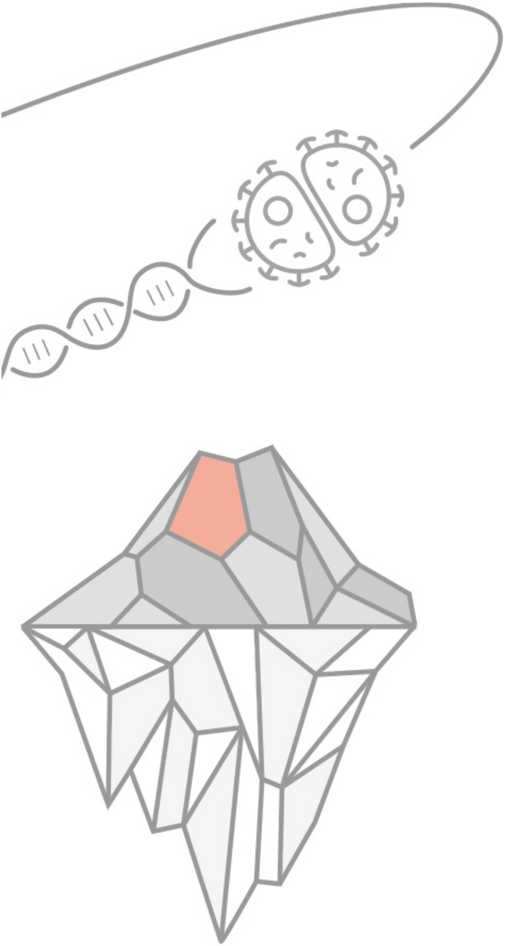
MICROBIOLOGY OF EXTREME ENVIRONMENTS



APPLICATIONS OF EXTREMOPHILES

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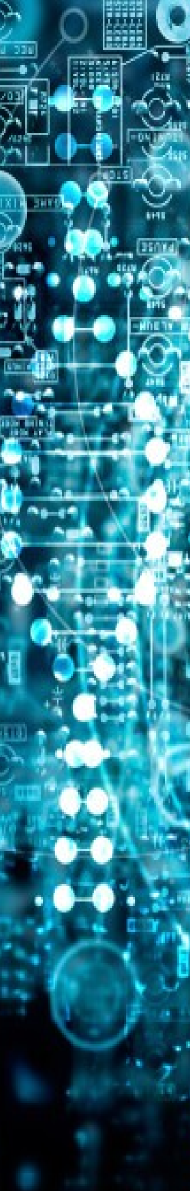
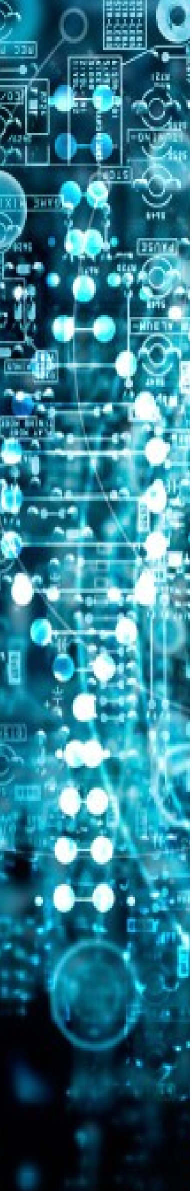
GIOVANNELLI LAB

BIOLOGY OF EXTREME ENVIRONMENTS

DIPARTIMENTO DI BIOLOGIA



BIOREMEDIATION



Bioremediation

Bioremediation is the use of biology to degrade or immobilize chemical compounds. It can be theoretically applied to the removal of any undesired compounds (organic or inorganic). Bioremediation has been used at a number of sites worldwide, including Europe, with varying degrees of success.

1972 - First commercial application: Sun Oil pipeline spill in Ambler, Pennsylvania

mid-1980s
Emphasis on bioengineering organisms for bioremediation. This technology did not live up to its initial promise

1990s
Emphasis switched to greater reliance on natural microorganisms and techniques to enhance their performance

Bioremediation: applications

Types of impact where bioremediation can be applied:

