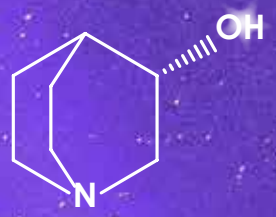
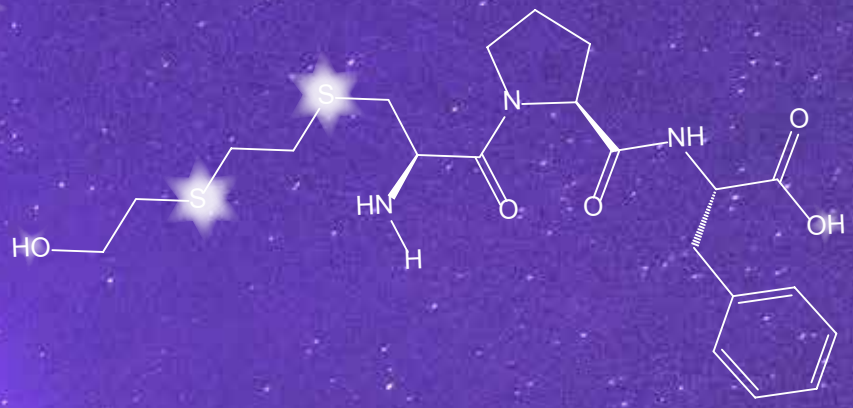
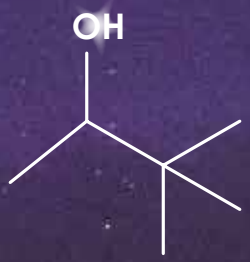
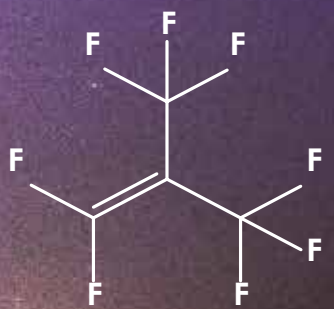
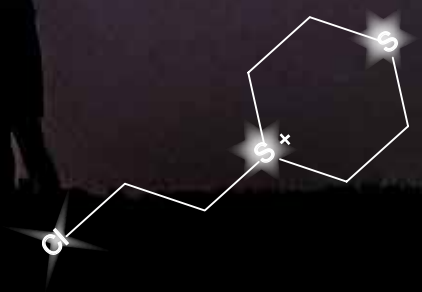




A Visual Guide to Science& Technology Relevant to The Chemical Weapons Convention







OPCW
Organisation for the Prohibition of Chemical Weapons

A Visual Guide to Science & Technology Relevant to The Chemical Weapons Convention

A compilation of posters and infographics produced by the Office of Strategy and Policy and the OPCW Laboratory. Original posters and infographics can be downloaded from the OPCW website:
http://www.opcw.org/special-sections/science-technology/

This document is produced by:

Office of Strategy & Policy
Organisation for the Prohibition of Chemical Weapons

Johan de Wittlaan 32
2517 JR The Hague
The Netherlands

Tel: +31 (0) 704163000
E-mail: scitech@opcw.org

Contributors: Wesam Alwan, Wardah Amir, Edoxie Allier-Gagneur, Lisa Bergstorm, Marc-Michael Blum, Darcy van Eerten, Thomas dos Reis Faria, Elena Fischer, Emily Dearing Crampton Flood, Hugh Gregg, Amirhossein Imani, Fauzia Nurul Izzati, Murty Mamidanna, Puja Mody, Johannes Niemeier, Joel De Saint-ours, Inam Siraj, Siqing Sun, Vivek Suri, Christopher M. Timperley, Pei Yang, Jonathan E. Forman.

Editors: Jonathan E. Forman (Science Policy Advisor), Wesam Alwan, Fauzia Nurul Izzati, Siqing Sun, Vivek Suri

Printing: OPCW Reprographic Centre

2018 Edition

Table of Contents

Scheduled Chemicals under the Chemical Weapons Convention (CWC)

Schedule 1

Guidelines for Schedule 1

The following criteria shall be taken into account in considering whether a toxic chemical or precursor should be included in Schedule 1:

(a) It has been developed, produced, stockpiled or used as a chemical weapon as defined in Article II;

(b) It poses otherwise a high risk to the object and purpose of this Convention by virtue of its high potential for use in activities prohibited under this Convention because one or more of the following conditions are met:

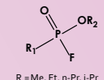
(i) It possesses a chemical structure closely related to that of other toxic chemicals listed in Schedule 1, and has, or can be expected to have, comparableproperties;

(ii) It possesses such lethal or incapacitating toxicity as well as other properties that would enable it to be used as a chemical weapon;

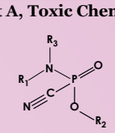
(iii) It may be used as a precursor in the final single technological stage of production of a toxic chemical listed in Schedule 1, regardless of whether this stage takes place in facilities, in munitions or elsewhere;

(c) It has little or no use for purposes not prohibited under this Convention.

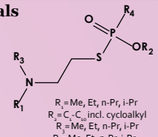
Schedule 1 Part A, Toxic Chemicals



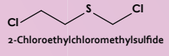
R_1=Me, Et, n-Pr, i-Pr
R_2=C_5-C_{10} incl. cycloalkyl
e.g. Sarin, Soman
1A(1)



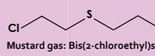
R_1=Me, Et, n-Pr, i-Pr
R_2=C_5-C_{10} incl. cycloalkyl
R_3=Me, Et, n-Pr, i-Pr
e.g. Tabun
1A(2)



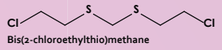
R_1=Me, Et, n-Pr, i-Pr
R_2=C_5-C_{10} incl. cycloalkyl
R_3=Me, Et, n-Pr, i-Pr
R_4=Me, Et, n-Pr, i-Pr
e.g. VX agent
Including corresponding alkylated and/or protonated salts
1A(3)



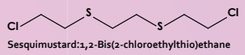
2-Chloroethylchloromethylsulfide



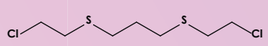
Mustard gas: Bis(2-chloroethyl)sulfide



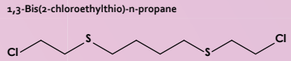
Bis(2-chloroethylthio)methane



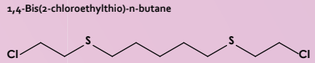
Sesquimustard:1,2-Bis(2-chloroethylthio)ethane



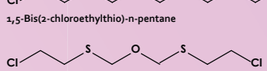
1,3-Bis(2-chloroethylthio)-n-propane



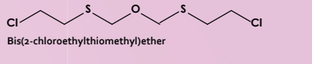
1,4-Bis(2-chloroethylthio)-n-butane



1,5-Bis(2-chloroethylthio)-n-pentane



Bis(2-chloroethylthiomethyl)ether

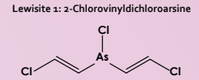


O-Mustard: Bis(2-chloroethylthioethyl)ether

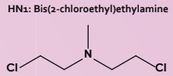
Sulfur mustards
1A(4)

Lewisite 1: 2-Chlorovinyldichloroarsine

HN1: Bis(2-chloroethyl)ethylamine



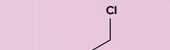
Lewisite 2: Bis(2-chlorovinyl)chloroarsine



HN2: Bis(2-chloroethyl)methylamine

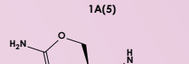
Lewisite 3: Tris(2-chlorovinyl)arsine

Lewisites
1A(5)

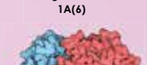


HN3: Tris(2-chloroethyl)amine

Nitrogen mustards
1A(6)



Saxitoxin
1A(7)



Ricin
1A(8)

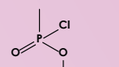
Schedule 1 Part B, Precursors

R_1=Me, Et, n-Pr, i-Pr
e.g. DF
1B(9)

R_1=Me, Et, n-Pr, i-Pr
R_2=C_5-C_{10} incl. cycloalkyl
R_3=Me, Et, n-Pr, i-Pr
R_4=Me, Et, n-Pr, i-Pr
e.g. QL

Including corresponding alkylated and/or protonated salts
1B(10)

Chlorosarin
1B(11)



Chlorosoman
1B(12)

Schedule 2

Guidelines for Schedule 2

The following criteria shall be taken into account in considering whether a toxic chemical not listed in Schedule 1 or a precursor to a Schedule 1 chemical or to a chemical listed in Schedule 2, part A, should be included in Schedule 2:

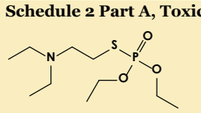
(a) It poses a significant risk to the object and purpose of this Convention because it possesses such lethal or incapacitating toxicity as well as other properties that could enable it to be used as a chemical weapon;

(b) It may be used as a precursor in one of the chemical reactions at the final stage of formation of a chemical listed in Schedule 1 or Schedule 2, part A;

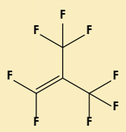
(c) It poses a significant risk to the object and purpose of this Convention by virtue of its importance in the production of a chemical listed in Schedule 1 or Schedule 2, part A;

(d) It is not produced in large commercial quantities for purposes not prohibited under this Convention.

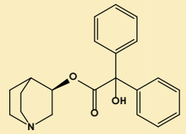
Schedule 2 Part A, Toxic Chemicals



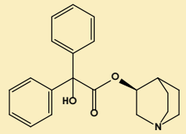
Including corresponding alkylated and/or protonated salts
Amiton
2A(1)



PFIB
2A(2)

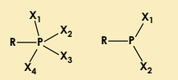


(R)-(-)-3-Quinuclidinyl benzilate

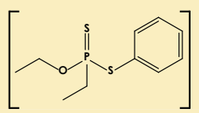


(S)-(+)-3-Quinuclidinyl benzilate
2A(3)*

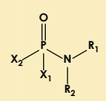
Schedule 2 Part B, Precursors



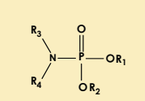
R=Me, Et, n-Pr, i-Pr
X_1-X_3=Any group not attached to the phosphorus atom through a carbon
2B(4)



Exemption: Fonofos

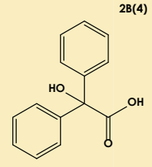


R_1, R_2=Me, Et, n-Pr, i-Pr
X_1, X_2=Halogens
2B(5)

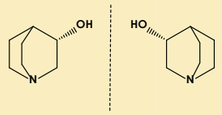


R_1, R_2, R_3, R_4=Me, Et, n-Pr, i-Pr
2B(6)

Arsenic Trichloride
2B(7)

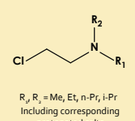


2,2-Diphenyl-2-hydroxyacetic acid
2B(8)

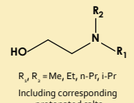


(S)-(+)-3-Quinuclidinol

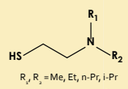
(R)-(-)-3-Quinuclidinol
2B(9)



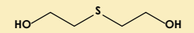
R_1, R_2=Me, Et, n-Pr, i-Pr
Including corresponding protonated salts
2B(10)



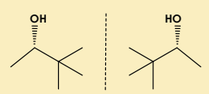
R_1, R_2=Me, Et, n-Pr, i-Pr
Including corresponding protonated salts
Exemptions: R_1=R_2=Me
R_1=R_2=Et
2B(11)



R_1, R_2=Me, Et, n-Pr, i-Pr
Including corresponding protonated salts
2B(12)



Thiodiglycol: Bis(2-hydroxyethyl)sulfide
2B(13)



(S)-(+)-Pinacolyl alcohol

(R)-(-)-Pinacolyl alcohol
2B(14)

Relationship between Schedules, illustrated with sulfur mustard.

Schedule 3

Guidelines for Schedule 3

The following criteria shall be taken into account in considering whether a toxic chemical or precursor, not listed in other Schedules, should be included in Schedule 3:

(a) It has been produced, stockpiled or used as a chemical weapon;

(b) It poses otherwise a risk to the object and purpose of this Convention because it possesses such lethal or incapacitating toxicity as well as other properties that might enable it to be used as a chemical weapon;

(c) It poses a risk to the object and purpose of this Convention by virtue of its importance in the production of one or more chemicals listed in Schedule 1 or Schedule 2, part B;

(d) It may be produced in large commercial quantities for purposes not prohibited under this Convention.

Schedule 3 Part A, Toxic Chemicals

Phosgene: Carbonyl dichloride
3A(1)

Cyanogen chloride
3A(2)

Hydrogen cyanide
3A(3)

Chloropicrin: Trichloronitromethane
3A(4)

Schedule 3 Part B, Precursors

Phosphorus oxychloride
3B(5)

Phosphorus trichloride
3B(6)

Phosphorus pentachloride
3B(7)

Trimethyl phosphite
3B(8)

Triethyl phosphite
3B(9)

Dimethyl phosphite
3B(10)

Diethyl phosphite
3B(11)

Sulfur monochloride
3B(12)

Sulfur dichloride
3B(13)

Thionyl chloride
3B(14)

Ethyldiethanolamine
3B(15)

Methyldiethanolamine
3B(16)

Triethanolamine
3B(17)

Scheduled chemicals, including those in schedules 1 and 2, can have scientifically and economically important uses. This chart captures the number of yearly scientific publications that refer to them.

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

@opcw @opcw_st /opcwonline /opcwonline /company/opcw /opcw

SAMPLING AND ANALYSIS RELEVANT TO THE IMPLEMENTATION OF THE CHEMICAL WEAPONS CONVENTION

Emily Dearing Crampton Flood
OPCW Laboratory, Rijswijk, The Netherlands

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

I. INTRODUCTION

Sampling and analysis is widely used in many industries to assess workplace contaminants and health and safety protocol adherence. Chemical analysis, in many ways, is the focal point of the verification activities of the OPCW. The objective of the sampling and analysis activities of the OPCW is to prove the presence or absence of a particular scheduled chemical in a sample. Used in this manner, chemical analysis provides unambiguous evidence for the presence of scheduled chemicals.

S&A is invoked in three OPCW activities: inspections (for example, chemical weapons destruction facilities or chemical industries), challenge inspections (CI), and investigations of alleged use (IAU). In the case of an inspection at a chemical industry for example, S&A is used to prove that the activities in a particular location are consistent with the information provided in the declarations provided by the industry. In the case of a challenge inspection, S&A is used to validate the allegations proposed by one State Party toward another with regards to adherence to the CWC. No CI's have been required so far in the history of the OPCW but regular training in CI S&A techniques is provided in the form of ASSISTEX exercises. An investigation of alleged use (IAU) involves sampling of environmental and biomedical samples and their analysis in an area where chemical weapons were allegedly used; the main example of recent times being Syria.

S&A related to the implementation of the CWC is performed on-site, in the OPCW Laboratory, and in a network of designated labs around the globe. 8-10 inspection missions are carried out per year by the verification division and the inspectorate team of the OPCW.

Figure 2. An inspector collecting a liquid sample during and challenge inspection (CI) exercise

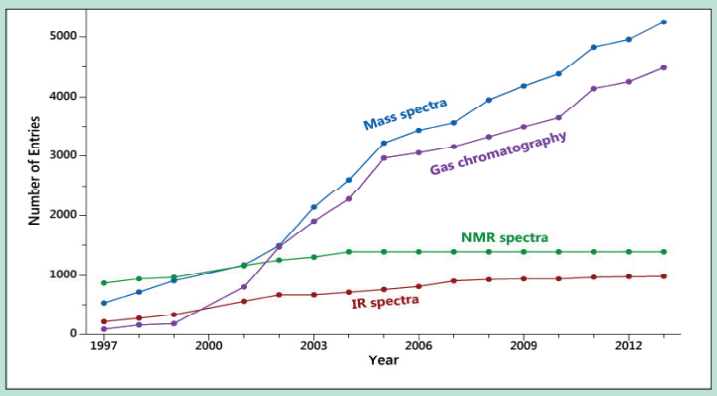


Figure 3. Additions to the OCAD from 1997-2014

II. TOOLS AND TECHNIQUES USED FOR S&A

Trained analytical chemists (ACs) perform the bulk of the S&A activities for the OPCW. Many of the AC inspectors hold chemical engineering or chemistry degrees, and are trained at the OPCW laboratory prior to departure on missions.

The main workhorse of most of the chemical analysis relevant to the CWC is a hyphenated analytical method called gas chromatography-mass spectrometry (GC-MS). A GC-MS instrument separates individual components in a mixture and records their masses, making identification of target compounds facile. To assist with identification, the OPCW Central Analytical Database (OCAD), which contains data from over 5,000 compounds, is used. An advantage of using GC-MS as the main analytical tool is that it can detect compounds in extremely diluted samples, usually at the part per million (ppm) level. GC-MS instruments require continuous calibration with a calibration mix provided by the OPCW.

Other chemical analysis tools include infrared (IR) and Raman spectroscopy. These tools were used in Syria as qualitative methods that rapidly indicate the presence of a particular class of chemicals which contain similar structural features. Raman spectroscopy was also used at Marchwood Military Port in the United Kingdom to verify the identity of chemicals received from the hydrolysis of chemical weapons aboard the Cape Ray.

In addition to the analytical tools mentioned above, a range of other equipment is needed for S&A during inspections, such as sample collection kits, sample preparation kits, and portable fume hoods.

