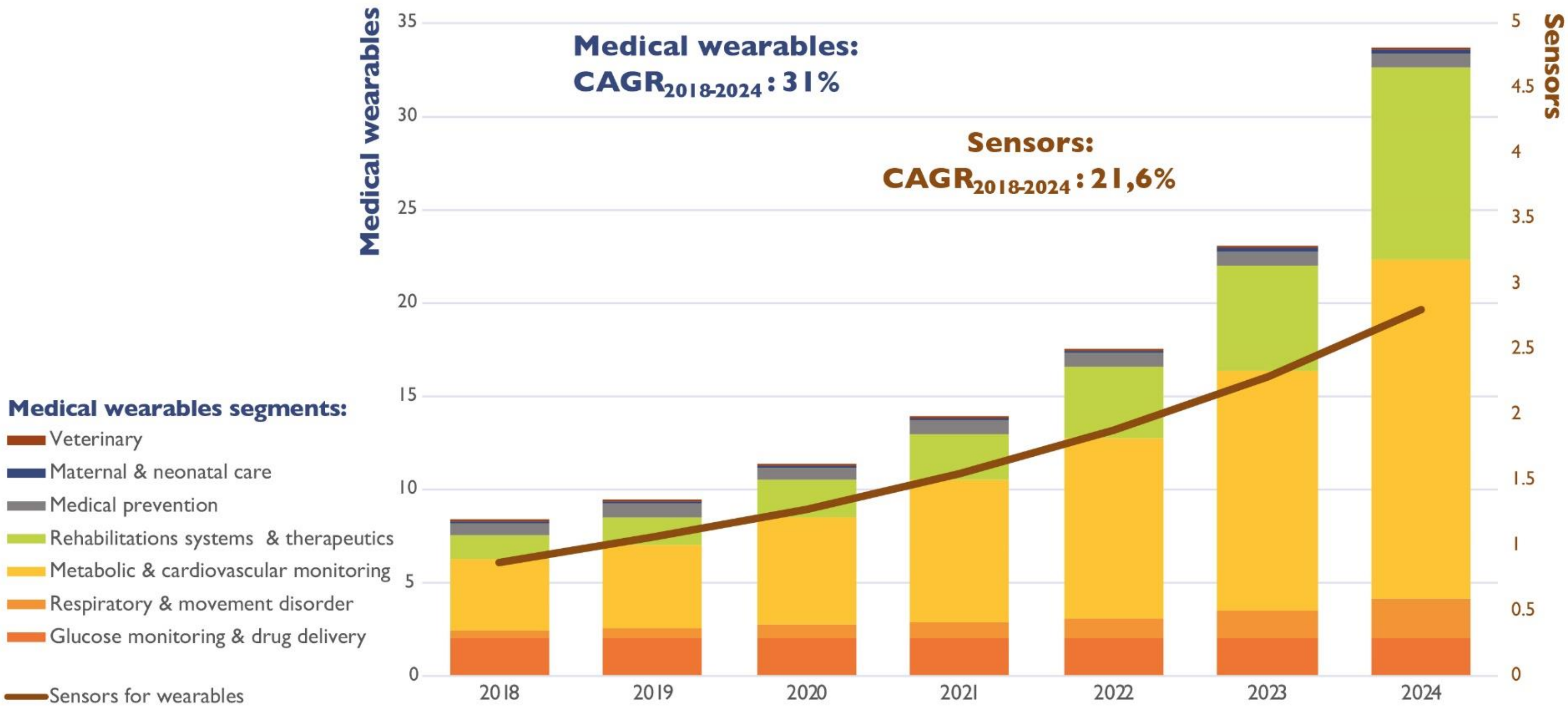




possible applica

Medical wearables and sensors: 2018 – 2024 market forecast (in B$)

(Source: Medical Wearables: Market and Technology Trends 2019 report, Yole Développement, March 2019)



Digitization transforms the Chemical Industry rapidly across its entire horizontal value chain

More efficient tracking of imports and exports?
Non-proliferation benefits?