Petroleum hydrocarbons

Chlorinated solvents

Polynuclear aromatic hydrocarbons

Pesticides

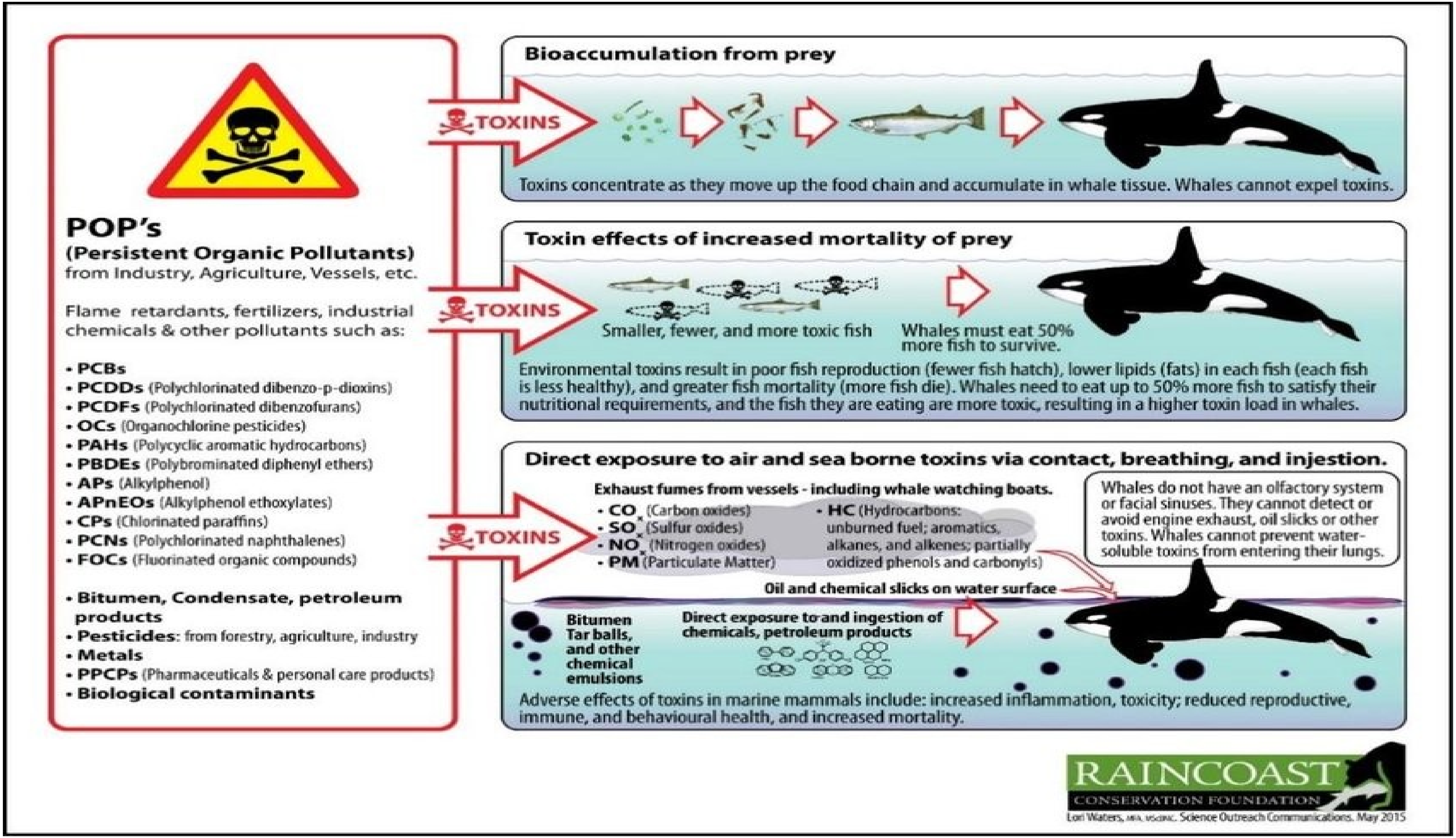
TNT and a variety of other organic chemicals

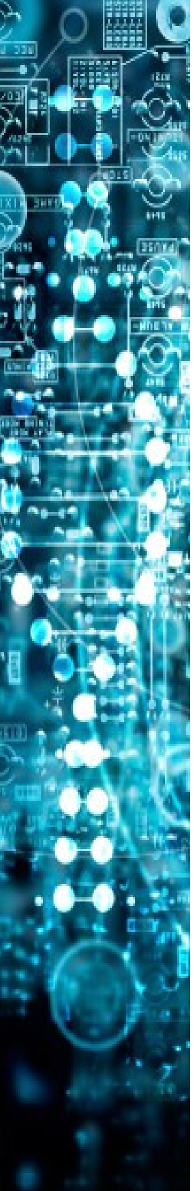
Inorganic nitrogen (nitrate, ammonia)

Excessive nutrients and OM

Heavy metals (Pu, Np, Cr, As)

Radioactive metals (U, Th)