Figure 1. Inspectors performing S&A activities during an exercise

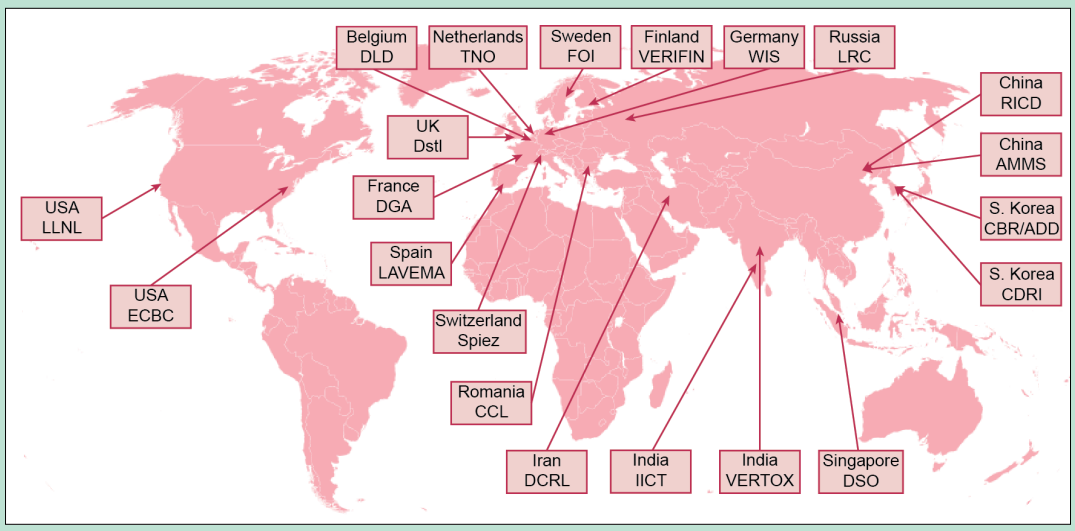
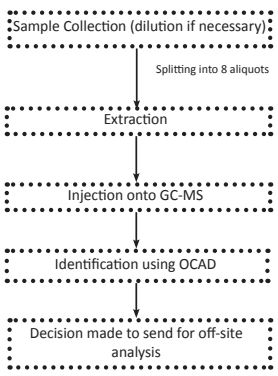


Figure 4. Current designated laboratories that the OPCW uses for off-site analysis (as of July 2014). All the designated laboratories have to maintain strict analytical practices and take part in annual profiency tests run by the OPCW Laboratory in Rijswijk

III. OVERVIEW OF THE S&A PROCESS



Beforehand:

- The number and category of samples to be collected and the equipment necessary is determined beforehand. Sample collection forms are initiated. OPCW-approved PPE appropriate to the mission is prepared.

Sample collection:

- In the case of a suspected neat agent (highly toxic), the sample would be diluted at the collection point before collection and storage. The sample would also be split into aliquots at the site of collection.

Sample types and usual quantities collected:

1. Aqueous (250 ml)
2. Organic liquid, non CW (5 ml)
3. Organic liquid, CW or super toxic (2.5 ml)
4. Soil (250 g)
5. Bulk solid chemical (10 g)
6. Wipe (1 wipe per solvent)
7. Paint, rubber, wood (surface scrape)

Sample extraction:

- The complexities of the sample matrix and possibility of contaminants oftentimes means that extraction has to be carried out. Extractions are usually performed in dichloromethane (DCM), water, or triethylamine (TEA)/methanol mixture. Lewisites require a different extraction procedure. Analysis using GC-MS and identification of compounds using the OCAD database.

- Samples are injected and analysed using the GC-MS instrument and the chromatograms and mass spectra of each compound are recorded. Unless run on "restricted" mode, mass spectral libraries can be used to compare data with the sample (common libraries include the NIST, and the Wiley). The laptop connected to the GC-MS has AMDIS (automated mass spectral deconvolution and identification system) software installed, which is a software used to deconvolute co-eluting peaks (different compounds eluting at similar retention times) on chromatograms.

Decision to send samples off-site:

- The inspection team leader (ITL) recommends to the Director-General if off-site analysis is required. Of the 8 aliquots prepared from the authentic sample, one is handed over to the Inspected State Party as a reference sample, 2 are used in on-site S&A activities, and the remaining 5 are set aside for off-site analysis if the occasion arises.

- If off-site analysis is required, the samples are sent to at least two off-site independent accredited laboratories to increase confidence in OPCW S&A testing results. Therefore, the need to properly develop a strong network of designated laboratories is realized (Figure 4).

IV. THE OCAD

During routine S&A inspections, the OCAD database is used to identify the presence or absence of scheduled chemicals in a given sample. However, in the case of an IAU, the analysis of the sample is not limited to scheduled chemicals alone and encompasses any chemicals that may not be found in OCAD up to that point.

The OCAD currently contains recorded data on 5,000 scheduled chemicals. Most of the data is in the form of mass spectra and retention indices recorded from GC-MS analyses of chemicals, however, data from infrared (IR) and nuclear magnetic resonance (NMR) analyses of chemicals are also present, albeit fewer entries are included for those techniques.

The OCAD is updated every year based on a stringent screening procedure for new entries. Data for the OCAD is generated by the OPCW laboratory and the designated laboratories. The data is then validated by external experts and submitted for review to the Executive Council (EC), which approves the material for inclusion onto the OCAD.

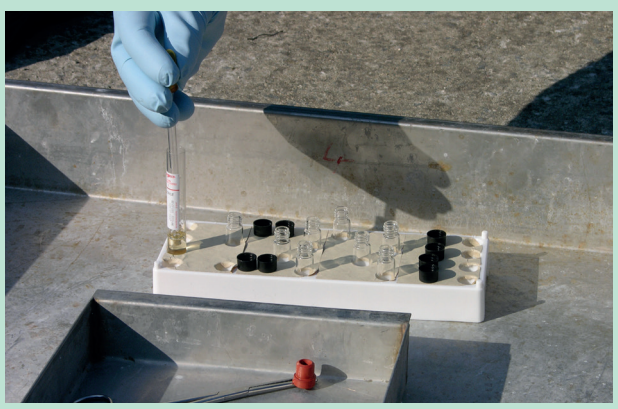


Figure 5. Sample splitting into 8 aliquots during a 2005 ASSISTEX field exercise

Figure 6. Sample preparation by an analytical chemist (AC) during and on-site inspection

V. LIMITATIONS AND CHALLENGES POSED BY S&A

- The biggest challenge posed by S&A are process related impurities and "false positives", which undermine the credibility of the results. For example, a false positive may indicate that a scheduled chemical is present when in fact it is not in the mixture. This of course has far-reaching implications in terms of politics and international relations.

- Another issue is the possibility that the OCAD may not contain the scheduled chemical being manufactured in a particular inspected location. Therefore, it is important to constantly keep updating the database.

- The restricted mode of analysis required by some businesses or companies (imposed to protect trade secrets and keep confidentiality) may limit analytical chemists' ability to fully characterize the constituents of the sample.

- Finally, if an IAU occurs, S&A may not be appropriate due to a range of factors including a dangerous military environment, limited time, and the lack of certain infrastructures in the location.

CONDUCTING ANALYSIS OF BIOMEDICAL SAMPLES TO ASSESS EXPOSURE TO ORGANOPHOSPHORUS NERVE AGENTS

Marc-Michael Blum, Murty Mamidanna, Hugh Gregg
OPCW Laboratory, Rijswijk, The Netherlands

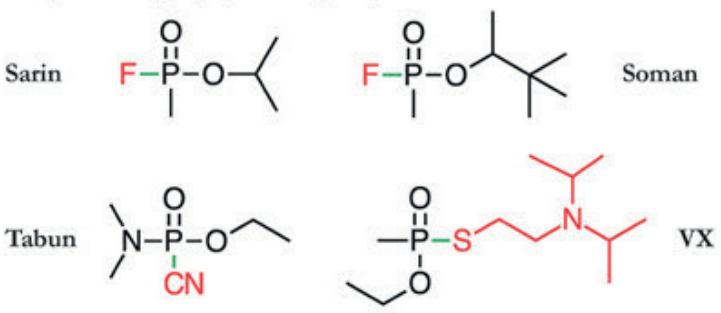
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

1. INTRODUCTION

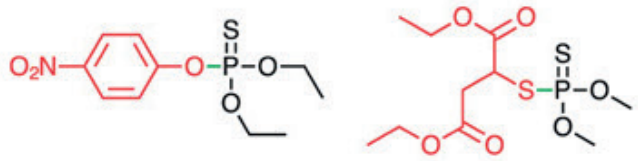
Highly toxic **nerve agents** such as **Tabun, Sarin, Soman** and **VX** are banned under the Chemical Weapons Convention (CWC) and formed major parts of **large stockpiles** of chemical weapons during the **Cold War**. **Terrorist attacks** carried out by the cult Aum Shinrikyo in **Japan** in 1994/95 employed **Sarin**. The OPCW supported UN mission that investigated the August 2013 chemical attacks in **Ghouta/Syria** determined that the chemical agent used was also **Sarin**. **Sampling and analysis** of **environmental samples** can reveal the presence of absence of these agents (and/or their degradation products) but in order to assess if a **potential victim** was exposed, the analysis of **biomedical samples** is required. **Blood** and **urine** samples are preferred as they are easily collected but the analysis of body **tissues** is also possible. Tissue samples are especially relevant in case of deceased individuals.

2. NERVE AGENTS - CHEMISTRY AND STRUCTURE

Nerve agents are **organophosphorus** compounds and are liquid at room temperature. For understanding their reactions in the human body it is helpful to introduce the concept that the molecules are made up by **two different parts**: A. The **phosphorus containing part** (shown in black) in which a phosphoryl group (P=O) is bonded to an O-alkyl (-O-R) group and a short alkyl group (R) or a small dialkylamino group ($-NR_2$) in case of Tabun. The other part of the molecule is the so-called **"leaving group"** (shown in red). In case of Sarin and Soman this is a fluorine atom (-F), in case of Tabun a cyano group (-CN) and in case of VX a larger group containing nitrogen and sulphur. Most relevant reactions of the agents involve the chemical bond connecting these two groups (shown in green).

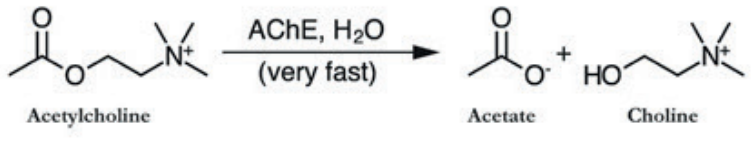


Organophosphorus **pesticides** are **similar** in structure (nerve agents were found while looking for new effective pesticides) and mode of action. Parathion and Malathion are shown as examples below. The substitution of oxygen in the phosphoryl group with sulphur lowers toxicity for humans.



3. ACETYLCHOLINESTERASE - THE TARGET

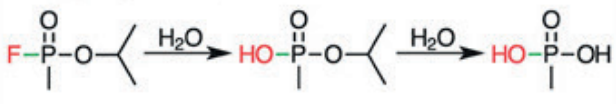
The primary **toxicity** of nerve agents is due to their ability to **inhibit** the action of an **enzyme** (protein with catalytic activity) crucial in the process of **conducting nerve signals**. **Acetylcholinesterase** (**AChE**) is responsible to break down the **neurotransmitter acetylcholine** at neuronal junctions by hydrolysis (reaction with water, see figure below). In a simplified view this switches a nerve signal from on to off. If the enzyme is **blocked**, acetylcholine will **accumulate** and signal transmission cannot be terminated. This leads to **cholinergic crisis** and typical symptoms including **sweating, salivation, miosis (pinpoint pupils), paralysis, respiratory failure** and eventually **death**. Because **AChE** is a very **fast and efficient enzyme** (one enzyme molecule can break down 25000 molecules of acetylcholine per second) and is not present in very large amounts, blocking of the enzyme quickly leads to fatal consequences.



Human AChE consists of **640 amino acids**. In the human body most of the AChE is found as units of two (**dimer**) or four (**tetramer**) AChE molecules that are **anchored** to a **membrane**. The figure to the left shows the complicated folding of the protein leading to its three dimensional **structure**. Helical substructures and so called beta-sheets (thick arrows) can be identified. The catalytic active site is buried deep inside the enzyme. It contains three amino acids crucial for catalytic activity: Serine 200, Histidine 440 and Glutamate 327. The nerve agents attach to Serine 200 to block the enzyme.

4. ANALYSIS OF METABOLITES

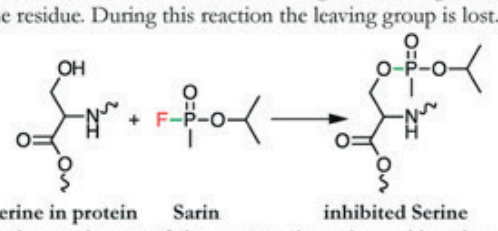
Nerve agents that are not interacting with AChE or other proteins in the human body (see below) normally **hydrolyze** quite rapidly. This is especially the case of **hydrophilic** agents such as Sarin while **lipophilic** agents such as VX can form **depots** of intact agent **in fatty tissues**. In case of Sarin the **primary hydrolysis product** (which is unable to block AChE) is **isopropyl methylphosphonic acid (IMPA)** that can further degrade to **methylphosphonic acid (MPA)**. Other indicators for the presence of the agent are **typical sideproducts** formed during Sarin synthesis such as **diisopropyl methylphosphonate (DIMP)**.



These compounds can be detected in **urine** and **blood** samples using **liquid** or **gas chromatography**. Due to the **low concentrations** in body fluids (in the **parts per billion** range) **GC-MS/MS** or **LC-MS/MS** methods employing **single ion monitoring (SIM)** or **multiple reaction monitoring (MRM)** modes are commonly used. This requires **targeted analysis**, meaning that one has to specifically analyize for a specific compound such as IMPA.

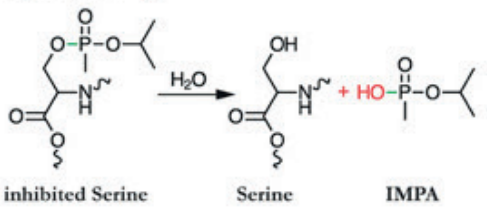
5. PROTEIN ADDUCTS AND THEIR FATE

Nerve agents do not only react with AChE but also with other proteins. One highly similar to AChE is **Butyrylcholinesterase (BChE)**. In contrast to the membrane anchored AChE, BChE is found in **blood serum** and can be used for analysis more easily. The active site of BChE also contains a **catalytic triad** of serine, histidine and glutamate and the **molecular mechanism of inhibition** is **identical** with AChE with the agent attaching itself to the serine residue. During this reaction the leaving group is lost.

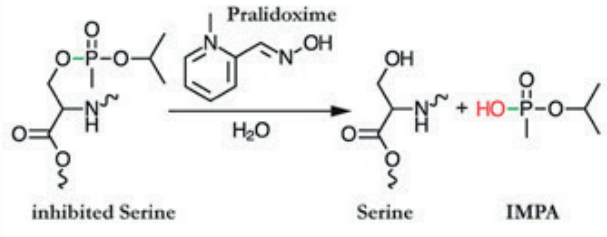


After the attachment of the agent to the serine residue, the enzyme is **blocked** and cannot perform its normal activity. This primary protein adduct can react further in a number of ways:

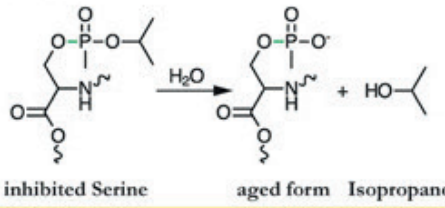
Spontaneous reactivation:
The inhibited Serine might react with water to **produce the original and functional serine residue** plus the hydrolysis product of the agent (IMPA in case of Sarin). While this process plays a role for certain pesticides, it is **too slow** to be of relevance in case of nerve agent poisoning.



Reactivation with a nucleophile
Nucleophilic compounds such as **oximes** can be used for induced **reactivation**. Such oximes are commonly used as **therapeutics** in case of nerve agent poisoning. They include compounds such as 2-PAM (Pralidoxime), Obidoxime, HI-6, MMB-4 and TMB-4.

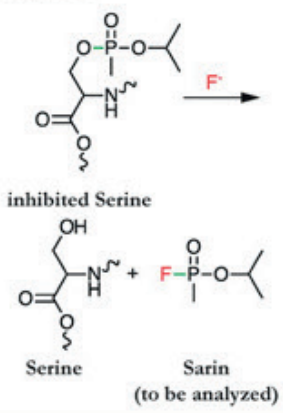


Ageing
The inhibited serine can **loose an additional group** from the phosphorus atom leading to a structure with a negative charge at an oxygen connected to the phosphorus (a process called ageing). This structure **cannot be reactivated** using oximes. While some agents age relatively slow ly (over hours and days) others are much faster. **Soman ages within minutes**, making medical therapy even more difficult.



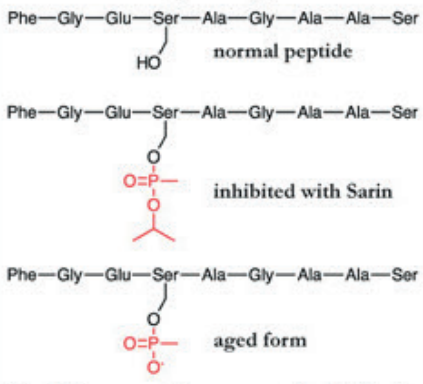
6. FLUORIDE REACTIVATION

One advantage of analysing protein adducts over free metabolites in blood is that they persist for much longer times. While **free metabolites** are cleared from blood in a **couple of days, protein adducts** may persist for **several weeks**. One approach for analysis that does not require a look at large protein molecules or fragments is **fluoride regeneration**. Sodium fluoride solution is added to the blood or plasma sample and the **fluoride ions** react with the protein adducts to **release the agent** again. In case of Sarin, Soman and Cyclosarin the original agent is regenerated. In case of Tabun, Fluorotabun is produced and in case of VX the product of fluoride regeneration is Ethylsarin. The one problem that exists with this procedure is that **aged protein does not react with fluoride** and **these molecules escape detection**.



7. DIRECT ANALYSIS OF ADDUCTS

When a nerve agent binds to AChE or BChE there is a **characteristic mass change in the protein** that can be used to identify the agent. The established procedure is relying on BChE in human blood plasma. Instead of using the intact protein (consisting of 574 amino acids) the **protein is cut into smaller pieces** (so called peptides) by using the **digestive enzyme Pepsin**. The fragment of interest is a **peptide of nine amino acids** that contains the serine residue inhibited by nerve agents:



The different peptides generated by the Pepsin digest are **separated** using **liquid chromatography (LC)** and analysed using **tandem mass spectrometry (MS/MS)**. As the **leaving group** of the agent is **lost** when binding to AChE or BChE, this analysis **can not reveal the absolute identity** of the used agent (the same is true for fluoride regeneration and any other analysis that does not identify the intact agent). For example, an adduct that is identical to the one produced upon exposure to Sarin might actually come from an agent that featured a leaving group similar to that of VX. Aged adducts caontain less information, but these peptides contain **more information** than just finding free MPA, as MPA is also a degradation product of some legitimate chemicals such as the flame retardant dimethyl methylphosphonate (DMMP). The **aged adduct is clear proof** that the body was **exposed** to a **toxic methyl-phosphonic chemical** that is **able to bind to and block AChE and BChE**. DMMP, for example, is unable to do this.
An alternative source for protein adducts is **serum albumin**. After digestion with **Pronase** adducts with the amino acid **Tyrosine** can be detected.