THE DIGITAL CHEMICAL COMPANY

Big-data/ advanced analytics in OpEx/ CapEx: Big data-driven raw material analytics to optimize feedstock costs

End to end supply chain integration: Production data sharing with suppliers/ real-time supply tracking

Process automation: Sensor-based production control and real-time optimization of YETQ[1]

Integrated lean system: IT-based integrated lean system to drive manufacturing excellence

Engineering/ R&D 4.0: Machine-learning-driven recipe and formulation improvements

New roads to market: Using online/marketplace sales channels

Digitization of customer experience: Customer self-service platform

Digital procurement tools: Digital tools enabling more efficient procurement processes

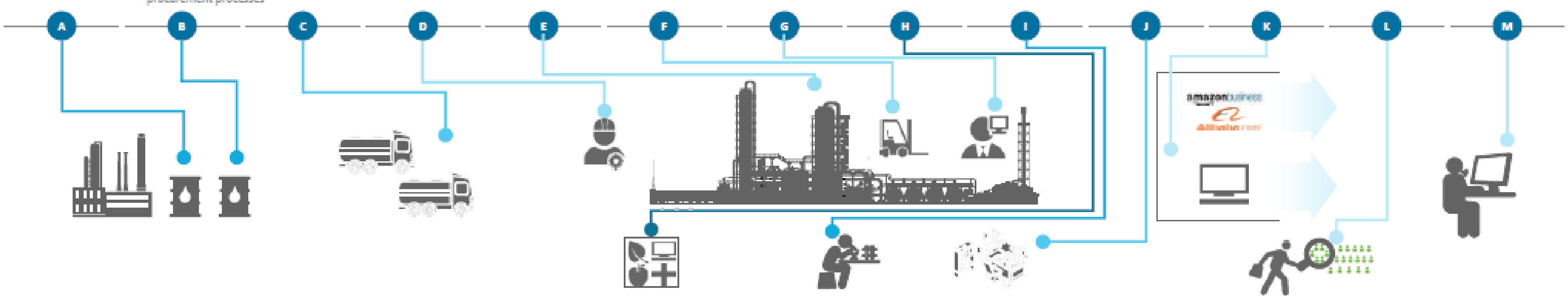
Predictive maintenance Advanced analytics-based predictive and risk-based maintenance

Digital manufacturing Production automation by application of autonomous logistics, drone inspections