POP's
(Persistent Organic Pollutants)
from Industry, Agriculture, Vessels, etc.
Flame retardants, fertilizers, industrial chemicals & other pollutants such as:
• PCBs
• PCDDs (Polychlorinated dibenzo-p-dioxins)
• PCDFs (Polychlorinated dibenzofurans)
• OCs (Organochlorine pesticides)
• PAHs (Polycyclic aromatic hydrocarbons)
• PBDEs (Polybrominated diphenyl ethers)
• APs (Alkylphenol)
• APnEOs (Alkylphenol ethoxylates)
• CPs (Chlorinated paraffins)
• PCNs (Polychlorinated naphthalenes)
• FOCs (Fluorinated organic compounds)
• Bitumen, Condensate, petroleum products
• Pesticides: from forestry, agriculture, industry
• Metals
• PPCPs (Pharmaceuticals & personal care products)
• Biological contaminants
TOXINS
Bioaccumulation from prey
Toxins concentrate as they move up the food chain and accumulate in whale tissue. Whales cannot expel toxins.
TOXINS
Toxin effects of increased mortality of prey
Smaller, fewer, and more toxic fish
Whales must eat 50% more fish to survive.
Environmental toxins result in poor fish reproduction (fewer fish hatch), lower lipids (fats) in each fish (each fish is less healthy), and greater fish mortality (more fish die). Whales need to eat up to 50% more fish to satisfy their nutritional requirements, and the fish they are eating are more toxic, resulting in a higher toxin load in whales.
TOXINS
Direct exposure to air and sea borne toxins via contact, breathing, and injestion.
Exhaust fumes from vessels - including whale watching boats.
• CO_x (Carbon oxides)
• SO_x (Sulfur oxides)
• NO_x (Nitrogen oxides)
• PM (Particulate Matter)
• HC (Hydrocarbons: unburned fuel; aromatics, alkanes, and alkenes; partially oxidized phenols and carbonyls)
Whales do not have an olfactory system or facial sinuses. They cannot detect or avoid engine exhaust, oil slicks or other toxins. Whales cannot prevent water-soluble toxins from entering their lungs.
Oil and chemical slicks on water surface
Bitumen Tar balls, and other chemical emulsions
Direct exposure to and ingestion of chemicals, petroleum products
Adverse effects of toxins in marine mammals include: increased inflammation, toxicity; reduced reproductive, immune, and behavioural health, and increased mortality.
RAINCOAST
CONSERVATION FOUNDATION
Lori Waters, MFA, MScBMC. Science Outreach Communications. May 2015



Bioremediation: ups

1. Bioremediation can be “natural process” and is therefore perceived by the public as an acceptable waste treatment process for contaminated material. Microbes able to degrade the contaminant increase in numbers when the contaminant is present.

2. Theoretically, bioremediation is useful for the complete destruction of a wide variety of contaminants. The complete destruction of target pollutants is theoretically possible.

3. Bioremediation can often be carried out on site, often without causing a major disruption of normal activities. This also eliminates the need to transport quantities of waste off site and the potential threats to human health and the environment that can arise during transportation.

4. Bioremediation can prove less expensive than other technologies that are used for cleanup of hazardous waste.

Bioremediation: downs

1. Bioremediation is generally very costly, labor intensive, and time consuming considering the extent of the impact considered.

2. Bioremediation is limited to those compounds that are biodegradable. Not all compounds are susceptible to rapid and complete degradation.

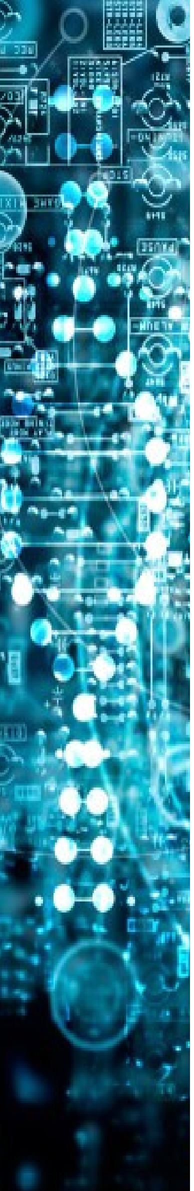
3. There are some concerns that the byproducts of biodegradation may be more persistent or toxic than the parent compound.

4. Biological processes are often highly specific.

5. It is difficult to extrapolate from bench and pilot-scale studies to full-scale field operations.

6. Bioremediation often takes longer than other treatment options, such as excavation and removal of soil or incineration.