Degradation and Environmental Fate of Sulfur Mustard

Darcy van Eerten

• $SCl_2 + H_2C{=}CH_2$ (HMD Process)
• $S_2Cl_2 + H_2C{=}CH_2$ (Levinstein Process)

Chlorinating Agent (Meyer Process)

Thiodiglycol (TDG)

Common chlorinating agents:

HCl

Mercaptan

Time

Chlorinating Agent

Na_2CO_3

H_2O

HNO_3

RNH_2

Ammonia and primary amines (found in fertilizers)

Oxidation

Where X is a nucleophile

Thiourea, found in flame retardant textiles

1. NaOH
2. HCl

+ NaCl

Sea Water

Metabolic pathway for TDG utilization by bacteria isolated from the Baltic Sea

(TDG)

DNA adducts to purine bases can result in cross-linked strands which can lead to cancer and/or cell death

Bis G

O6 Guanine

N3 Adenine

N7 Guanine

DNA

Episulfonium ion adducts to Cysteine-34 in Human Serum Albumin in the blood

Cys

Pro

Phe

Albumin Adduct at Cys34

Blood

Beta Lyase

Urine

SBSNAE

SBMSE

SBMTE

MSMTESE

GSH-SM-Guanine

Glutathione (GSH)

DNA

Hydrolysis

Oxidation

TDG

Dichloramine T
Used as disinfectant in WWI

Decontamination with agents including DS2 and STB

Mustard heel

Formation of Agent Q, through synthesis but is also an impurity from the Levinstein process

Sesquimustard (Q)

Heat

Phosgene

Agent T

Present in ton containers

Levinstein mustards

Formed in containers and munitions

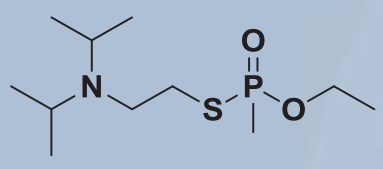
Environmental fate in: Cement & Soil | Sea Water | Synthesis Routes | Toxicology | Reported Impurities | Decontamination • Scheduled Chemical

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

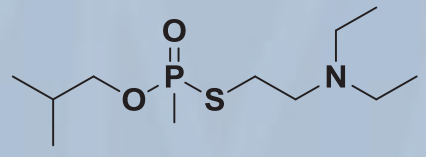
Working Together For a World Free of Chemical Weapons

Organophosphorus (OP) Nerve Agents and their Countermeasures

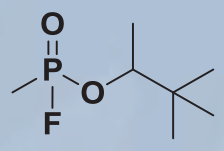
Examples of nerve agents:



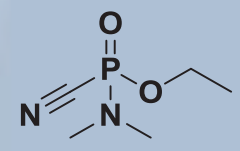
VX



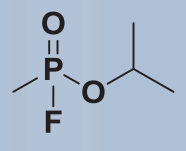
Russian VX



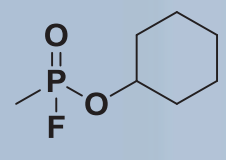
Soman (GD)



Tabun (GA)

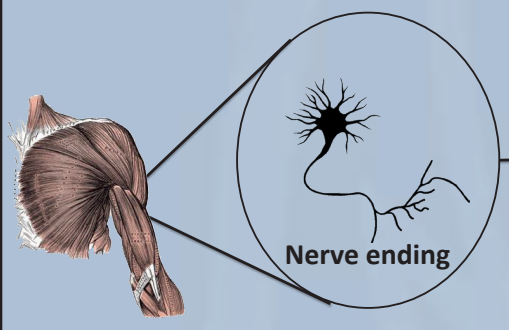


Sarin (GB)



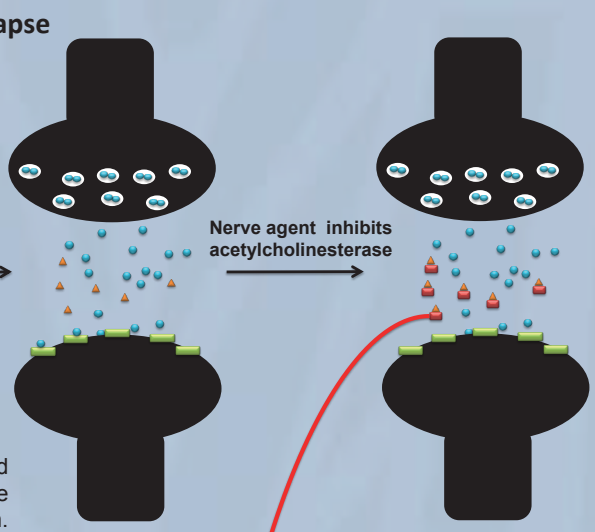
Cyclosarin (GF)

Mechanisms

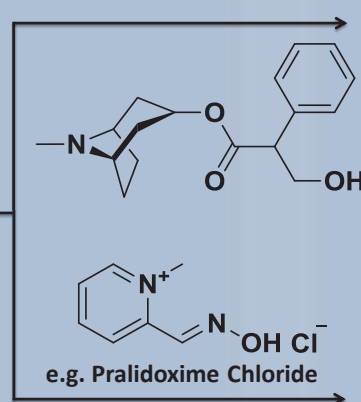


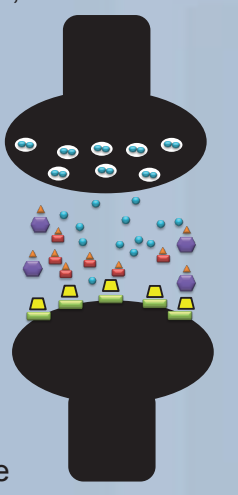
The neurotransmitter acetylcholine (ACh) is released into the synapse followed by binding to acetylcholine receptors which results in muscle contraction. Immediately after ACh binding, the enzyme acetylcholinesterase (AChE) breaks down ACh, removing it from the synapse to allow the muscle to relax.

Nerve agents inhibit AChE, which results in an excess of ACh and over-stimulation of the neuromuscular junction. SLUDGE syndrome followed by paralysis and death results.



Atropine, blocks the action of ACh at muscarinic receptors and treats SLUDGE syndrome (salivation, lacrimation, urination, diaphoresis, gastrointestinal motility, emesis)



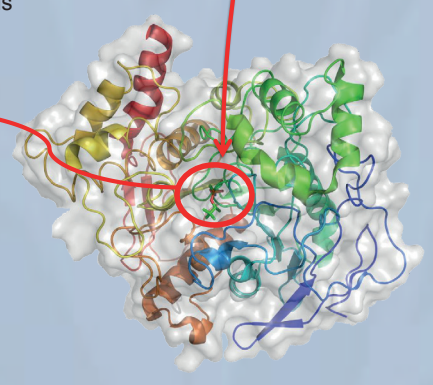


Oximes, reactivate acetyl cholinesterase before the process of aging (e.g. irreversible inhibition of the enzyme. Oximes can be co-administered with atropine, commonly used oximes include pralidoxime chloride, HI-6, trimedoxime and obidoxime

Soman ( ) adduct

Non-aged soman (GD) conjugate of *Torpedo californica* acetylcholinesterase

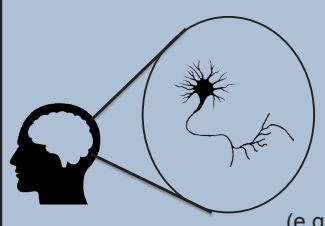
(Protein Data Bank structure 2WFZ)

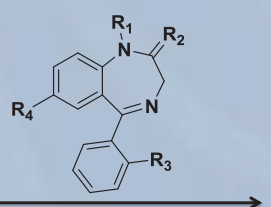


- Inhalation toxicity
- Dermal toxicity
- Neurological complications

Nerve agent countermeasures Atropine and Pralidoxime Chloride auto injector

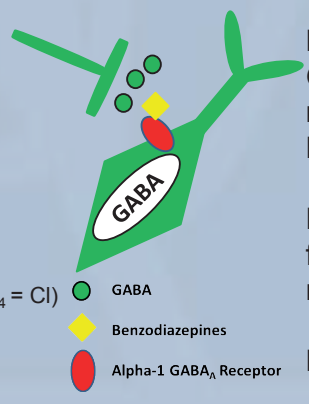
Secondary effect





Benzodiazepines

(e.g. Diazepam; $R_1 = CH_3$, $R_2 = O$, $R_3 = H$, $R_4 = Cl$)

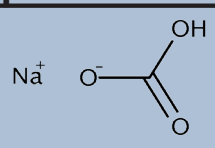


Benzodiazepines (BDZs, a class of anticonvulsants) bind to the gamma sub-unit of the $GABA_A$ receptor. Binding results in an allosteric (structural) modification of the receptor that increases receptor activity and inhibits excessive nerve cell activity. BDZs used for this purpose include diazepam, lorazepam and midazolam.

Neuroprotective substances that bind to the $GABA_A$ receptor such as BDZs are helpful for preventing neurological damage in the brain (atropine and oximes are targeted at muscle tissue).

Ketamine has also been studied as a neuroprotective substance.

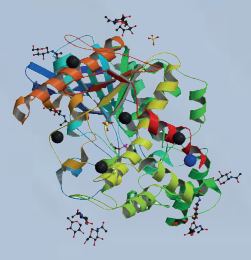
Other reported countermeasures



Sodium bicarbonate infusion has been reported to neutralize nerve agents. This is not a generally recommended procedure but there are reports of its use. *Iran J Med Sci. 2012 Jun; 37(2): 74–91*

Hemoperfusion and **fresh frozen plasma** can also be used to increase the excretion rate of nerve agent from the body. *Arch Toxicol. 2014 Feb;88(2):301-7*

Bioscavengers are enzymes that detoxify OPs by stoichiometric reaction or by catalytically cleaving the OPs into biologically inert products. Butyrylcholinesterase (illustrated below) represents an example of a stioichiometric bioscavenger.
Chem Biol Interact. 2013 Dec 5;206(3):536-44



Non-aged form of human butyrylcholinesterase inhibited by the tabun analogue TA1.
(Protein Data Bank structure 2WID).

www.opcw.org

@OPCW
@OPCW_ST

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together For a World Free of Chemical Weapons

Blood Agents and their Countermeasures

$N\equiv C-H$ **Hydrogen Cyanide**		$N\equiv C-C\equiv N$ **Cyanogen**		$N\equiv C^{-}{}^{+}Na$ **Sodium Cyanide**		$N\equiv C-Br$ **Cyanogen Bromide**	
LD_{50}*		LD_{50}*		LD_{50}*		LD_{50}*	
Inhalation	300 mg/kg	**Inhalation**	350 mg/kg	**Ingestion**	64 mg/kg	**Inhalation**	39 –52 mg/kg
Ingestion	50 – 200 mg/kg	**Skin**	10 - 15 mg/kg	**Skin**	77 mg/kg	**Ingestion**	25-50 mg/kg
Skin	100 mg/kg					**Skin**	250-1000 mg/kg

** LD_{50}: Median lethal dose in humans extrapolated from animals, toxicological profile of Cyanide, Agency for Toxic Substances and Disease Registry, U.S. Department of Health & Human Services.*

Effect

Cyanide ion (CN^-) Produced by blood agents

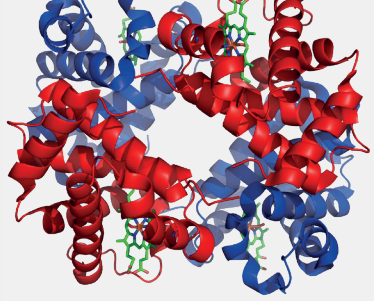
Inhalation

Ingestion

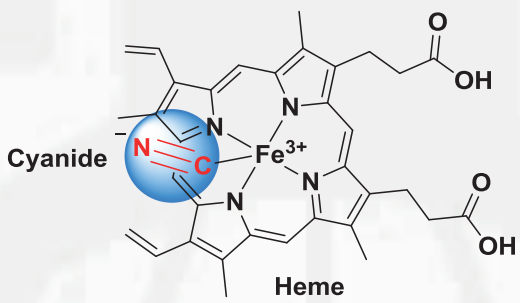
Skin (Adsorption)

Red Blood Cells

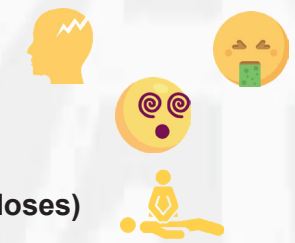
Hemoglobin

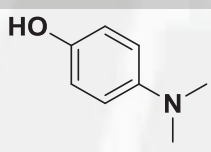
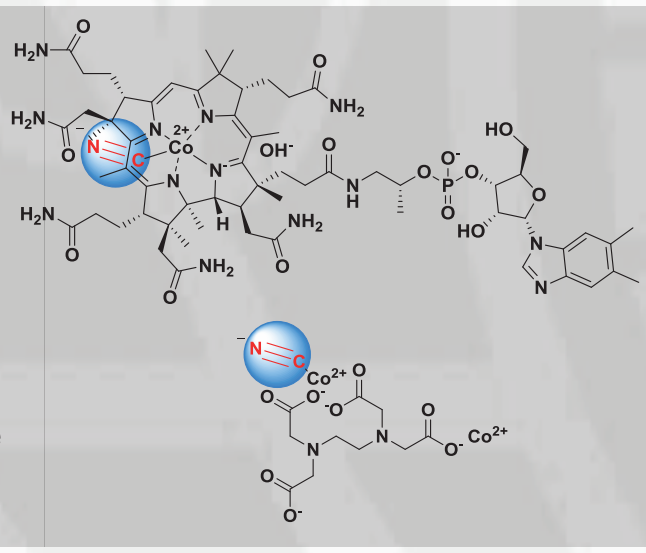


Heme-Cyanide Complex



- **Cyanide ion (CN^-) binds to hemoglobin, the oxygen-carrying molecule in red blood cells.**
- **It distributes throughout the body via the bloodstream where it binds to the metabolic enzyme cytochrome c oxidase. This prevents cells from using oxygen and producing energy.**
- **Symptoms of hydrogen cyanide poisoning:**
  - **Headache, nausea, dizziness (mild doses)**
  - **Convulsions and coma (high doses)**
  - **Respiratory and cardiac arrest (very high doses)**



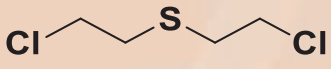
Countermeasures including supportive measures	Structure	Effect
Sodium nitrite/ Sodium Thiosulfate (administered intravenously)	$NaNO_2$/ $Na_2S_2O_3$	Nitrite oxidizes iron from the ferrous (+2) state to the ferric (+3) state, increasing the concentration of circulating ferric ion which competes for cyanide binding to the ferric ion of cytochrome c oxidase. Sodium thiosulfate binds to cyanide to produce thiocyanate, which is less toxic and eliminated via the kidneys.
4-Dimethylaminophenol (4-DMAP) (administered intravenously)		Oxidizes iron from ferrous (+2) to ferric (+3) state at a faster rate then sodium nitrite.
Hydroxocobalamin (a form of Vitamin B_{12} , administered intravenously) Dicobalt EDTA Caution: High incidents of side effects have been observed in patients receiving this treatment.		Binds to cyanide to form a complex that can be cleared from the body via the kidneys.
Nitrocobinamide	NO_2-vitamin B_{12}	Reverses cyanide inhibition of the enzyme cytochrome c oxidase.
Hyperbaric Oxygen Therapy	 O_2	Potentiates activity of other counter-measures by displacing CN^- from heme.