Risk management: Advanced analytics-based risk manage-ment/cyber security

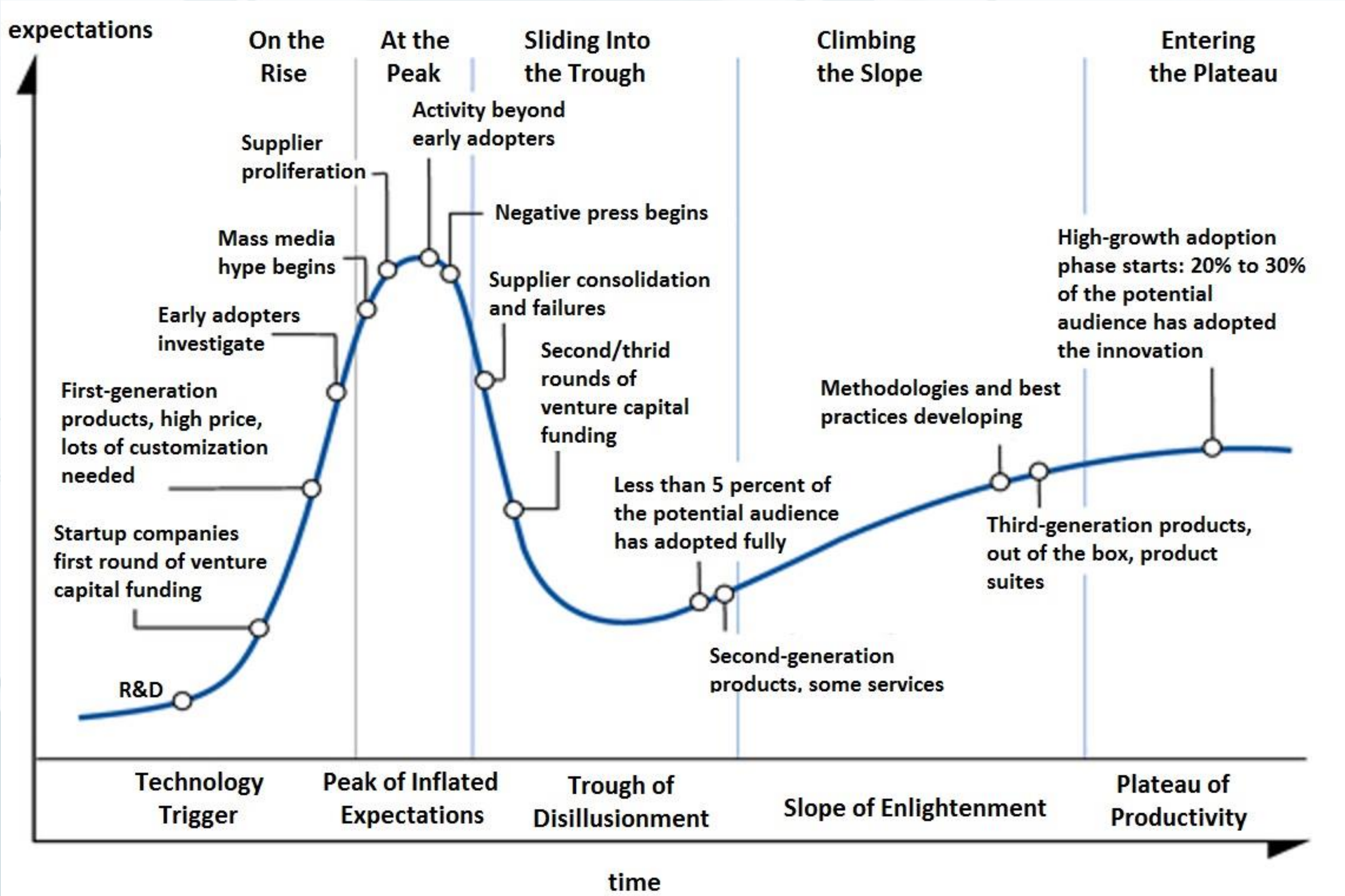
G&A 4.0: Back office automation, e.g., no touch orders

Commercial engines: Use advanced analytics for lead generation, etc.