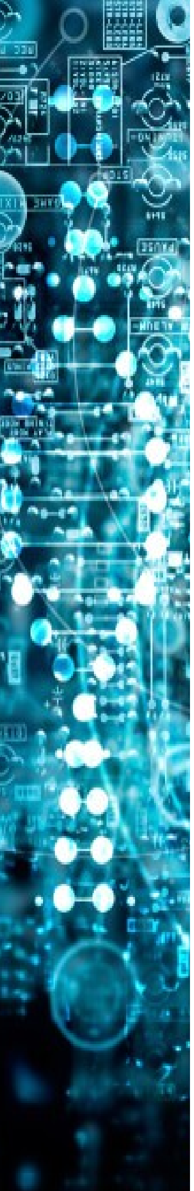
7. Regulatory uncertainty remains regarding acceptable performance criteria for bioremediation.



Bioremediation: in situ and ex situ

In situ bioremediation *means there is no need to excavate or remove soils or water in order to accomplish remediation. In situ biodegradation can involve the addition of microorganisms, oxygen and nutrients. In its intrinsic version is the most widely applied type of bioremediation, although has several drawbacks.*

Ex situ bioremediation *requires excavation or removal of contaminated soil, sediments or waters (permanent or temporary) to facilitate microbial degradation. This technique is more expensive but it is able to overcome some of the disadvantage of in situ approaches.*



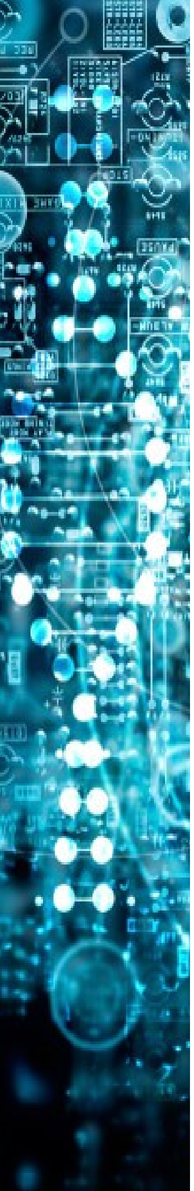
Bioremediation: intrinsic vs engineered

Intrinsic bioremediation

This approach deals with stimulation of indigenous or naturally occurring microbial populations by feeding them nutrients and oxygen to increase their metabolic activity (Biostimulation). Chemotaxis is important to the study of in situ bioremediation because microbial organisms with chemotactic abilities can move into an area containing contaminants.

Engineered bioremediation

Involves the introduction of external (exogenous) microorganisms to enhance degradation (Bioaugmentation).



Basic Bioremediation Approaches

Natural attenuation – *naturally occurring degradation of the pollutants by naturally occurring microbial populations* ***not supported*** *by human intervention*

Biostimulation *– Naturally occurring degradation of the pollutants by naturally occurring microbial population* ***supported by the additions*** *of nutrient, stimulants and surfactants*

Bioaugmentation *– Introduction of allochthonous engineered populations of microorganisms to enhance the degradation of the pollutants*

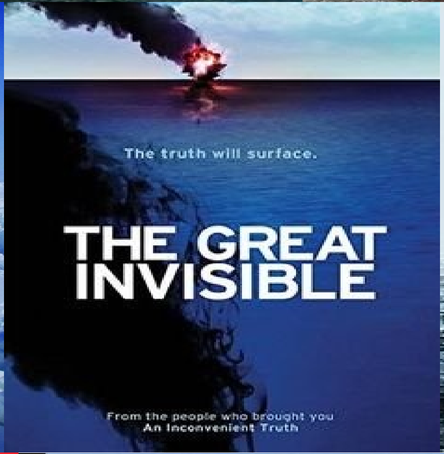
Microbial groups involved in degradation

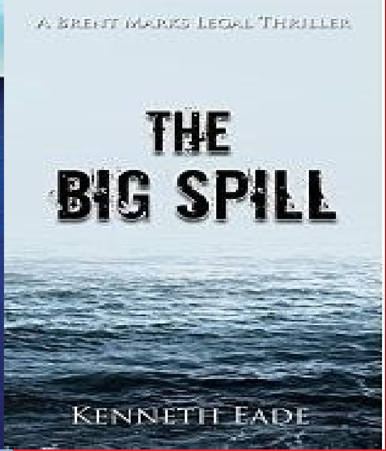
Aerobic: *Examples of aerobic bacteria recognized for their degradative abilities are Pseudomonas, Alcaligenes, Sphingomonas, Rhodococcus, and Mycobacterium. These microbes have often been reported to degrade pesticides and hydrocarbons, both alkanes and polyaromatic compounds. Many of these bacteria use the contaminant as the sole source of carbon and energy.*

Anaerobic. *Anaerobic bacteria are not as frequently used as aerobic bacteria. There is an increasing interest in anaerobic bacteria used for bioremediation of polychlorinated biphenyls (PCBs) in river sediments, dechlorination of the solvent trichloroethylene (TCE) and chloroform.*