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

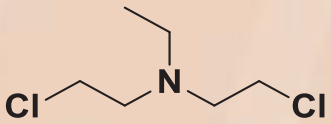
Working Together For a World Free of Chemical Weapons

Blister Agents and their Countermeasures

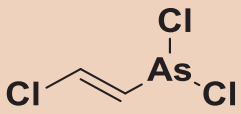
Examples of blister agents:



Sulfur Mustard (HD)



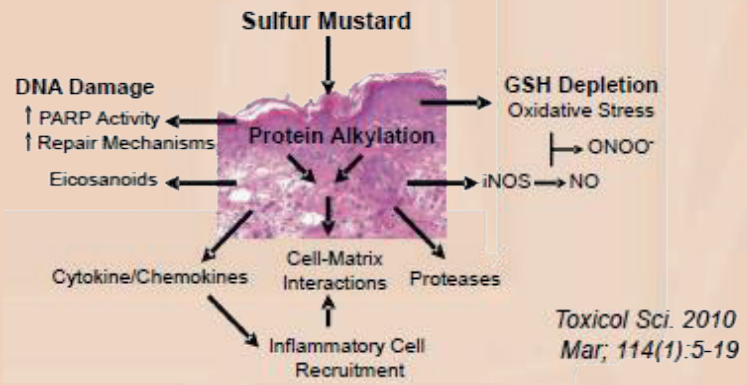
Nitrogen Mustard (HN-1)



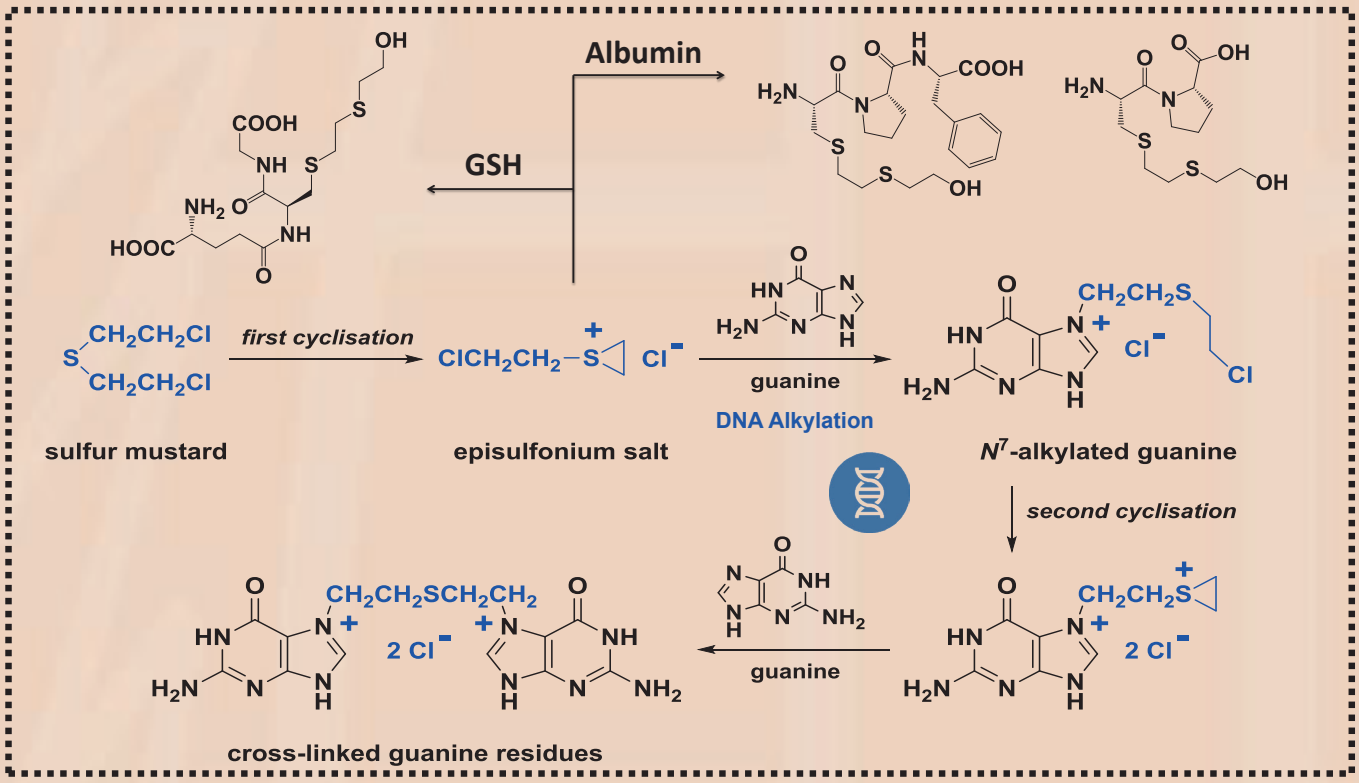
Lewisite (L)

Effects of sulfur mustard

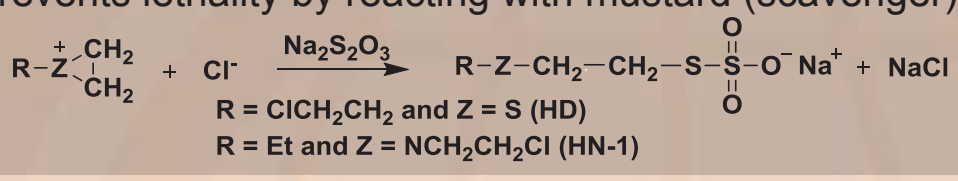
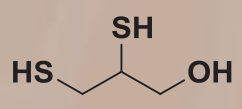
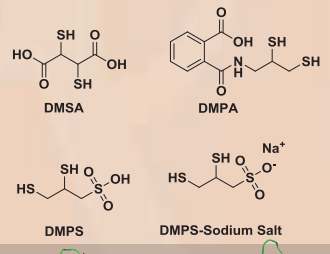
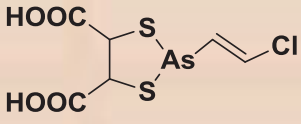
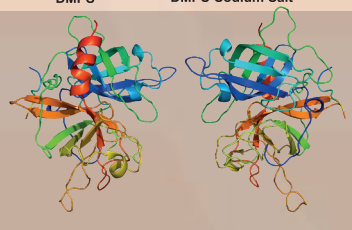
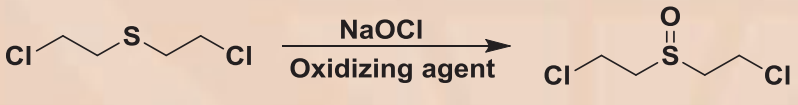
-Reddening of the skin
-Resembling sunburn
-Swollen skin
-Lesions
-Pain



Toxicol Sci. 2010 Mar; 114(1):5-19



Blister agents alkylate biological molecules such as nucleic acids, proteins and cellular membrane components. This results in a cascade of complications. Alkylation and cross linking of DNA can lead to a risk of cancer.

Countermeasures including supportive measures	Structure	Effect
Sodium Thiosulfate (administered intravenously)	$Na_2S_2O_3$	Prevents lethality by reacting with mustard (scavenger). 
Reactive Skin Decontamination Lotion – RSDL A Mixture of Dekon 139 and 2,3, butanedione monoxime (DAM) in a polyethylene glycol monomethyl ether (MPEG) and water solvent system (also works as a countermeasure against organophorphorus agents). Commercially available, www.rsdl.com.		Prevents dermal absorption and rapidly neutralizes the vesicant chemical
BAL (British Anti Lewisite) (administered intramuscularly)		Chelating agent that binds to Lewisite to form a water soluble complex. 
DMSA DMPS DMPA DMPS-Sodium Salt (used for Lewisites)		These chelating agents bind to Lewisite to form water soluble complexes. 
Tissue plasminogen activator (tPA) (Experimental therapeutic, administered intravenously) *Am J Respir Cell Mol Biol. 2013 Apr; 48(4): 439–447*		Diminishes airway obstructive fibrin–containing casts; this improves clinical respiratory distress, pulmonary gas exchange and tissue oxygenation.
Sodium Hypochlorite Can be used as a skin decontaminant. However, it is not a recommended treatment due to caustic properties.	NaOCl	Oxidizes (and inactivates) blister agents. 

The effects of blister agents appear within minutes of exposure. To minimize injury, decontaminate immediately!

www.opcw.org

@OPCW
@OPCW_ST

ORGANISATION FOR THE
PROHIBITION OF CHEMICAL WEAPONS

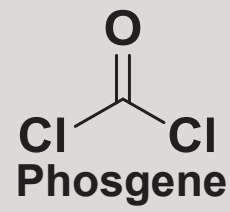
Working Together For a World Free of Chemical Weapons

Choking Agents and their Countermeasures

Cl—Cl

Chlorine

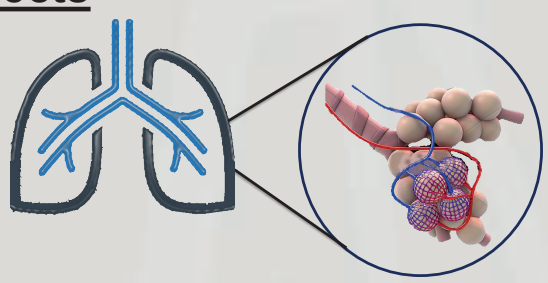
Chlorine is a yellow-green gas with a strong, bleach like odour. Soldiers describe its smell as a distinct mix of pepper and pineapple. Its density (3.21 kg/m^3) is about three times that of air.



Phosgene

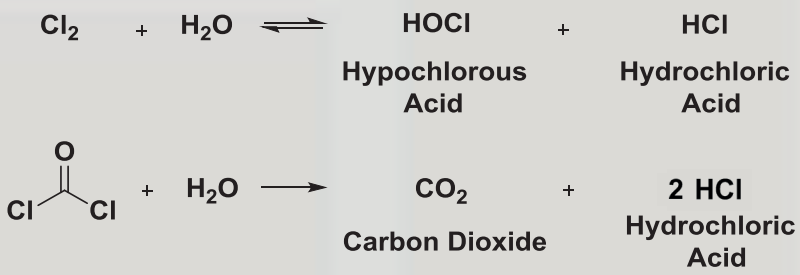
Phosgene is a colourless gas with a musty odour. Its density (4.25 kg/m^3) is about four times that of air.

Effects



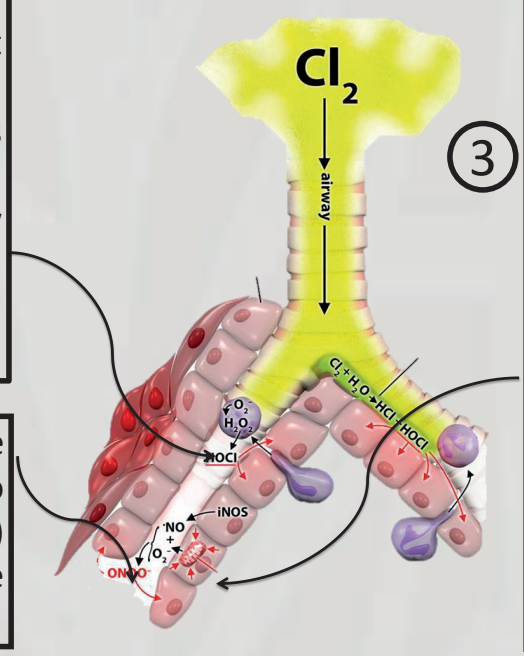
Choking agents react instantly with biological fluids, skin and eyes

- Chest Discomfort
- Shortness of breath
- Irritation of nose and throat
- Lachrymation



1. Both Cl_2 and HOCl react with airway lining constituent molecules. Reactive oxygen species (ROS) such as superoxide (O_2^-), hydrogen peroxide (H_2O_2) and hydroxy radicals (·OH) also form, and cause irreversible biochemical changes.

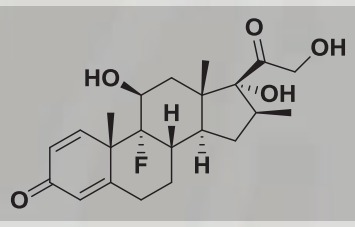
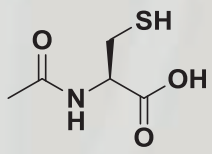
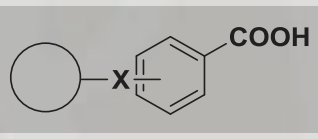
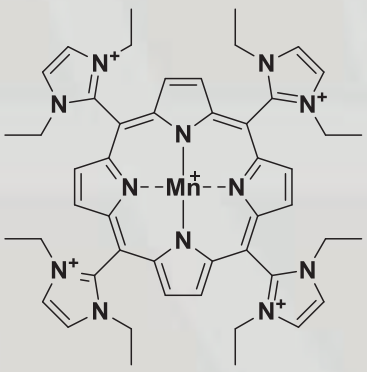
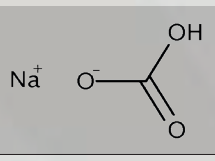
2. Induction of nitric oxide synthase (iNOS) can lead to formation of nitric oxide (NO) and, secondarily, peroxynitrite ($ONOO^-$).



3. These reactive species damage DNA repair enzymes; activate some inflammatory cascades; and induce vascular dysfunction, oxidative stress, mitochondrial damage, and arterial plaque formation.

Bronchospasm, increased mucous production causes damage of alveoli-capillary membranes, in addition to a life-threatening build-up of fluid on the lungs (pulmonary edema).

Phosgene rapidly hydrolyses in water to form carbon dioxide and hydrochloric acid which produces ocular, naso-pharyngeal, and central airway irritation. The carbonyl group (C=O) of phosgene can undergo acylation reactions with amino (-NH_2), hydroxyl (-OH), and sulfhydryl (-SH) groups. These reactions account for the major pathophysiological effects of phosgene (severe dyspnoea and clinically evident pulmonary edema).

Countermeasures including supportive measures	Structure	Indication
Steroids (Inhaled or intravenous) e.g. Betamethasone (illustrated on the right)		Decrease respiratory complications by inhibiting inflammatory responses.
N-Acetyl cysteine (NAC)		Prevents cells from oxidative damage (anti-oxidant)
Non Steroidal Anti Inflammatory Drugs (NSAIDs)		Reduce pulmonary oedema
AEOL 10150 Newly available countermeasure *Curr Opin Investig Drugs. 2006 Jan;7(1):70-80*		This countermeasure has multiple mechanisms of action that include: anti-oxidant, anti-inflammatory and anti-angiogenic activity; and the catalytic consumption of reactive oxygen and nitrogen species (free radicals)
Nebulized Sodium Bicarbonate (is not generally recommended but there are reports of its use). *Inhal Toxicol. 2006 Oct;18(11):895-900*		Neutralization of the choking agent in the affected area.

Riot Control Agents

Fauzia Nurul Izzati, Jonathan E. Forman and Christopher M. Timperley

OPCW

What is the definition of a Riot Control Agent (RCA)?

From paragraph 7, Article II of the Chemical Weapons Convention:

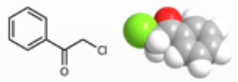
"Any chemical not listed in a Schedule, which can produce rapidly in humans sensory irritation or disabling physical effects which disappear within a short time following termination of exposure."

How do Riot Control Agents work?

RCAs produce irritation through binding to TRP (Transient Receptor Potential) receptors. This activates some of the same biochemical pathways that are triggered by eating horseradish or hot peppers.

What are Riot Control Agents?

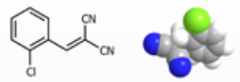
Chemicals that meet the criteria of an RCA include the following:



2-Chloroacetophenone (CN)

Synonyms:
Mace, CAP, KhAf CNB (10% CN, 45% benzene, 40% carbon tetrachloride), CNC (30% CN, 70% chloroform), and CNS (23% CN, 38.4% chloropicrin, 38.4% chloroform).

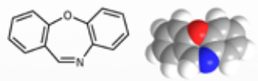
Physical states:
White solid with odour of apple blossom
Melting Point 54-56 °C; Boiling Point 245 °C



2-Chlorobenzylidenemalononitrile (CS)

Synonyms:
2-Chlorbenzalmalononitrile, *o*-chlorobenzylidene malononitrile, K62 CS (pure), CS1 (95% CS, 5% silica aerogel), CS2 (CS and silica aerogel), CSX (1 g CS, 99 g tri-n-octyl phosphite). CS dissolved in methyl ethyl ketone is used in spray devices.

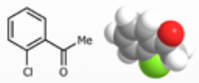
Physical states:
White solid with pungent peppery odour
Melting Point 93-95 °C;
Boiling Point 310-315 °C dec



Dibenzo[*b*,*f*][1,4]oxazepine (CR)

Synonym:
CR

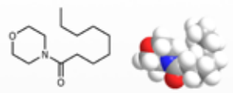
Physical states:
Yellow stable powder
Melting Point 72 °C; Boiling Point 335 °C



2'-Chloroacetophenone

Synonym:
o-chloroacetophenone

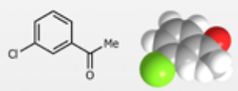
Physical states:
Colourless liquid
Boiling Point 229 °C



4-Nonanoylmorpholine

Synonyms:
MPA, MPK, pelargonic acid morpholide

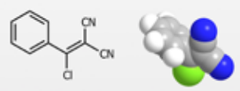
Physical states:
Liquid
Boiling Point 310 °C



3'-Chloroacetophenone

Synonym:
m-chloroacetophenone

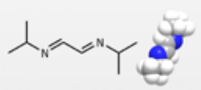
Physical states:
Colourless liquid
Boiling Point 228°C



***α*-Chlorobenzylidenemalononitrile**

Synonym:
none

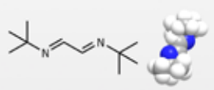
Physical states:
White solid
Melting Point 68-70 °C;
Boiling Point 126 °C/0.1 mmHg



***N*,*N*'-Bis(isopropyl)ethylenediimine**

Synonym:
Diimine

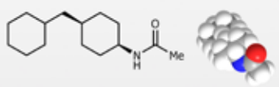
Physical states:
Volatile tan-coloured solid
Melting Point 48-50 °C



***N*,*N*'-Bis(*tert*-butyl)ethylenediimine**

Synonym:
none

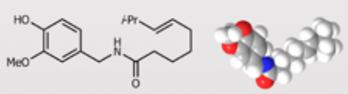
Physical states:
White solid
Melting Point 39-43 °C



***Cis*-4-Acetylaminodicyclohexylmethane**

Synonym:
none

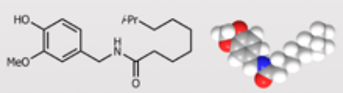
Physical states:
White solid
Melting Point 112 °C



8-Methyl-*N*-vanillyl-*trans*-6-nonenamide

Synonyms:
C, capsaicin, Moitin, Zacin

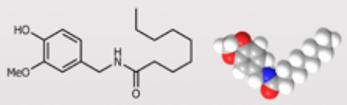
Physical states:
White solid
Melting Point 62-65 °C; Boiling Point 210-220 °C at 0.01 mmHg



8-Methyl-*N*-vanillylnonanamide

Synonyms:
Dihydrocapsaicin, DHC

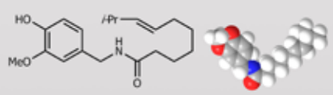
Physical states:
White solid
Physical data unavailable



***N*-Vanillylnonanamide**

Synonyms:
N-(4-hydroxy-3-methoxy-benzyl)nonanamide, nonivamide, pseudo-capsaicin, pelargonic acid vanillylamide, PAVA

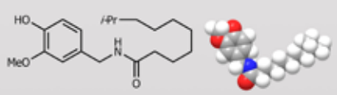
Physical states:
White solid with stinging odour
Melting Point 57 °C



***N*-Vanillyl-9-methyldec-7-(*E*)-enamide**

Synonym:
homocapsaicin

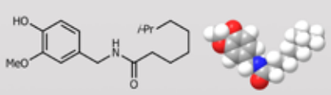
Physical states:
Lipophilic colourless odourless crystalline or waxy solid



***N*-Vanillyl-9-methyldecanamide**

Synonym:
homodihydrocapsaicin

Physical states:
Lipophilic colourless odourless crystalline or waxy solid



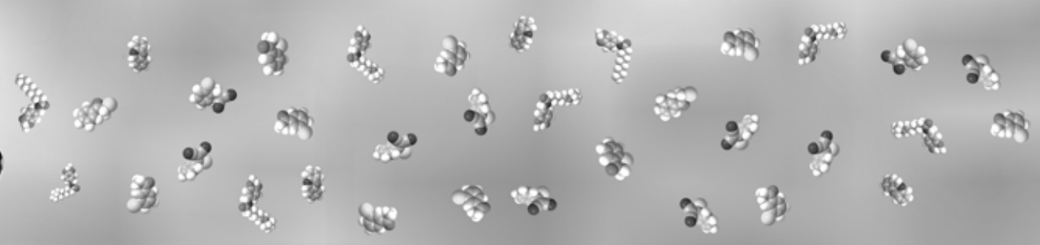
***N*-Vanillyl-7-methyloctanamide**

Synonym:
nordihydrocapsaicin

Physical states:
Lipophilic colourless odourless crystalline or waxy solid

Oleoresin capsicum (OC)

This is a mixture containing ≥ 8% capsaicins: capsaicin, dihydrocapsaicin, and nordihydrocapsaicin dissolved in an organic solvent.