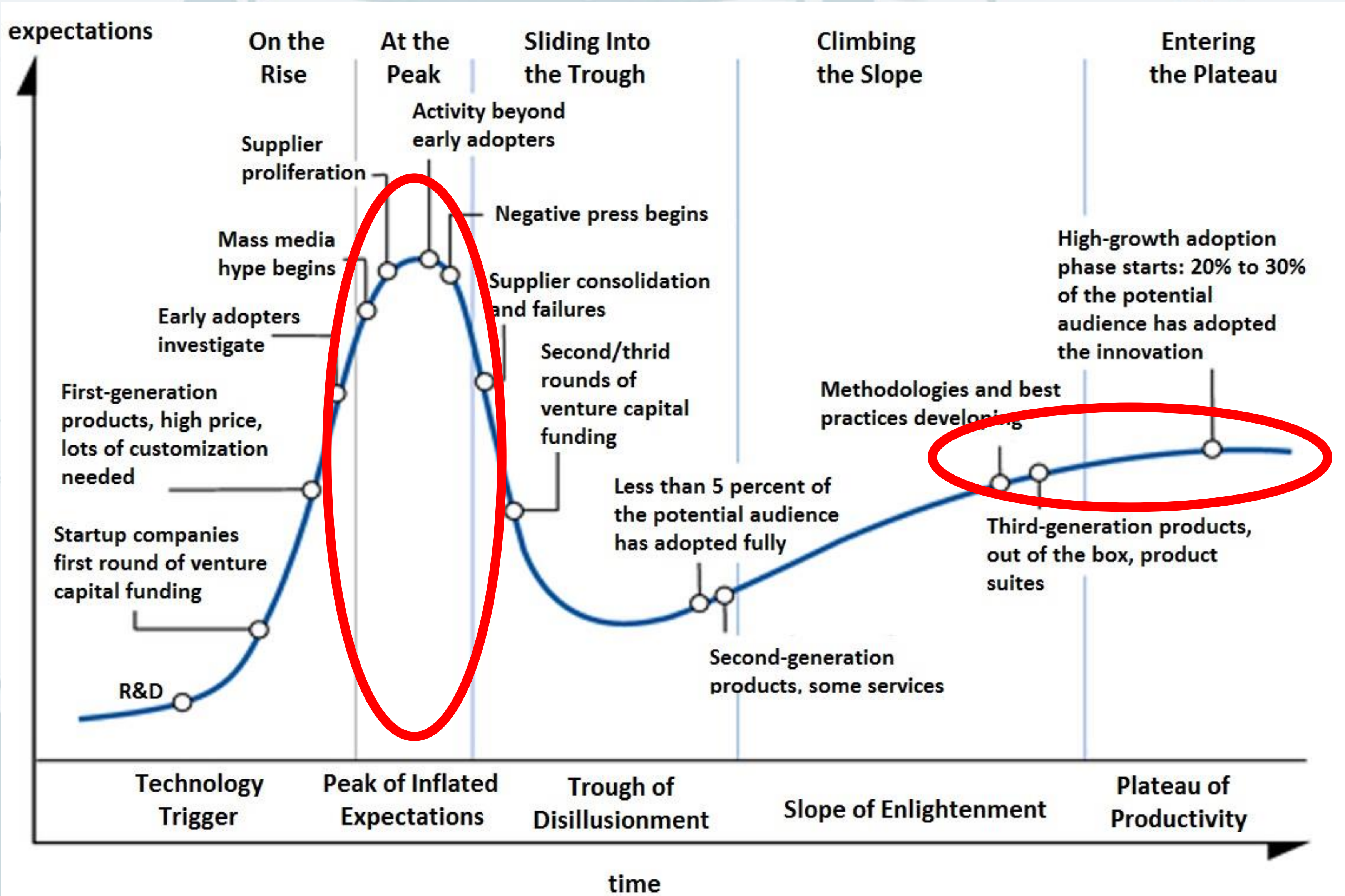


PLUS: new, radically different business models