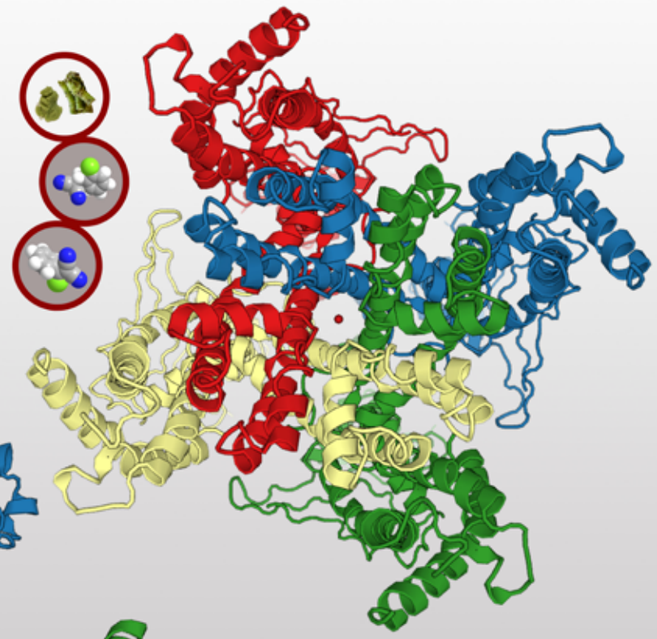
What are TRP Receptors?

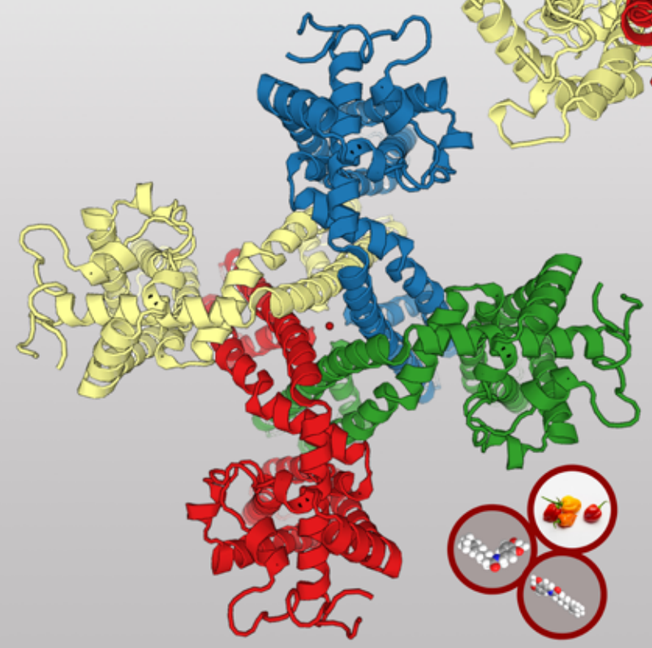
TRP receptors are a family of ion channel receptors mainly located on cell membranes of multicellular organisms. TRP receptors are classified into seven subfamilies: TRPC (canonical or classical), TRPV (vanilloid), TRPM (melastatin), TRPA (ANKTM1 homologues), TRPP (polycystin), TRPML (mucolipin), and TRPN (NOMP-C homologues).

TRP receptor functions are diverse; the receptors serve as versatile sensors that allow individual cells and entire organisms to detect changes in their environment. This includes experiencing changes in temperature, touch, taste and other stimuli (including pain).

TRPA1

CS and isothiocyanate compounds bind to the TRPA1 receptor. Allyl isothiocyanate is the main pungent ingredient in wasabi, horseradish, and mustard oil - this chemical also binds to the TRPA1 receptor.





TRPV1

Capsaicin, homocapsaicin, and other related compounds bind to the TRPV1 receptor. These chemicals are naturally found in hot chili peppers.

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together For a World Free of Chemical Weapons

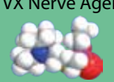
Physicochemical Properties & Relative Toxicity of Chemical Warfare Agents

Lethal Concentration, LCt_{50} in mg•min/m^3
Decreasing acute toxicity

Median Lethal Dose, LD_{50} in mg/kg (Skin Exposure)
Decreasing acute toxicity

Nerve Agents[1]

VX Nerve Agent

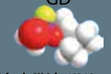


Molecular Weight: 267.38 g•mol^{-1}
State at 20°C: Colourless to to amber liquid
Odour: None
Density: 1.0083 g cm^{-3} at 20°C
Boiling Point: 298°C
Vapour Pressure: 0.0007 mm Hg at 20°C
Volatility: 10.5 mg/m^3 at 25°C
LD_{50}: **0.071** mg/kg
LCt_{50}: **15** mg•min/m^3

Cyclosarin GF

Molecular Weight: 180.2 g•mol^{-1}
State at 20°C: Colourless Liquid
Odour: Sweet; musty; peaches; shellac
Density: 1.133 g cm^{-3} at 20°C
Boiling Point: 239°C
Vapour Pressure: 0.044 mm Hg at 20°C
Volatility: 438 mg/m^3 at 20°C
LD_{50}: **0.42** mg/kg
LCt_{50}: **35** mg•min/m^3

Soman GD

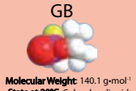


Molecular Weight: 182.18 g•mol^{-1}
State at 20°C: Colourless to brown liquid
Odour: Fruity; camphor when impure
Density: 1.022 g cm^{-3} at 25°C
Boiling Point: 198°C
Vapour Pressure: 0.4 mm Hg at 20°C
Volatility: 3900 mg/m^3 at 25°C
LD_{50}: **0.71** mg/kg
LCt_{50}: **35** mg•min/m^3

Tabun GA

Molecular Weight: 162.3 g•mol^{-1}
State at 20°C: Colourless to brown liquid
Odour: Faintly Fruity: none when pure
Density: 1.073 g cm^{-3} at 25°C
Boiling Point: 240°C
Vapour Pressure: 0.037 mm Hg at 20°C
Volatility: 610 mg/m^3 at 25°C
LD_{50}: **21.42** mg/kg
LCt_{50}: **70** mg•min/m^3

Sarin GB



Molecular Weight: 140.1 g•mol^{-1}
State at 20°C: Colourless liquid
Odour: Almost none when pure
Density: 4.86 cm^{-3} at 25°C
Boiling Point: 158°C
Vapour Pressure: 2.10 mm Hg at 20°C
Volatility: 22000 mg/m^3 at 25°C
LD_{50}: **24.28** mg/kg
LCt_{50}: **35** mg•min/m^3

Blister Agents[2]

Nitrogen Mustard HN2

Molecular Weight: 156.07 g•mol^{-1}
State at 20°C: Dark Liquid
Odour: Soapy (Low concentration), Fruity (High concentration)
Density: 1.15 g cm^{-3} at 20°C
Boiling Point: 75°C at 15 mmHg
Vapour Pressure: 0.29 mm Hg at 20°C
Volatility: 3580 mg/m^3 at 25°C
LD_{50}: **10** mg/kg
LCt_{50}: **3000** mg•min/m^3

Nitrogen Mustard HN3

Molecular Weight: 204.54 g•mol^{-1}
State at 20°C: Dark Liquid
Odour: None
Density: 1.24 g cm^{-3} at 20°C
Boiling Point: 256°C
Vapour Pressure: 0.0109 mm Hg at 25°C
Volatility: 121mg/m^3 at 25°C
LD_{50}: **10** mg/kg
LCt_{50}: **1500** mg•min/m^3

Nitrogen Mustard HN1

Molecular Weight: 170.08 g•mol^{-1}
State at 20°C: Dark Liquid
Odour: Fishy or Musty
Density: 1.09 g cm^{-3} at 20°C
Boiling Point: 194°C
Vapour Pressure: 0.24 mm Hg at 25°C
Volatility: 1520 mg/m^3 at 20°C
LD_{50}: **20** mg/kg
LCt_{50}: **1500** mg•min/m^3

Lewisite L

Molecular Weight: 207.35 g•mol^{-1}
State at 20°C: Colourless to brownish liquid
Odour: Varies; may resemble geraniums
Density: 1.89 g cm^{-3} at 20°C
Boiling Point: 190°C
Vapour Pressure: 0.394 mm Hg at 20°C
Volatility: 4480 mg/m^3 at 20°C
LD_{50}: **30** mg/kg
LCt_{50}: **1400** mg•min/m^3

Sulfur Mustard HD

Molecular Weight: 159.08 g•mol^{-1}
State at 20°C: Colourless to pale yellow liquid
Odour: Garlic or horseradish
Density: 1.27 g cm^{-3} at 20°C
Boiling Point: 217°C
Vapour Pressure: 0.72 mm Hg at 20°C
Volatility: 610 mg/m^3 at 20°C
LD_{50}: **100** mg/kg
LCt_{50}: **900** mg•min/m^3

Blood Agent[3]

Hydrogen Cyanide AC

Molecular Weight: 27.02 g•mol^{-1}
State at 20°C: Colourless gas or liquid
Odour: Bitter almonds
Density: 0.687 g cm^{-3} at 20°C
Boiling Point: 25.7°C
Vapour Pressure: 742 mm Hg at 25°C
Volatility: 1080000 mg/m^3 at 25°C
LD_{50}: **100** mg/kg
LCt_{50}: **5000** mg•min/m^3

Choking Agents[4]

Diphosgene DP

Molecular Weight: 197.85 g•mol^{-1}
State at 20°C: Colourless gas
Odour: New-mown hay; green corn
Density: 1.65 g cm^{-3} at 20°C
Boiling Point: 127°C
Vapour Pressure: 4.2 mm Hg at 20°C
Volatility: 45000 mg/m^3 at 20°C
LD_{50}: **800** mg/kg
LCt_{50}: **3200** mg•min/m^3

Phosgene CG

Molecular Weight: 113.94 g•mol^{-1}
State at 20°C: Colourless solid or liquid
Odour: Sharp, Penetrating
Density: 4.25 g cm^{-3} at 25°C
Boiling Point: 53-54°C at 28 mmHg
Vapour Pressure: 11.2 mm Hg at 25°C
Volatility: 1800 mg/m^3 at 20°C
LD_{50}: **800** mg/kg
LCt_{50}: **3000** mg•min/m^3

Chlorine CL

Molecular Weight: 70.90 g•mol^{-1}
State at 20°C: Pale yellow-green gas
Odour: pungent suffocating odor
Density: 3.2 g cm^{-3} at 25°C
Boiling Point: -34.04 °C
Vapour Pressure: 4788 mm Hg at 20°C
LCt_{50}: **6000** mg•min/m^3

3-Quinuclidinyl benzilate[6] BZ

Molecular Weight: 337.41 g•mol^{-1}
State at 20°C: White crystalline solid
Odour: Odourless incapacitating agent
Density: 1.3 g cm^{-3} at 25°C
Boiling Point: 320 °C
Vapour Pressure: 0.03 mm Hg at 70°C
Volatility: 0.5 mg/m^3 at 70°C
LCt_{50}: **200,000** mg•min/m^3

Perfluoroisobutene[5]

Molecular Weight: 200.03 g•mol^{-1}
State at 20°C: Colourless gas
Odour: Pungent metallic smell
Density: 1.592 g cm^{-3} at 0°C
Boiling Point: 7 °C
Vapour Pressure: 2.6x10^3 mm Hg at 25°C
LCt_{50}: **870** mg•min/m^3

Skin exposure LD_{50} is not available or not applicable

References

1. *US army medical research institute pf chemical defense (USAMRICS). Medical management of chemical casualties Handbook, chemical casualty care division. USAMRICD, Aber deen Proving Ground, MD21010-25400, USA; 2007.*
   National Research Council Committee on Toxicology Review of Acute Human Toxicity estimates of Selected Chemical Warfare Agents, 1997.

2. *Strategies to Protect the Health of Deployed U.S. Forces: Detecting, Characterizing, and Documenting Exposures; Division of Military Science and Technology and Board on Environ mental Studies and Toxicology, National Research Council, Commission on Life Sciences, Commission on Engineering and Technical Systems; National Academies Press, Mar 21, 2000.*
   Manoj Sharma, R. Vijayaraghavan, Uma Pathak, and K. Ganesan; Prophylactic Efficacy of Amifostine, DRDE-07, and their Analogues against Percutaneously Administered Nitrogen Mustards and Sulphur Mustard; Defence Science Journal, Vol. 59, No. 5, September 2009, pp. 512-516.

3. *Risk Assessment for Water Infrastructure Safety and Security; Anna Doro-on; CRC Press, Aug 17, 2011.*

4. *Toxnet, Toxicology data network, Toxicology and Environmental Health Information Program (TEHIP) in the Division of Specialized Information Services (SIS) of the National Library of Medicine (NLM). USA.*

5. *Herman P. M. Helden vana, Dory Meent van dea, John P. Oostdijka, Marloes J. A. Joosena, Joep H. M. Esch vana, Arnold H. Hammera & Robert V. Diemelb; Protection of Rats Against Perfluoroisobutene (PFIB)-Induced Pulmonary Edema by Curosurf and N-Acetylcysteine; Inhalation Toxicology: International Forum for Respiratory Research; Volume 16, Issue 8, 2004.*

6. *Committee on Acute Exposure Guideline Levels; Committee on Toxicology; Board on Environmental Studies and Toxicology; Division on Earth and Life Studies; National Research Council; Acute Exposure Guideline Levels for Selected Airborne Chemicals: Volume 14; Washington (DC): National Academies Press (US); 2013 Apr 26.*

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

Biological Toxins and their Relative Toxicity

What are Toxins?

Toxins are toxic substances produced by animals, plants or microbes. They are classified by their source and mechanism of action (neurotoxic or cytotoxic). Neurotoxins affect neurons and are further classified based on the mechanism by which they create their toxic effect; the subclasses are presynaptic neurotoxins, postsynaptic neurotoxins, ion channel-binding toxins and ionophores. Cytotoxins affect all cell types in the body, causing cellular destruction or interfering with metabolic processes such as cell respiration and protein synthesis.

Examples of toxins from plants

Ricin
LD_{50}: 3000 ng/kg
Molecular weight: 64,000 g/mol
Source: Castor Bean
Ricinus communis

Abrin
LD_{50}: 40 ng/kg
Molecular weight: 65,000 g/mol
Source: Rosary Pea

Aconitine
LD_{50}: 100000 ng/kg
Molecular weight: 1647 g/mol
Source: Monkshood
Aconitum

Examples of toxins from fungus

Aflatoxin B_1
LD_{50}: 2000000 ng/kg
Molecular weight: 312.8 g/mol
Source: Aspergillus flavus

T-2 Toxin
LD_{50}: 1210000 ng/kg
Molecular weight: 466 g/mol
Source: Fungal Mycotoxin
Fusarium

Examples of toxins from insects & animals

Taipoxin
LD_{50}: 5000 ng/kg
Molecular weight: 46,000 g/mol
Source: Elapid Snake
Oxyuranus scutellatus

Batrachotoxin
LD_{50}: 2000 ng/kg
Molecular weight: 539 g/mol
Source: Poison Dart Frog

Conotoxin
LD_{50}: 5000 ng/kg
Molecular weight: 1,500 g/mol
Source: Cone Snail
Conus pennaceus

Tetrodotoxin
LD_{50}: 8000 ng/kg
Molecular weight: 319 g/mol
Source: Puffer Fish
Tetraodontidae

αTityustoxin
LD_{50}: 9000 ng/kg
Molecular weight: 8,000 g/mol
Source: Scorpion
Tityinae

Examples of toxins from cyanobacteria

Maitotoxin
LD_{50}: 100 ng/kg
Molecular weight: 3,400 g/mol
Source: Marine Dinoflagellate
Gambierdiscus toxicus

Palytoxin
LD_{50}: 150 ng/kg
Molecular weight: 2,700 g/mol
Source: Marine Soft Coral
Palythoa toxica

Ciguatoxin
LD_{50}: 400 ng/kg
Molecular weight: 1,000 g/mol
Source: Fish/Marine Dinoflagellate
Gymnothorax javanicus

Saxitoxin
LD_{50}: 10000 ng/kg
Molecular weight: 299 g/mol
Source: Marine Dinoflagellate
Ceratium furca

Microcystin
LD_{50}: 50000 ng/kg
Molecular weight: 994 g/mol
Source: Blue-Green Algae
Microcystis aeruginosa

Anatoxin-A(s)
LD_{50}: 50000 ng/kg
Molecular weight: 252 g/mol
Source: Blue-Green Algae
Anabaena flos-aquae

Examples of other bacterial toxins

Botulinum Toxin
LD_{50}: 1 ng/kg
Molecular weight: 150,000 g/mol
Source: *Clostridium botulinum*

Tetanus Toxins
LD_{50}: 2 ng/kg
Molecular weight: 150,000 g/mol
Source: Bacterium
Clostridium tetani

Shiga Toxin
LD_{50}: 2 ng/kg
Molecular weight: 55,000 g/mol
Source: *Shigella dysenteriae*

Diphtheria Toxin
LD_{50}: 100 ng/kg
Molecular weight: 62,000 g/mol
Source: *Corynebacterium diphtheriae*

C. perfringens toxins
LD_{50}: 310 ng/kg
Molecular weight: 40,000 g/mol
Source: *Clostridium perfringens*

SEB (Rhesus/Aerosol)
LD_{50}: 27000 ng/kg
Molecular weight: 28,494 g/mol
Source: *Staphylococcus aureus*

VX Agent
LD_{50}: 15000 ng/kg
Molecular weight: 267.36 g/mol

Soman (GD)
LD_{50}: 64000 ng/kg
Molecular weight: 182.18 g/mol

Sarin (GB)
LD_{50}: 100000 ng/kg
Molecular weight: 140.09 g/mol

Examples of Nerve Agents (For Reference)

Most Toxic ← Comparative Toxicity (Median Lethal Dose, LD_{50} in ng/kg) of Selected Toxins And Chemical Agents In Laboratory Mice → Least Toxic

Decreasing toxicity

References
1. David R. Franz, DVM, Defense Against Toxin Weapons, Veterinary Corps, United States Army (1997).
2. Chastain, James R., A heuristic methodology for locating monitoring stations to detect contamination events in portable water distribution systems (2004).
3. Maria Taciana Holanda Cavalcanti, Tatiana Porto, Ana Lúcia Figueiredo Porto, Igor Viana Brandi, José Luiz de Lima Filho, Adalberto Pessoa Junior, Large scale purification of Clostridium perfringens toxins: a review, Brazilian Journal of Pharmaceutical Sciences (2004).

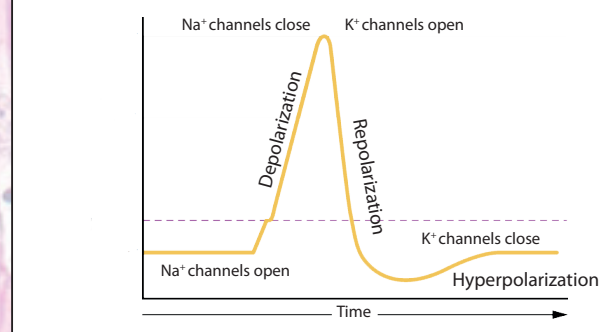
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

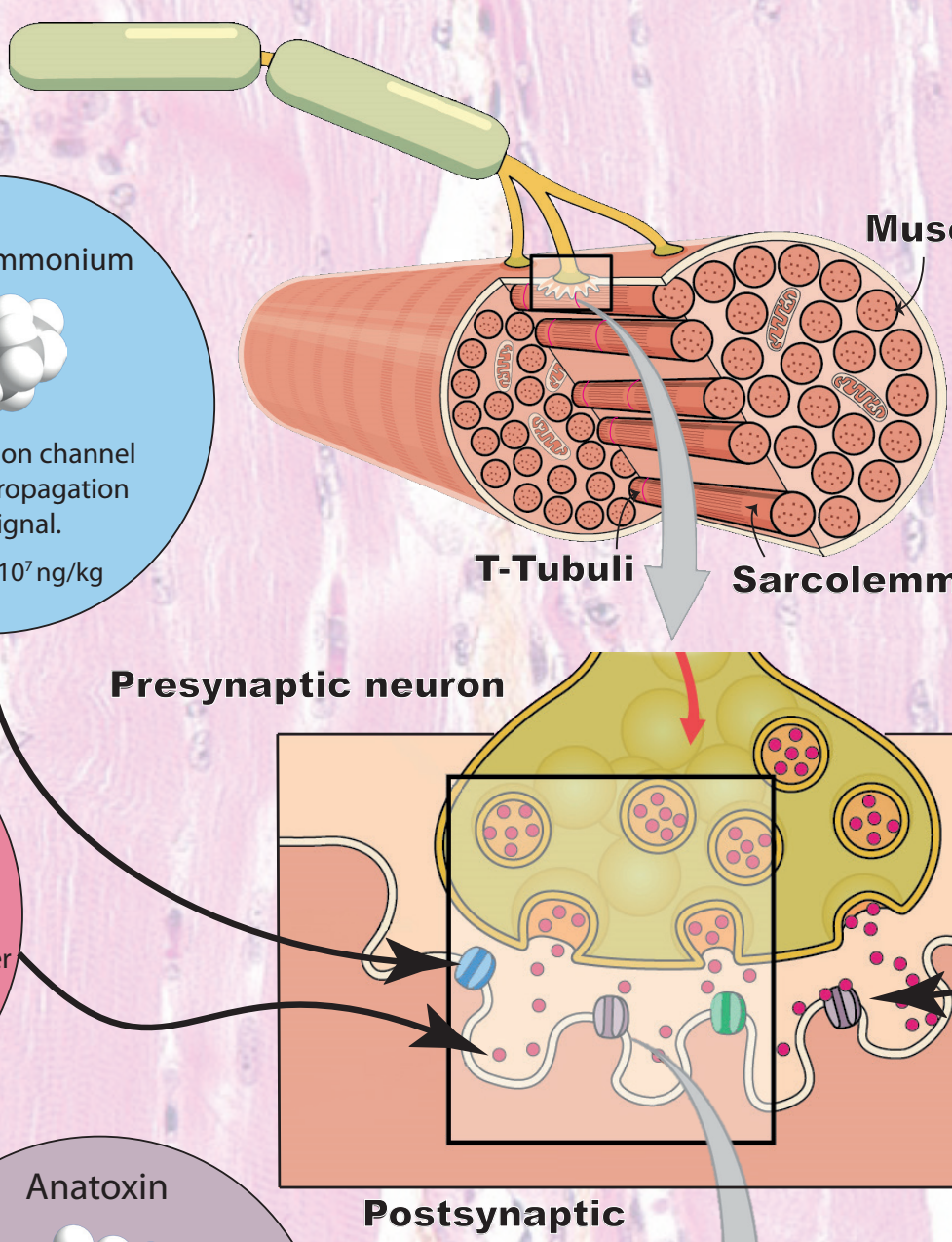
Toxins and the Neuromuscular System

Edoxie E. Allier-Gagneur, Wesam S. Alwan and Jonathan E. Forman

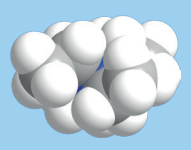
A **synapse**, the gap between two nerve cells (neurons), allows chemical signals to be relayed from one neuron to another. The junction between a motor neuron and a muscle is referred to as a **neuromuscular** synapse. Neurons rely on the movement of ions (charged species especially K^+, Ca^{2+}, Cl^-, Na^+) inducing a current, the so-called **action potential** responsible for electrical signalling. Signals are initiated when a **neurotransmitter** chemical (acetylcholine) binds to a specific **receptor** (acetylcholine receptor), triggering the opening of an **ion channel**. Information is transmitted along the neuron, employing a **signaling system** similar to Morse code.



Action Potential Mechanism



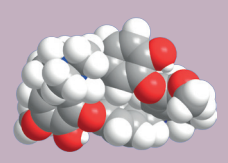
Tetraethylammonium



Blocks the K^+ ion channel preventing propagation of the signal.

LD_{50}= 6.5 x 10^7 ng/kg

Curare



Inhibits the acetylcholine receptor, resulting in paralysis.

LD_{50}= 5 x 10^5 ng/kg

Bungarotoxin β

Induces excessive neurotransmitter release, resulting in excessive muscle contraction.

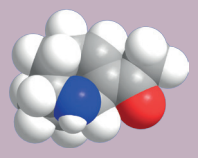
LD_{50}= 8 x 10^4 ng/kg

Botulinum Toxin

Prevents the fusion of vesicles to the pre-synaptic membrane. This prevents acetylcholine from entering the synapse, inducing paralysis.

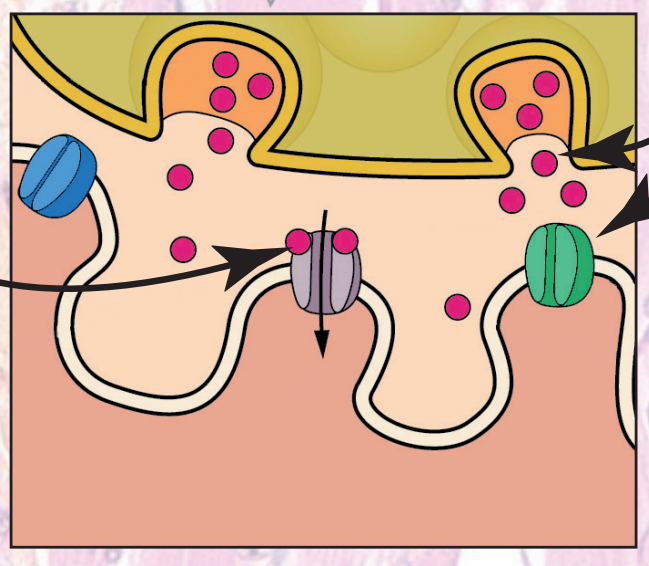
LD_{50}=1 ng/kg

Anatoxin



Binds to neurotransmitter receptors, inducing excessive muscle contraction.

LD_{50}= 5 x 10^4 ng/kg



Saxitoxin

Blocks voltage-gated Na^+ channels, preventing depolarization.This results in paralysis.

LD_{50}= 1 x 10^4 ng/kg

- Vesicles
- Neurotransmitter Receptors
- Acetylcholine (Neurotransmitter)
- Potassium (K^+) Channels
- Sodium (Na^+) Channels
- Point of initiation of toxin effect

Once a signal is released into the sarcolemma (a sheath surrounding the muscle), an action potential travels down the T-Tubuli (structure found between muscle fibers). This triggers a release of calcium ions into the sarcoplastic reticulum which results in muscle contraction. For more information, scan the QR code.

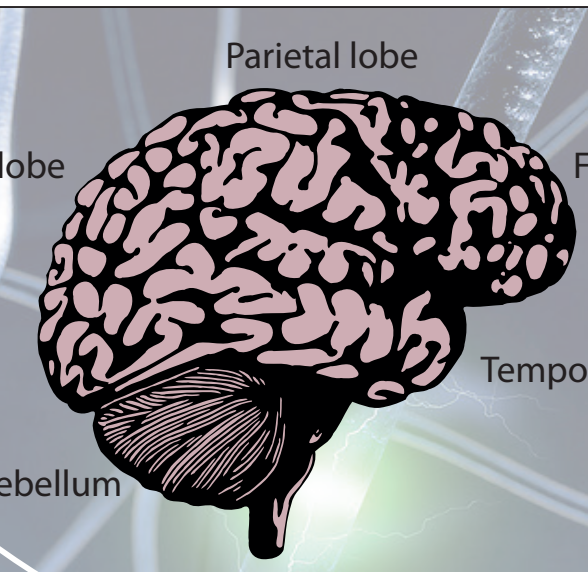
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

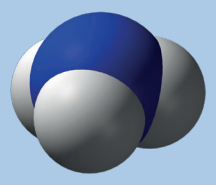
Neurochemistry of Toxins

Edoxie E. Allier-Gagneur, Wesam S. Alwan and Jonathan E. Forman

The Central Nervous System (CNS) is composed of the **brain** and **spinal cord**; it coordinates thoughts, memory and other complex processes, such as the body's reaction to stimuli. A **synapse** is the gap between two nerve cells (neurons) through which chemical signalling molecules (neurotransmitters) pass to ensure communication between nerve endings. There are several types of neurotransmitters; excitatory such as glutamate (in the brain) and acetylcholine (in the muscle and in the brain) or inhibitory, such as gamma-aminobutyric acid (GABA; present in the brain). There are three types of neurons: motor-, sensory- and inter-neurons. **Sensory neurons** are present in eyes, nose, skin and ears; they relay information about the environment to the CNS. **Motor neurons** send information to the muscles and glands; controlling movement and reaction. **Interneurons** are cells that connect other neurons.



Ammonia



Induces swelling of astrocytes (cells that protect neurons) which slows brain function.

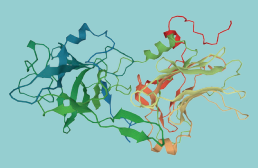
LD_{50}= 3.5 x 10^7 ng/kg

Ethanol

Reduces the stability of membranes, which can prevent neurotransmitters release and binding, disabling communication between neurons.

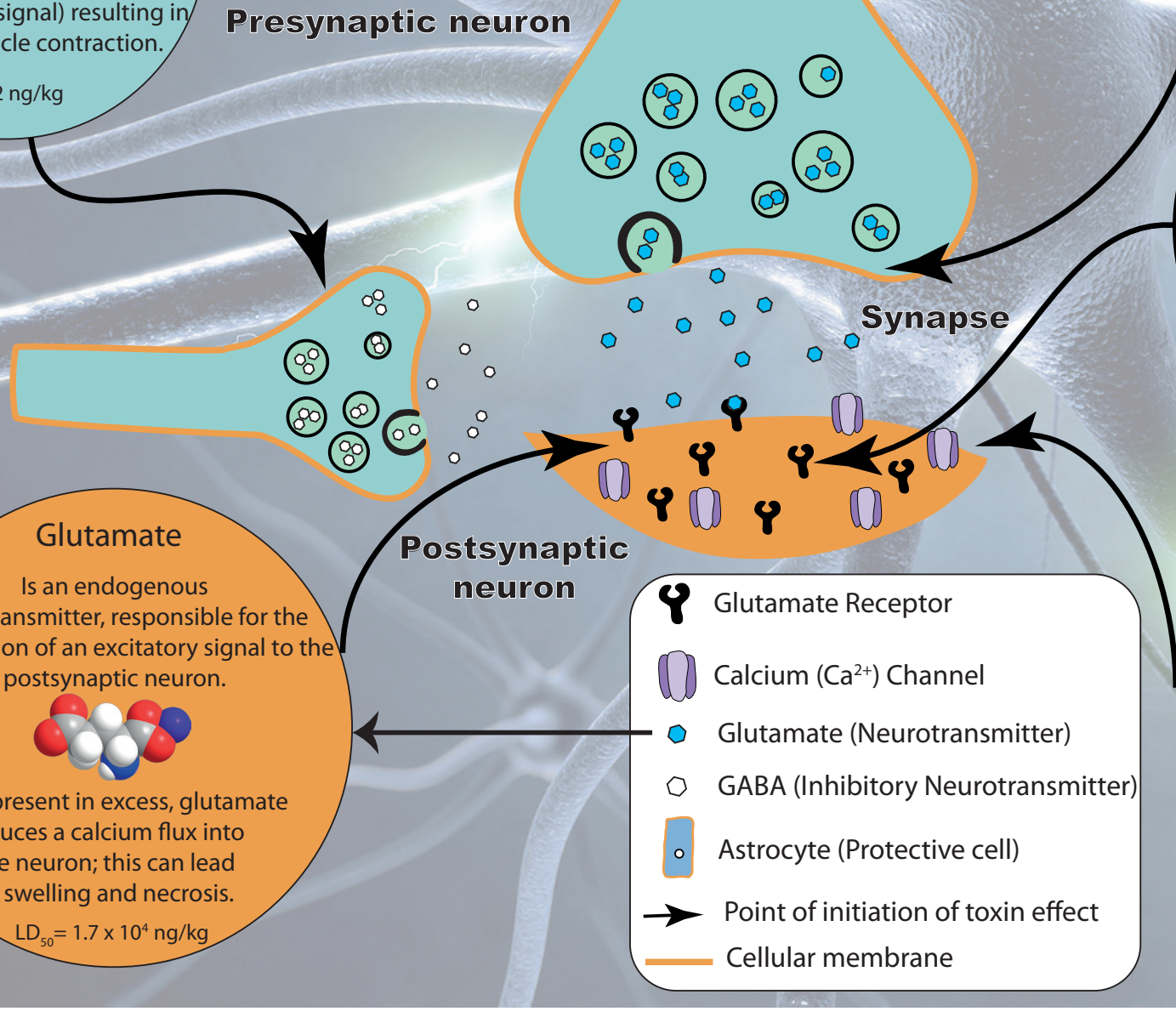
LD_{50}= 8.3 x 10^9 ng/kg

Tetanus Toxin

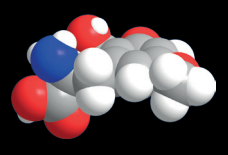


Disables inhibitory neurons (those sending an "off" signal) resulting in excessive muscle contraction.

LD_{50}= 2 ng/kg



Caramboxin



Overstimulates glutamate receptors, effectively producing a state similar to that of an excessive level of glutamate.

Glutamate

Is an endogenous neurotransmitter, responsible for the transmission of an excitatory signal to the postsynaptic neuron.

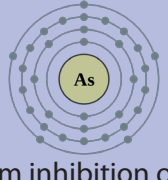
When present in excess, glutamate induces a calcium flux into the neuron; this can lead to swelling and necrosis.

LD_{50}= 1.7 x 10^4 ng/kg

- Glutamate Receptor
- Calcium (Ca^{2+}) Channel
- Glutamate (Neurotransmitter)
- GABA (Inhibitory Neurotransmitter)
- Astrocyte (Protective cell)
- Point of initiation of toxin effect
- Cellular membrane

Arsenic

in the form of soluble As^{3+}



Long term inhibition of neuron growth; short term increase of intra-cellular Ca^{2+} levels; this in turn can induce cell death.