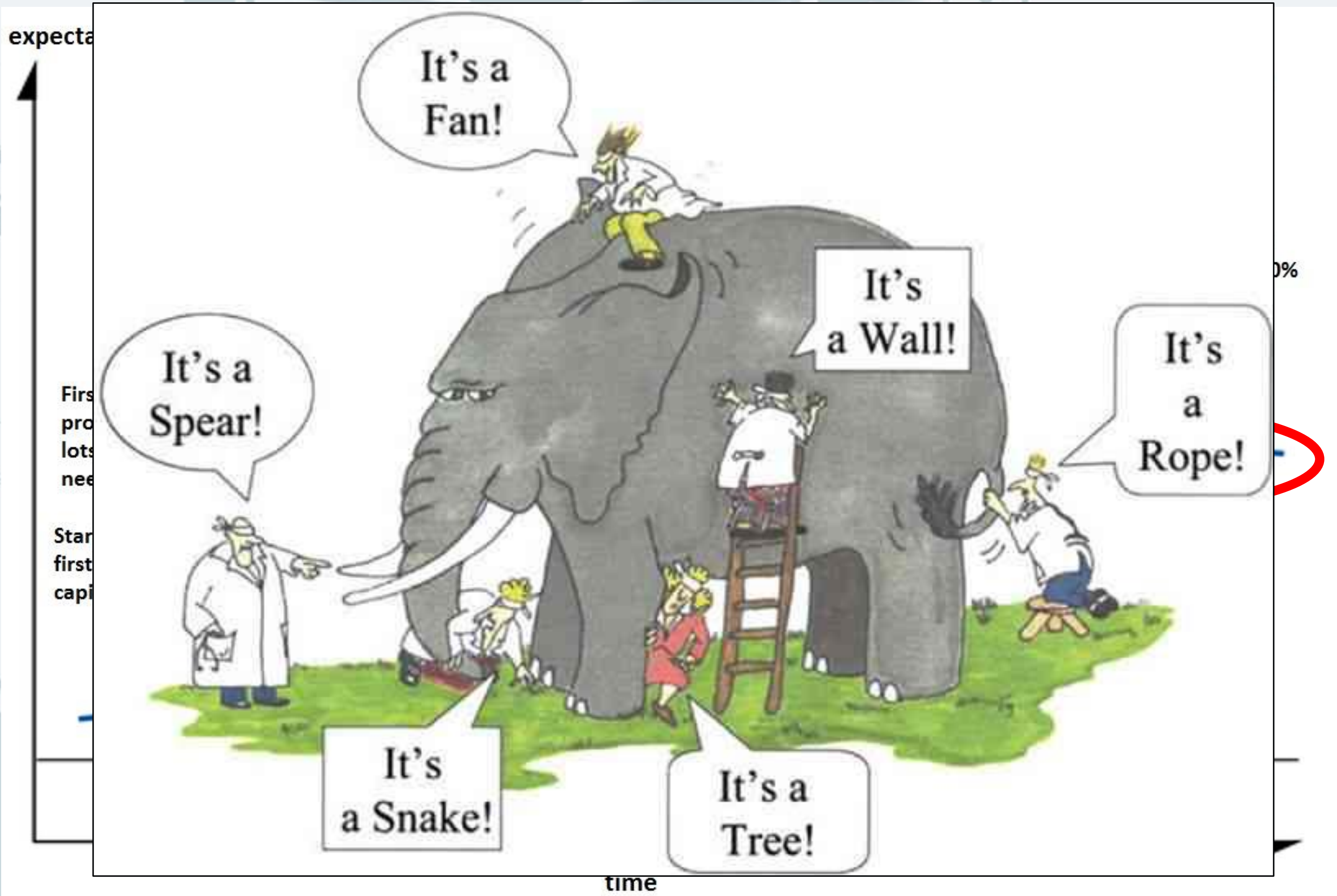
A Practical View of Science and Technology is Needed



A Practical View of Science and Technology is Needed



A Practical View of Science and Technology is Needed



Periodic Table of States Parties to the Chemical Weapons Convention

In Honour of the International Year of the Periodic Table of Chemical Elements 2019

LEGEND

Order of Entry into Force: 1 — Country Symbol: H — Country Element: Hydrogen — Date of Deposit: dd/mm/yyyy

- Western Europe and Other States (WEOG)
- Eastern Europe
- Africa
- Latin America and the Caribbean (GRULAC)
- Asia

No.	Symbol	Country Element	Date of Deposit
1	SE	Swedenium	17/06/1993
2	NO	Norwegium	07/04/1994
3	AU	Australium	06/05/1994
4	ES	Españium	03/08/1994
5	BG	Bulgarium	10/08/1994
6	DE	Deutschium	12/08/1994
7	MX	Mexicovium	29/08/1994
8	GR	Greecium	22/12/1994
9	RO	Romanium	15/02/1995
10	FR	Frenchium	02/03/1995
11	HR	Hrvatskium	23/05/1995
12	MC	Monacovium	01/06/1995
13	DZ	Algerium	14/08/1995
14	AT	Osterreichium	17/08/1995
15	PL	Polskavium	23/08/1995
16	JP	Japanium	15/09/1995
17	CA	Canadium	26/09/1995
18	AR	Argentinium	02/10/1995
19	NA	Namibium	24/11/1995
20	IT	Italium	08/12/1995
21	CI	Côte dIvorium	18/12/1995
22	MA	Moroccovium	28/12/1995
23	BR	Brazilium	13/03/1996
24	GB	Britanium	13/05/1996
25	MD	Moldovium	08/07/1996
26	PT	Portugalium	10/09/1996
27	HU	Hungarium	31/10/1996
28	PH	Philippinium	11/12/1996
29	BE	Belgium	27/01/1997
30	LU	Luxembourgium	27/01/1997
31	TN	Tunisium	15/04/1997
32	TG	Tongovium	23/04/1997
33	CN	Chinatium	25/04/1997
34	US	Americanium	25/04/1997
35	ZW	Zimbabwium	25/04/1997
36	IS	Icelandium	28/04/1997
37	ML	Malium	28/04/1997
38	MT	Maltavium	28/04/1997
39	FJ	Fijium	20/01/1993
40	MU	Mauritisium	09/02/1993
41	AL	Albanium	11/05/1994
42	CK	Cook Islandium	15/02/1994
43	LK	Sri Lankium	19/08/1994
44	PY	Paraguayium	01/12/1994
45	TJ	Tajikistanium	11/01/1995
46	MN	Mongolium	17/01/1995
47	FI	Finlandium	07/02/1995
48	CH	Switzerium	10/03/1995
49	NL	Netherlandium	30/06/1995
50	DK	Denmarkium	13/07/1995
51	PE	Peruvium	20/07/1995
52	EC	Ecuadorium	06/09/1995
53	ZA	South Africavium	13/09/1995
54	SK	Slovakium	17/10/1995
55	SV	El Salvadorium	30/10/1995
56	GE	Georgium	27/11/1995
57	CZ	Czechium	06/03/1996
58	PG	Papua New Guinium	17/04/1996
59	ET	Ethiopium	13/05/1996
60	CR	Costaricium	31/05/1996
61	IE	Irelandium	24/06/1996
62	BY	Belarusium	11/07/1996
63	CL	Chilium	12/07/1996
64	NZ	Aotearoavium	15/07/1996
65	IN	Indium	03/09/1996
66	CM	Cameroonium	16/09/1996
67	NE	Nigeratium	09/04/1997
68	BD	Bangladeshium	25/04/1997
69	GQ	Equatorial Guinium	25/04/1997
70	KR	Koreatium	28/04/1997
71	SC	Seychellium	07/04/1993
72	UY	Uruguayium	06/10/1994
73	KE	Kenyatium	24/07/1994
74	SA	Saudia Arabium	09/08/1996
75	OM	Omanium	08/02/1995
76	BH	Bahrainium	28/04/1997
77	AM	Armenium	27/01/1997
78	LC	Saint Lucium	09/04/1997
79	LV	Latvium	23/07/1996
80	LA	Laovium	25/02/1997
81	SZ	Eswatinium	20/11/1996
82	MV	Maldivium	31/05/1994
83	TM	Turkmenistanium	25/02/1997
84	LS	Lesothium	07/12/1994
85	UZ	Uzbekistanium	23/07/1996
86	BA	Bosnium	25/02/1997
87	SR	Surinamium	28/04/1997
88	CU	Cubatium	29/04/1997