LD_{50}= 2 x 10^7 ng/kg

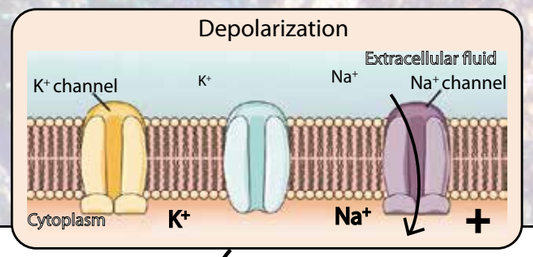
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

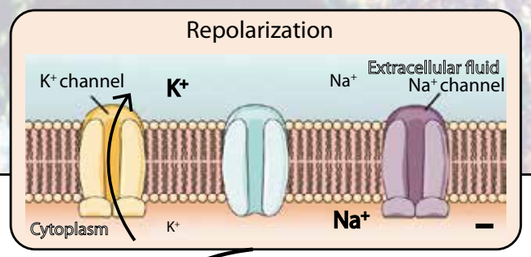
Working Together for a World Free of Chemical Weapons

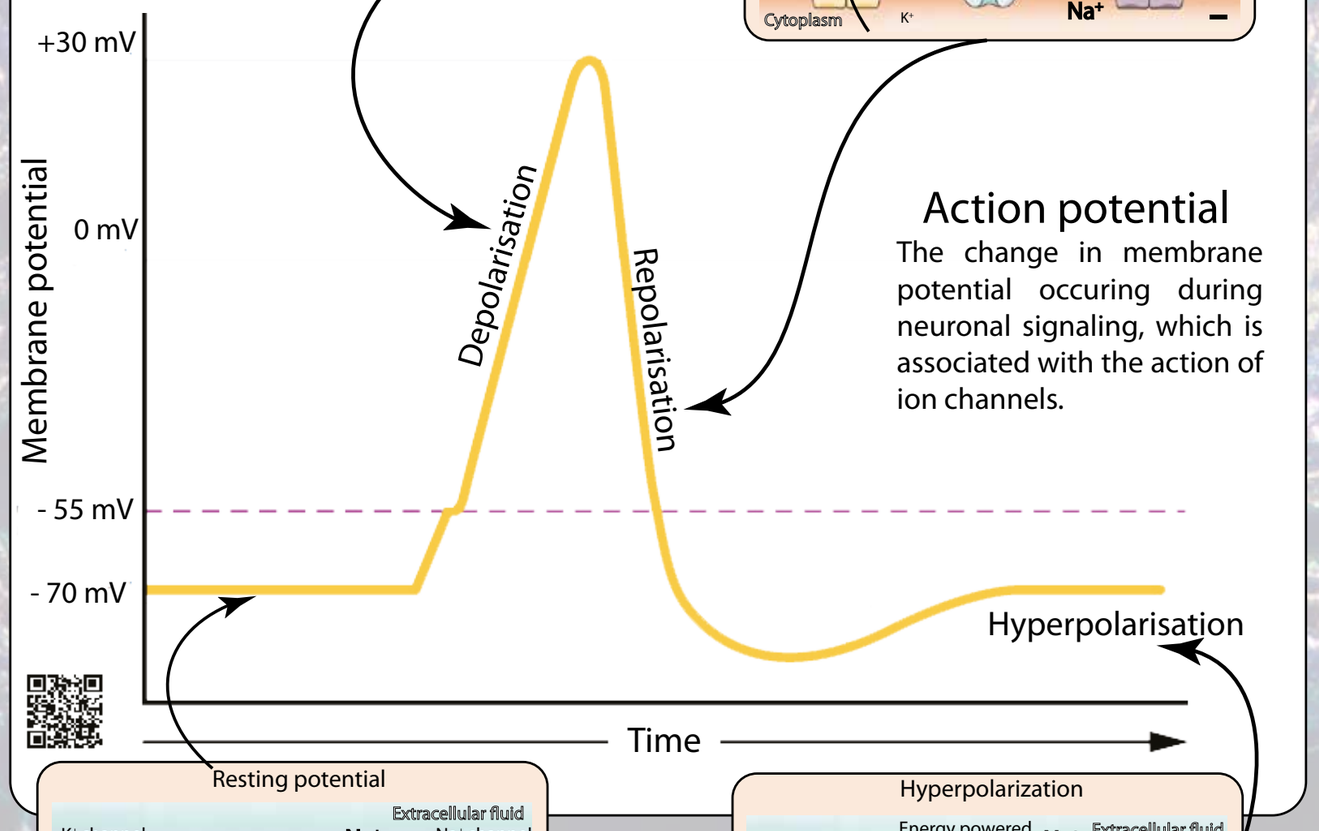
Ion channels of the Nervous System

Edoxie E. Allier-Gagneur and Jonathan E. Forman

Nerve agents and neurotoxins (such as botulinum toxin and saxitoxin) affect life processes by disrupting chemical signalling between nerve cells (neurons). Neurological signalling processes involve ion channels. Those are proteins that enable the transport of ions (specifically K^+, Na^+, Ca^{2+}, Cl^-) across cellular membranes. The direction of ion flow is driven by concentration gradients, with the ions flowing from higher to lower concentration.

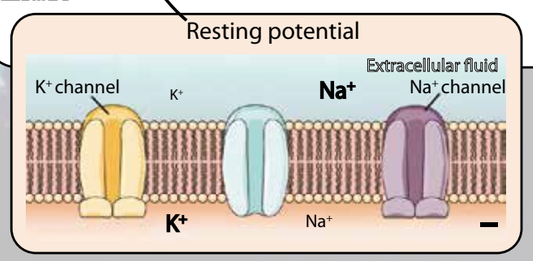


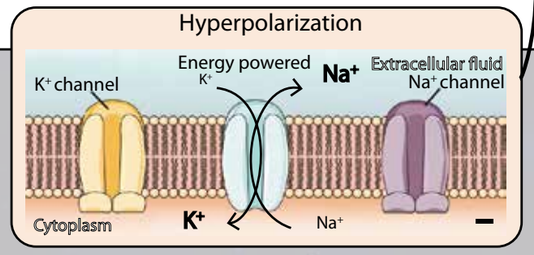




Action potential

The change in membrane potential occuring during neuronal signaling, which is associated with the action of ion channels.





Type of ion channel	Mechanism
Ligand gated	Activated by the binding of a ligand. In the nervous system, neurotransmitters such as acetylcholine or glutamate often serve as binding ligands.
Voltage-gated	Activated when the membrane potential exceeds or falls behind a triggering threshold (see action potential chart).
Inwardly-rectifying/ tandem pore domain	Allows K^+ ions to flow into the cell while at negative membrane potential. This allows the cell to maintain the resting potential state.

Ion channels		Ion Flow	Effect when Blocked	Effect when Overstimulated
Sodium Na^+	Voltage-gated Ligand-gated	Inward (depolarisation)	No signaling. Muscle: Paralysis Brain: Neurological shut-down	Constant excitation. Muscle: Contractions Brain: Neurological shut-down
Potassium K^+	Voltage-gated Ligand-gated	Outward (repolarisation)	No new signal sent. Muscle: Paralysis Brain: Neurological shut-down	No signaling. Muscle: Paralysis Brain: Neurological shut-down
Potassium K^+	Inwardly-rectifying/ tandem pore domain	Inward (resting potential/ hyperpolarisation)	Cell cannot achieve resting potential. Muscle: Convulsions Brain: Neurological shut-down	Processes that disrupt the action of these channels only result in blocking.
Calcium Ca^{2+}	Voltage-gated Ligand-gated	Inward (depolarisation)	No signaling. Muscle: Paralysis Brain: Neurological shut-down	Constant excitation. Muscle: Contractions Brain: Neurological shut-down
Chloride Cl^-	Voltage-gated Ligand-gated	Outward (depolarisation)	No signaling. Muscle: Paralysis Brain: Neurological shut-down	Constant excitation. Muscle: Contractions Brain: Neurological shut-down

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together For a World Free of Chemical Weapons

Gas Mask Development During WWI

First Use of Tear Gas, Battle of the Frontiers, France

August

1914

October

Tear Gas Goggles [1]

Large Scale Use Tear Gas of Battle of Bolimów, Poland

Exercises, Pereyaslav Regiment of the Russian Army

January

March

1915

April

First use of Chlorine Gas [3], Ieper, Belgium

Large scale Use of Chlorine Gas, Bolimów, Poland

May

Cotton Mouth Protector [2]

June

Gas Helmet [4]

July

Hypo Helmet

December

First Use of Phosgene Gas [5], Ieper Salient, Belgium

1916

Phenate Hexamine Helmet

January

April

Small Box Respirator

" Large Box Respirator also known as the Respiratory Tower "

June

1917

First use of Mustard Gas [8] Battle of Passchendaele Third Battle of Ieper, Belgium

July

February

German Gas Mask [6]

Horse and dog mask s were invented during WWI [7]

End of WWI [9]

November

1918

April

British Gas Casualties, Battle of the Lys, Ieper, Belgium

Top row, left to right: US Navy Mark I mask; US Navy Mark II mask; US CE mask; US RFK mask; US AT mask; U.S. KT mask; US model 1919 mask. Middle row, left to right: British Black Veil mask; British PH helmet; British BR mask; French M2 mask; French artillery mask; French ARS mask. Bottom row, left to right: German mask; Russian mask; Italian mask; British Motor Corps mask; US Rear Area mask; US Connell mask.

1. Tear gas goggles image via Gants militaria,
2. cotton mouth protector via Old Photos,
3. First use of chlorine gas via Wikipedia (US public domain),
4. Gas helmet via Wikipedia (Creative Commons),
5. First use of Phosgene Gas
6. German Gas Mask via Wikipedia,
7. Dog mask via flicker,
8. First use of Mustard Gas via Wikipedia (U.S. federal government),
9. End of World War I via Wikipedia (Australian public domain, Creative Commons).

The Scientific Advisory Board with the OPCW Director-General at their 25th Session (March 2017)

The OPCW Scientific Advisory Board (SAB)

> *"To enable the Director-General, 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, Paragraph 21(h)**

Nationalities of SAB members in 2017

The membership of the Scientific Advisory Board includes experts from 25 States Parties each serving up to two consecutive 3 year terms.

Map: Modified from Map No. 4170 Rev. 13, UNITED NATIONS.
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the Organization for the Prohibition of Chemical Weapons. The final boundary between the Republic of Sudan and the Republic of South Sudan has not yet been determined. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. A dispute exists between the Governments of Argentina and the United Kingdom of Great Britain and Northern Ireland concerning sovereignty over the Falkland Islands (Malvinas).

Topics considered in 2017 :

- Emerging technologies
- Nanotechnology
- Toxins
- Verification
- Medical countermeasures and treatment
- Chemical forensics and investigative technologies
- Trends in chemical production

Recent Reports:

Report of the Scientific Advisory Board

25th Session
(SAB-25/1, dated 31 March 2017)

24th Session
(SAB-24/1, dated 28 October 2016)

23rd Session
(SAB-23/1, dated 22 April 2016)

Response to the Director-General's Request to the Scientific Advisory Board to Provide Consideration on Which Riot Control Agents are Subject to Declaration Under the Chemical Weapons Convention
(SAB-25/WP .1, dated 27 March 2017)

Report of the Scientific Advisory Board's workshop on Chemical Warfare Agent Toxicity, Emergency Response and Medical Countermeasures
(SAB-24/WP .2, dated 14 October 2016)

Report of the Scientific Advisory Board's Workshop on Chemical Forensics
(SAB-24/WP.1, dated 14 July 2016)

Response to the Director-General's Request to the Scientific Advisory Board to Provide Further Advice on Chemical Weapons Sample Stability and Storage
(SAB-23/WP.2, dated 25 May 2016)

Response to the Director-General's Request to the Scientific Advisory Board to Provide Further Advice on Scheduled Chemicals
(SAB-23/WP .1, dated 28 April 2016)

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together For a World Free of Chemical Weapons

Recommendations From The OPCW Scientific Advisory Board's Report on Convergence of Chemistry & Biology

Recommendation 1

The SAB, or a suitable TWG, and the TS should continue to monitor advances in production facilities and technologies, and related trends such as outsourcing and modularisation of equipment. Assessments should be made on a periodic basis to determine their relevance to verification under the CWC. Regular engagement with subject matter experts, e.g. from the biotechnology industry, will be required.

Recommendation 2

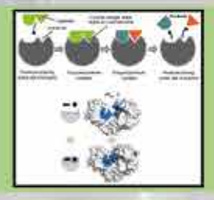
The SAB should monitor developments in biological and biologically-mediated chemical production processes, such as metabolic engineering, synthetic biology and associated enabling technologies. Regular engagement with subject matter experts will be required.

Recommendation 3

The SAB should continue to monitor the range of chemicals being studied and produced using biological or biologically-mediated processes.

Recommendation 4

The SAB, or a suitable TWG, should review advances in rational enzyme design prior to the next review conference.

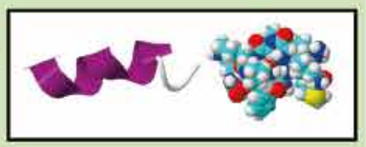


Recommendation 5

The SAB, or a suitable TWG, should review the feasibility of using metabolic engineering or synthetic biology to obtain toxins prior to the next review conference.

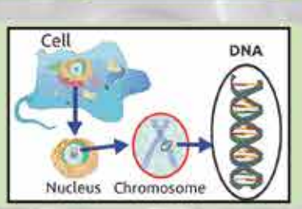
Recommendation 6

The TS should increase and maintain in-house knowledge of bioregulators, and possible applications of new developments in drug delivery.



Recommendation 7

The SAB, or a suitable TWG, should review the synthesis of replicating organisms prior to the next review conference.



Recommendation 8

The SAB, or a suitable TWG, should review progress in the use of enzymes for decontamination prior to the next review conference.

Recommendation 9

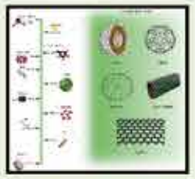
The OPCW should monitor advances in protective equipment and possible applications for OPCW personnel as they become commercially available

Recommendation 10

The OPCW should consider possible applications of diagnostic devices to on-site activities as they become commercially available.

Recommendation 11

The SAB should monitor advances in nanotechnology prior to the next review conference. Regular engagement with subject matter experts will be required.



Recommendation 12

The SAB and TS should examine ways to increase and maintain in-house, high level knowledge of a broader range of scientific disciplines.

https://www.opcw.org/special-sections/science-technology/science-technology-monitor/

Recommendation 13

A venue like the TWG on convergence of chemistry and biology should continue to exist, possibly as a temporary working group or a standing arrangement under the SAB.

Recommendation 14

National Authorities could be encouraged to engage more actively on convergence issues, including interacting with relevant biological and chemical scientific communities and hosting relevant events. A standing item on science and technology at National Authority Days might provide an opportunity to promote and report back on such an activity. Adopting convergence as a major theme for a future National Authority Day would help draw attention to this issue.

Recommendations 15 & 16

The SAB and TS should continue to work across areas of overlap between the CWC and the BWC. The Director-General might ask States to consider knowledge of the biological sciences when considering nominating experts to the SAB.

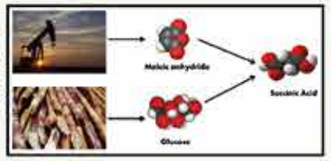
The TS, supported by the SAB, should continue to participate in such meetings and continue to address convergence.

Recommendation 17

The Director-General might consider meeting with the Chair of the BWC and heads of relevant international scientific bodies to explore issues around convergence.

Recommendation 18

Taking into consideration the convergence of chemistry and biology as it relates to the synthesis of chemicals, the TWG was of the view that any process designed for the formation of a chemical substance should be covered by the term "produced by synthesis".



Recommendation 19

The TS should review the technical feasibility of converting a bio-based chemical processing facility to produce chemicals of concern to the CWC.

@opcw
@opcw_st

/opcwonline

/opcwonline

/company/opcw

/opcw

Report available at: https://www.opcw.org/fileadmin/OPCW/SAB/en/TWG_Scientific_Advsiory_Group_Final_Report.pdf

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together for a World Free of Chemical Weapons

Recommendations from the OPCW Scientific Advisory Board's Report on Verification

Recommendation 1

The Secretariat should consider adopting a comprehensive, more analytical approach to verification utilising all available and verifiable information.

Recommendation 2

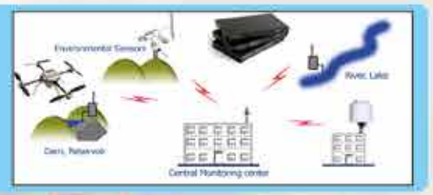
The Secretariat should acquire the capability to use open-source information on a routine basis.

Recommendation 3

The Secretariat should put in place an information management structure that can provide the support required for the verification process.

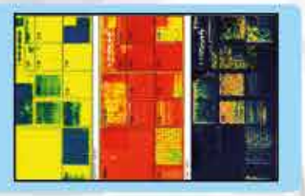
Recommendation 4

Remote/automated monitoring technologies should be added to the list of approved inspection equipment.



Recommendation 5

The Secretariat should look into the option of using satellite imagery for the planning of non-routine missions, in particular for IAU and CL



Recommendation 6

The Secretariat should visit the National Authorities to obtain assurance on the accuracy and completeness of declarations. The outcome of such visits may impact on the inspection frequency.

Recommendation 7

The Secretariat must commission an independent review of all activities pertaining to the missions carried out in the Syrian Arab Republic.

Recommendation 8

The list of declarable OCPFs submitted by States Parties should include all facilities which fall under the definition/requirement of paragraph 1 of Part IX of the Verification Annex, regardless of the purity level of a DOC or DOC mixtures produced.

Recommendation 9

Not all facilities that fall under Part IX of the Verification Annex should be considered of the same relevance to the object and purpose of the Convention. The TWG recommends a practical approach for enhancing the utilisation of verification resources for OCPF declaration and on-site inspection processes.

Recommendation 10

The verification thresholds for OCPFs producing highly relevant chemicals, and the possibility of revision of the product group codes, should be addressed by the SAB as well as the industry cluster.

Recommendation 11

The OPCW should increase the staff of the OPCW Laboratory to cope with various aspects of IAU, biomedical samples, trace environmental analysis, toxins, and on-site analysis. Establishing a network of DLs for biomedical sample analysis should be a high priority.

Recommendation 12

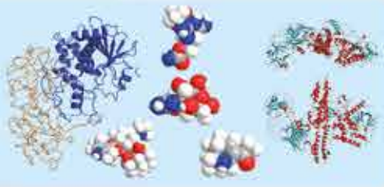
Lessons on chemical sampling and analysis from the OPCW's support to the 2013 United Nations Mission to Investigate the Use of Chemical Weapons in the Syrian Arab Republic, and all subsequent OPCW activities in relation to the Syrian Arab Republic must be identified and implemented.

Recommendation 13

PTs should incorporate a broader range of chemicals, and at a wider range of concentrations, to prepare laboratories for IAU-type scenarios.

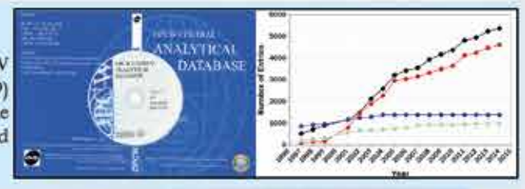
Recommendation 14

The Secretariat should expedite toxin identification exercises.



Recommendation 15

Continuous additions to the OPCW Central Analytical Database (OCAD) are recommended to allow the OPCW to meet all its mandated inspection aims, including IAU.

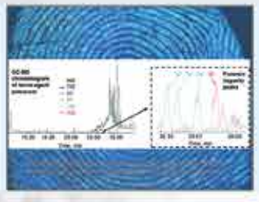


Recommendation 16

Developments in analytical instrument portability, miniaturisation and disposable biosensors should be periodically reviewed by the Secretariat and the SAB for potential applicability to on-site analysis.

Recommendation 17

The Secretariat should monitor developments in attribution analysis/chemical forensics.



Recommendation 18

The Secretariat should augment its capability to monitor and forecast developments in science and technology of relevance to the Convention and its verification regime.

https://www.opcw.org/special-sections/science-technology/science-technology-monitor/

@opcw
@opcw_st

/opcwonline

/opcwonline

/company/opcw

Report available at: https://www.opcw.org/fileadmin/OPCW/SAB/en/Final_Report_of_SAB_TWG_on_Verification_-_as_presented_to_SAB.pdf

ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

Working Together For a World Free of Chemical Weapons

Temporary Working Group on Investigative Science and Technology

Reporting to the Scientific Advisory Board (SAB), the Temporary Working Group (TWG) will in particular consider the following questions:

Question 1:

Which methods and capabilities used in the forensic sciences could usefully be developed and/or adopted for Chemical Weapons Convention-based investigations?

Question 2:

What are the best practices and analysis tools used in the forensic sciences for effectively cross-referencing, validating, and linking together information related to investigation sites, materials collected/analysed, and individuals interviewed?

Question 3:

What are the best practices for management of data collected in investigations, including compilation, curation, and analytics?

Question 4:

What are the best practices for the collection, handling, curation and storage, and annotation of evidence?

Question 5:

Which technologies and methodologies (whether established or new) allow point-of-care and non-destructive measurements at an investigation site to help guide evidence collection?

Question 6:

Which technologies and methodologies (whether established or new) can be used in the provenancing of chemical and/or material samples collected in an investigation?

Question 7:

Which methods are available (or are being developed) for the sampling and analysis of environmental and biomedical materials and can be used in the detection of toxic industrial chemicals relevant to the Chemical Weapons Convention?

Question 8:

Which technologies and methodologies (whether established or new) can be used in ensuring chain of custody and verifying authenticity (especially in regard to digital images and video recordings)?

Question 9:

Which technologies and methodologies (whether established or new) can be used to ensure the integrity of an investigation site?

Question 10:

Do collections of physical objects, samples, and other information for chemical weapons-related analysis exist and can they be made available to investigators for retrospective review? How might these collections be used to support investigations?

Question 11:

Are there stakeholders that the Technical Secretariat could usefully engage with to leverage their capabilities on investigative matters?

In addition, the TWG will provide advice on Technical Secretariat proposals for methodologies, procedures, technologies, and equipment for investigative purposes.

The Hague Ethical Guidelines

Applying the norms of the practice of chemistry to support the Chemical Weapons Convention

Core element. Achievements in the field of chemistry should be used to benefit humankind and protect the environment.

Sustainability. Chemistry practitioners have a special responsibility for promoting and achieving the UN Sustainable Development Goals of meeting the needs of the present without compromising the ability of future generations to meet their own needs.

Awareness and engagement. Teachers, chemistry practitioners, and policymakers should be aware of the multiple uses of chemicals, specifically their use as chemical weapons or their precursors. They should promote the peaceful applications of chemicals and work to prevent any misuse of chemicals, scientific knowledge, tools and technologies, and any harmful or unethical developments in research and innovation. They should disseminate relevant information about national and international laws, regulations, policies and practices.

Safety and Security. Chemistry practitioners should promote the beneficial applications, uses, and development of science and technology while encouraging and maintaining a strong culture of safety, health, and security.

Oversight. Chemistry practitioners who supervise others have the additional responsibility to ensure that chemicals, equipment and facilities are not used by those persons for illegal, harmful or destructive purposes.

Education. Formal and informal educational providers, enterprise, industry and civil society should cooperate to equip anybody working in chemistry and others with the necessary knowledge and tools to take responsibility for the benefit of humankind, the protection of the environment and to ensure relevant and meaningful engagement with the general public.

Ethics. To adequately respond to societal challenges, education, research and innovation must respect fundamental rights and apply the highest ethical standards. Ethics should be perceived as a way of ensuring high quality results in science.

Accountability. Chemistry practitioners have a responsibility to ensure that chemicals, equipment and facilities are protected against theft and diversion and are not used for illegal, harmful or destructive purposes. These persons should be aware of applicable laws and regulations governing the manufacture and use of chemicals, and they should report any misuse of chemicals, scientific knowledge, equipment and facilities to the relevant authorities.

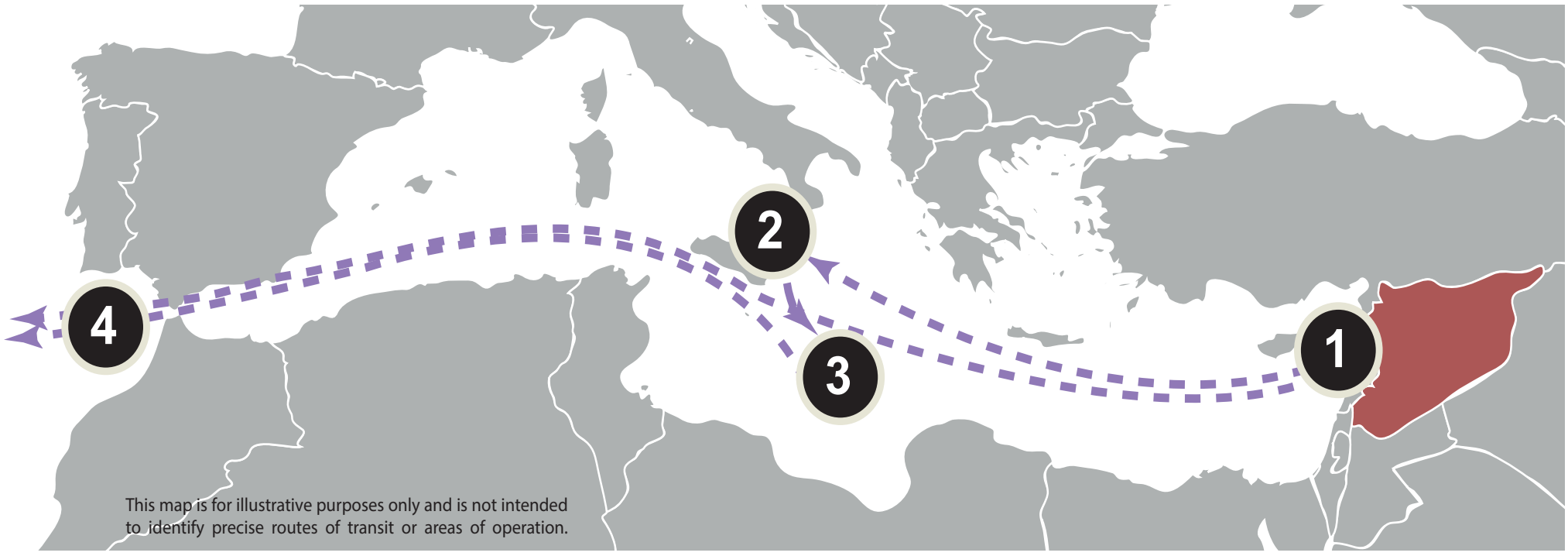
Exchange of information. Chemistry practitioners should promote the exchange of scientific and technical information relating to the development and application of chemistry for peaceful purposes.

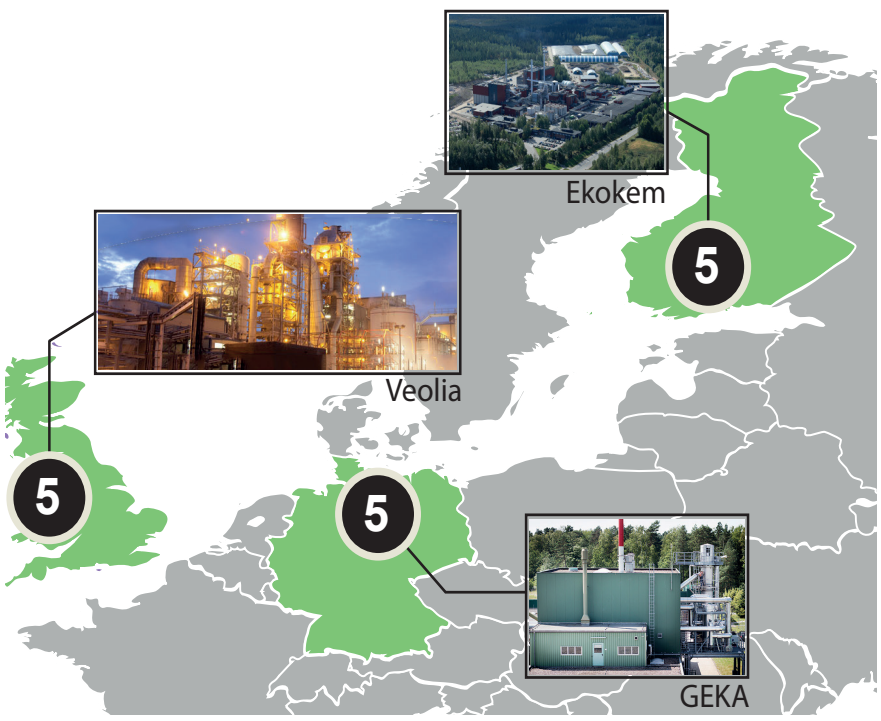
ORGANISATION FOR THE PROHIBITION OF CHEMICAL WEAPONS

WORKING TOGETHER FOR A WORLD FREE OF CHEMICAL WEAPONS

@OPCW @OPCW_ST /OPCWONLINE /OPCWONLINE /OPCW/COMPANY /OPCW

REMOVAL AND DESTRUCTION OF SYRIAN CHEMICAL WEAPONS





1 Latakia

Latakia is the port of embarkation for chemicals to be removed from Syria . These chemicals have been packed and loaded securely in containers that meet international standards for the transport of dangerous goods by sea, and have been inventoried and sealed by OPCW inspectors. At Latakia, the chemicals are being loaded onto Danish and Norwegian cargo vessels. (MV Ark Futura and MV Taiko respectively).

2 Italy

The Italian port of Gioia Tauro will be used for transferring some Priority 1 chemicals (i.e. a precursor for chemical weapons and a small amount of mustard agent) from the Danish cargo vessel to the MV Cape Ray. The transloading will take place with minimal handling of the standardized shipping containers holding the chemicals and emergency response equipment and personnel will be available to deal with any unlikely chemical incidents. OPCW inspectors will be present at Gioia Tauro to inventory the materials that will be transloaded from one ship to the other.

3 MV Cape Ray

The MV Cape Ray has been fitted with two Field Deployable Hydrolysis Systems (FDHS) that will neutralise about 600 metric tonnes of Priority 1 chemicals in international waters of the Mediterranean. These chemicals will be transferred from the Danish cargo vessel to the MV Cape Ray at Gioia Tauro in Italy. At all stages of the process aboard the MV Cape Ray, the chemicals to be neutralised and the resulting effluent will be safely stored and handled by trained and experienced personnel. OPCW inspectors will be continuously present aboard the MV Cape Ray to ensure that all requirements of the Convention are properly observed, including those related to the safety of the crew and protection of the environment. Once neutralisation has been completed, the resulting effluent will be transported by the MV Cape Ray to be finally disposed of at facilities in Finland and Germany.

www.defense.gov/home/features/2014/0114_caperay/

4

The Chemical Weapons Convention expressly bans the dumping of chemicals in any body of water and requires States Parties to ensure that during operations the highest priority is assigned to ensuring the safety of the people and to protecting the environment.

All transportation of chemicals and subsequent operations at their final destinations will follow stringent national and international regulations for transportation safety and protection of the environment.

5 Shipments to Europe

Under an in-kind contribution from the Government of the United Kingdom, Veolia, a commercial waste company, will destroy around 150 tonnes of chemicals at Ellesmere Port. The chemicals are similar in nature to standard industrial materials which are safely processed on a regular basis at the facility. They will be off-loaded at a British port from the Danish cargo vessel Ark Futura and inventoried by OPCW inspectors.

www.veolia.com

The Finnish hazardous waste management company Ekokem AB was awarded a contract by the OPCW to destroy around 360 metric tonnes of Priority 2 industrial chemicals. The chemicals will be off-loaded from the Norwegian vessel Taiko at a designated port in Finland, inventoried by OPCW inspectors and then treated at Ekokem's Riihimäki treatment centre in southern Finland. Ekokem will also dispose of around 4,500 litres of effluent generated on the MV Cape Ray, which will be brought to Finland by the MV Cape Ray. www.ekokem.fi

Under an in-kind contribution from the government of Germany, the Gesellschaft zur Entsorgung von chemischen Kampfstoffen und Ruestungsaltlasten (GEKA) in Munster will destroy the effluent created by the neutralisation of the mustard agent aboard the MV Cape Ray The effluent will be off-loaded from the MV Cape Ray at a designated port in Germany and will be inventoried by OPCW inspectors.

www.geka-munster.de

OPCW inspectors will also confirm and report the destruction of the effluent and ensure that all requirements of the Convention are properly observed during operations.

Multi-National Maritime Task Force

A Multinational Maritime Task Force comprised of naval forces from China, Denmark, Norway, Russia, and the United Kingdom is positioned in the eastern Mediterranean Sea to provide secure transportation of chemicals to their ultimate destruction location. The cargo ships have additional capacity to deal with chemical spills or emergencies and a special chemical response team is available, along with expert chemical response personnel from Finland.

6 Shipment to USA

Veolia Environmental Services Technical Solutions in the USA was one of two companies awarded a contract by the OPCW to destroy chemicals from Syria following a rigorous solicitation process, in this case around 145 metric tonnes of Priority 2 inorganic chemicals. The chemicals will be off-loaded from the Norwegian vessel Taiko at a designated port in the USA and inventoried by OPCW inspectors. The five types of chemicals that will be destroyed here by incineration are standard industrial chemicals, which are transported and widely used across the United States every day.

www.veoliaes.com

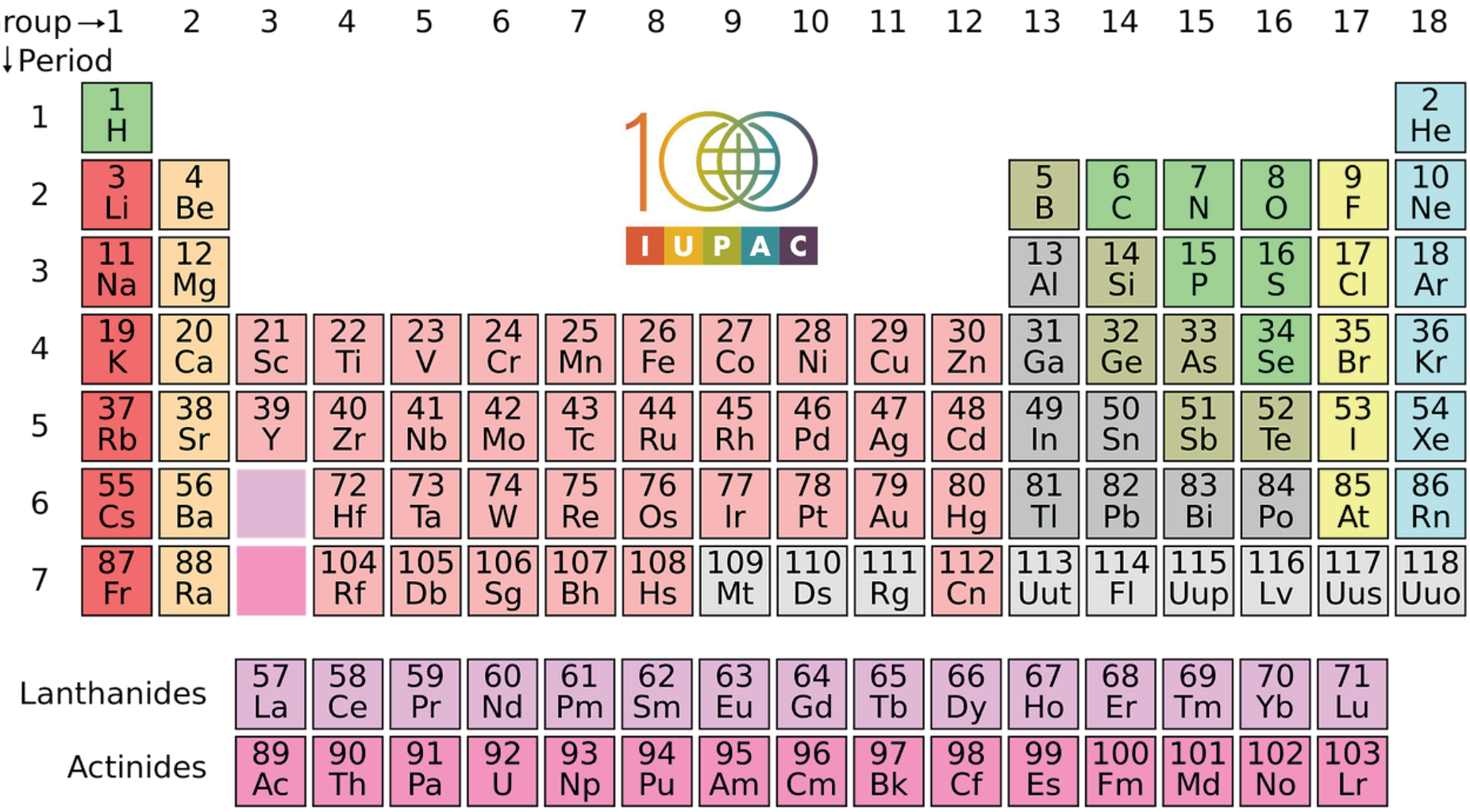
/OPCW
@OPCW

More information is available on

opcw.unmissions.org/Default.aspx?tabid=6668&language=en-US
www.opcw.org/special-sections/syria-and-the-opcw/frequently-asked-questions/

For more infomation on science and technology at OPCW go to opcw.org and follow our SciTech twitter feed @opcw_st

Periodic Table 2019 *



* Periodic Table 2019 from IUPAC: http://www.iupac.cnr.it/news-archive/142-proclamation-of-2019-as-the-united-nation-international-year-of-the-periodic-table-of-chemical-elements

1869 is considered the year of discovery of the Periodic System by Dimitry Mendeleev.

2019 will be the **150th anniversary of the Periodic Table of Chemical Elements** and has been proclaimed the "International Year of the Periodic Table of Chemical Elements (IYPT2019)" by the United Nations General Assembly and United Nations Educational, Scientific and Cultural Organization (UNESCO).

Discover more about #IYPT2019 via:
https://www.iypt2019.org/