89	TR	Turkium	22/05/1997
90	SG	Singaporium	21/05/1997
91	KW	Kuwaitium	29/05/1997
92	GN	Guinium	09/06/1997
93	SI	Slovenium	11/06/1997
94	MK	Macedonium	20/06/1997
95	TT	Trinibagium	24/06/1997
96	BF	Brukina Fasium	08/07/1997
97	GH	Ghanium	09/07/1997
98	BN	Brunium	28/07/1997
99	QA	Qatarium	03/09/1997
100	GY	Guyanium	12/09/1997
101	PK	Pakistanium	28/10/1997
102	JO	Jordanium	29/10/1997
103	IR	Iranacium	03/11/1997
104	RU	Russium	05/11/1997
105	NP	Nepalium	18/11/1997
106	VE	Venezuelium	03/12/1997
107	MR	Mauritanium	09/02/1998
108	LT	Lithuanium	15/04/1998
109	BJ	Beninium	14/05/1998
110	GM	Gambium	19/05/1998
111	MW	Malawium	11/06/1998
112	TZ	Tanzanium	25/06/1998
113	SN	Senegalium	20/07/1998
114	BO	Bolivium	14/08/1998
115	CY	Cyprussium	28/08/1998
116	BW	Botswanium	31/08/1998
117	BI	Burundium	04/09/1998
118	VN	Vietnamium	30/09/1998
119	PA	Panamanium	07/10/1998
120	UA	Ukrainium	14/10/1998
121	ID	Indonesiuum	12/11/1998
122	VA	Vaticanium	12/05/1999
123	NG	Nigerium	20/05/1999
124	SD	Sudanium	24/05/1999
125	EE	Estonium	26/05/1999
126	FM	Micronesium	21/06/1999
127	NI	Nicaragium	05/11/1999
128	LI	Lichtensteinium	24/11/1999
129	SM	Sanmarinium	10/12/1999
130	ER	Eritrium	24/02/2000
131	AZ	Azerbijanium	29/02/2000
132	KZ	Kazakhstanium	23/03/2000
133	CO	Colombium	05/04/2000
134	MY	Malaysium	20/04/2000
135	RS	Serbium	20/04/2000
136	MZ	Mozambiqium	15/08/2000
137	KI	Kiribatium	07/09/2000
138	GA	Gabonium	08/09/2000
139	JM	Jamaicium	08/09/2000
140	YE	Yemenium	02/10/2000
141	AE	Emiratium	28/11/2000
142	ZM	Zambium	09/02/2001
143	DM	Dominicium	12/02/2001
144	NR	Nauruvium	12/11/2001
145	UG	Ugandium	30/11/2001
146	VC	Vincentium	18/09/2002
147	WS	Samoatium	27/09/2002
148	TH	Thailandium	10/12/2002
149	PW	Palauvium	05/02/2003
150	GT	Guatemalium	12/02/2003
151	AD	Andorrium	27/02/2003
152	TL	Timor Lestium	07/05/2003
153	TO	Tongovium	29/05/2003
154	AF	Afghanistanium	24/09/2003
155	ST	Saotomium	09/09/2003
156	KG	Kyrgyzstanium	29/09/2003
157	CV	Carboverdium	10/10/2003
158	BZ	Belizium	01/12/2003
159	LY	Libyatium	06/01/2004
160	TV	Tuvalium	19/01/2004
161	TD	Chadium	13/02/2004
162	RW	Rwandum	31/03/2004
163	MH	Marshallium	19/05/2004
164	KN	Kittsnevisium	21/05/2004
165	SB	Solomonium	23/09/2004
166	SL	Sierraleonium	30/09/2004
167	MG	Madagascarium	20/10/2004
168	NU	Niuium	21/04/2005
169	GD	Grenadium	03/06/2005
170	KH	Cambodium	19/07/2005
171	BT	Bhutanium	18/08/2005
172	HN	Hondurasium	29/08/2005
173	AG	Antigua barbudium	08/09/2000
174	VU	Vanuatium	16/09/2005
175	CD	Demcongonium	09/02/2001
176	DJ	Djiboutium	21/01/2006
177	HT	Haitium	22/02/2006
178	LR	Liberium	23/02/2006
179	ME	Montenegrium	15/04/1998
180	KM	Comorosium	18/08/2006
181	CF	Centrafricainium	21/01/2006
182	BB	Barbadosium	07/03/2007
183	CG	Congovium	04/12/2007
184	GW	Guineabisium	20/05/2008
185	LB	Lebanonium	20/11/2008
186	IQ	Iraqium	13/01/2009
187	DO	Dominicanium	27/03/2009
188	BS	Bahamasium	21/04/2009
189	SO	Somalium	29/05/2013
190	SY	Syrium	14/09/2013
191	MM	Myanmarium	06/07/2015
192	AO	Angolium	16/09/2015
193	PS	State of Palestinium	17/05/2018

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UNESCO — United Nations Educational, Scientific and Cultural Organization

2019 IYPT — International Year of the Periodic Table of Chemical Elements

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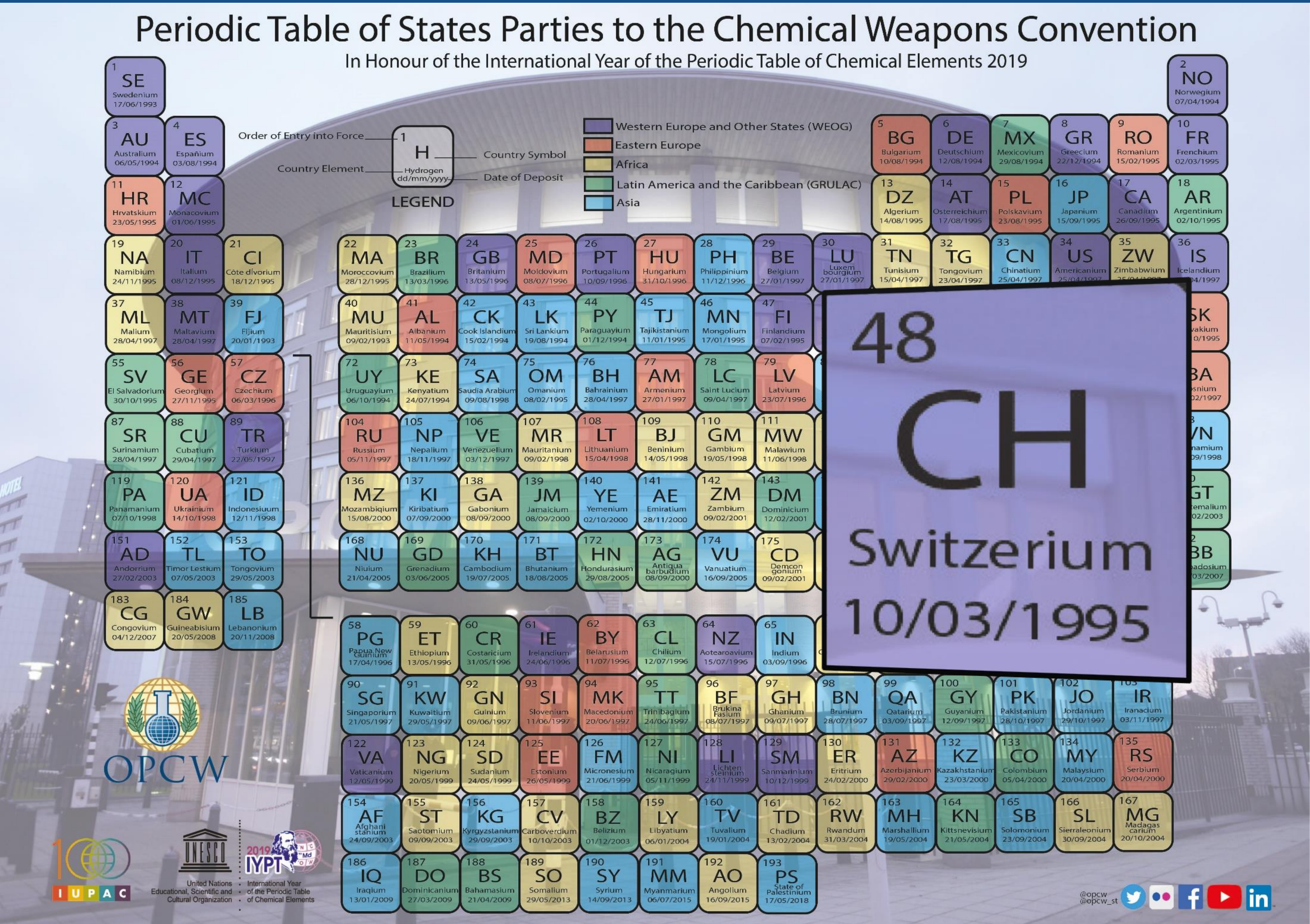
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Order of Entry into Force
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Date of Deposit
1 H Hydrogen dd/mm/yyyy
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8 GR Greecium 22/12/1994
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10 FR Frenchium 02/03/1995
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27 HU Hungarium 31/10/1996
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30 LU Luxembourgium 27/01/1997
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32 TG Tongovium 23/04/1997
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99 QA Qatarium 03/09/1997
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186 IQ Iraqium 13/01/2009
187 DO Dominicanium 27/03/2009
188 BS Bahamasium 21/04/2009
189 SO Somalium 29/05/2013
190 SY Syrium 14/09/2013
191 MM Myanmarium 06/07/2015
192 AO Angolium 16/09/2015
193 PS State of Palestinium 17/05/2018
48 CH Switzerium 10/03/1995
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United Nations Educational, Scientific and Cultural Organization
International Year of the Periodic Table of Chemical Elements
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Scientific and Technological Change

- **Uncertainty is the challenge!**
- **Technological change is inevitable**
- ***Disarmament non-proliferation cannot afford scientific illiteracy***
- **We Need Innovative ideas, approaches and policies**

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منظمة حظر الأسلحة الكيميائية

禁 止 化 学 武 器 组 织

Organisation for the Prohibition of Chemical Weapons

Organisation pour l’Interdiction des Armes Chimiques

Организация по запрещению химического оружия

Organización para la Prohibición de las Armas Químicas