Methylotrophs. *Aerobic bacteria that grow utilizing methane for carbon and energy. The initial enzyme in the pathway for aerobic degradation, methane monooxygenase, has a broad substrate range and is active against a wide range of compounds, including the chlorinated aliphatic trichloroethylene and 1, 2 dichloroethane.*


RESPONDING TO
Oil Spills
IN THE U.S. ARCTIC
MARINE ENVIRONMENT
NATIONAL RESEARCH COUNCIL

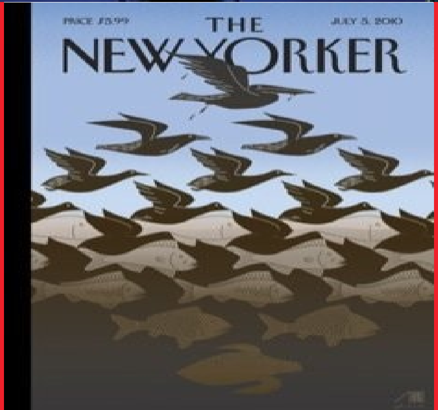

The truth will surface.
THE GREAT INVISIBLE
From the people who brought you
An Inconvenient Truth


A BRENT MARKS LEGAL THRILLER
THE BIG SPILL
KENNETH EADE


TIME
THE WEEKLY NEWSMAGAZINE
THE POLLUTED AIR
LOS ANGELES
AT 3:30 P.M.

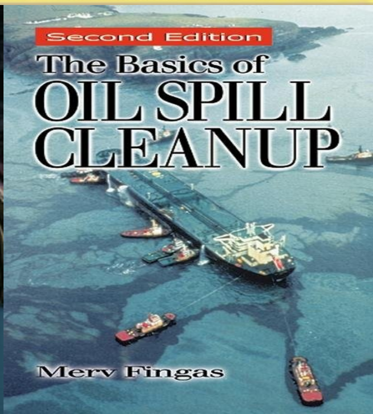

NATIONAL GEOGRAPHIC
Alaska's
Big Spill
CAN THE WILDERNESS HEAL?

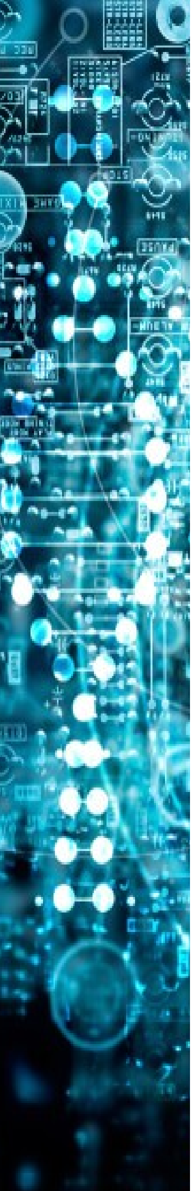

TIME
How to Clean Up
The Mess
And who's to blame*


THE
NEW YORKER
JULY 5, 2010


Special Report: The Times Square Bomber
TIME
The Big Spill
What the disaster in the Gulf means for the future of energy


Newsweek
CRUDE AWAKENING
OBAMA AND THE TRAGEDY IN THE GULF
BY EVAN THOMAS AND DANIEL STONE
SEAL OF THE PRESIDENT OF THE UNITED STATES


Second Edition
The Basics of
OIL SPILL
CLEANUP
Merv Fingas



The cost of cleaning

Different costs need to be take into account while considering bioremediation appraoches vs natural attenuation

Economic cost of bioremediation effort

Economic cost of the damage caused by the no-intervetion alternative

Economic cost of the post bioremediation dismantling

Ecological cost of bioremediation effort

Ecological cost of the post bioremediation dismantling

Economic and ecological cost of long term effects of the bioremediation effort

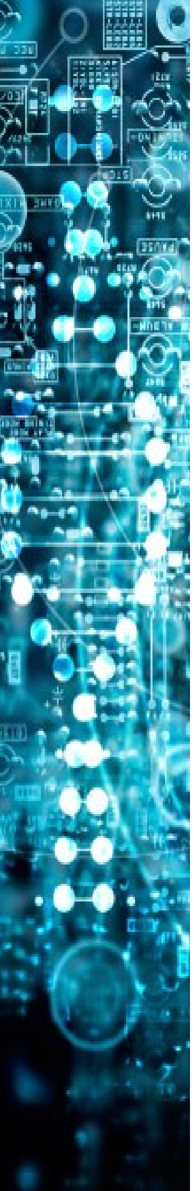


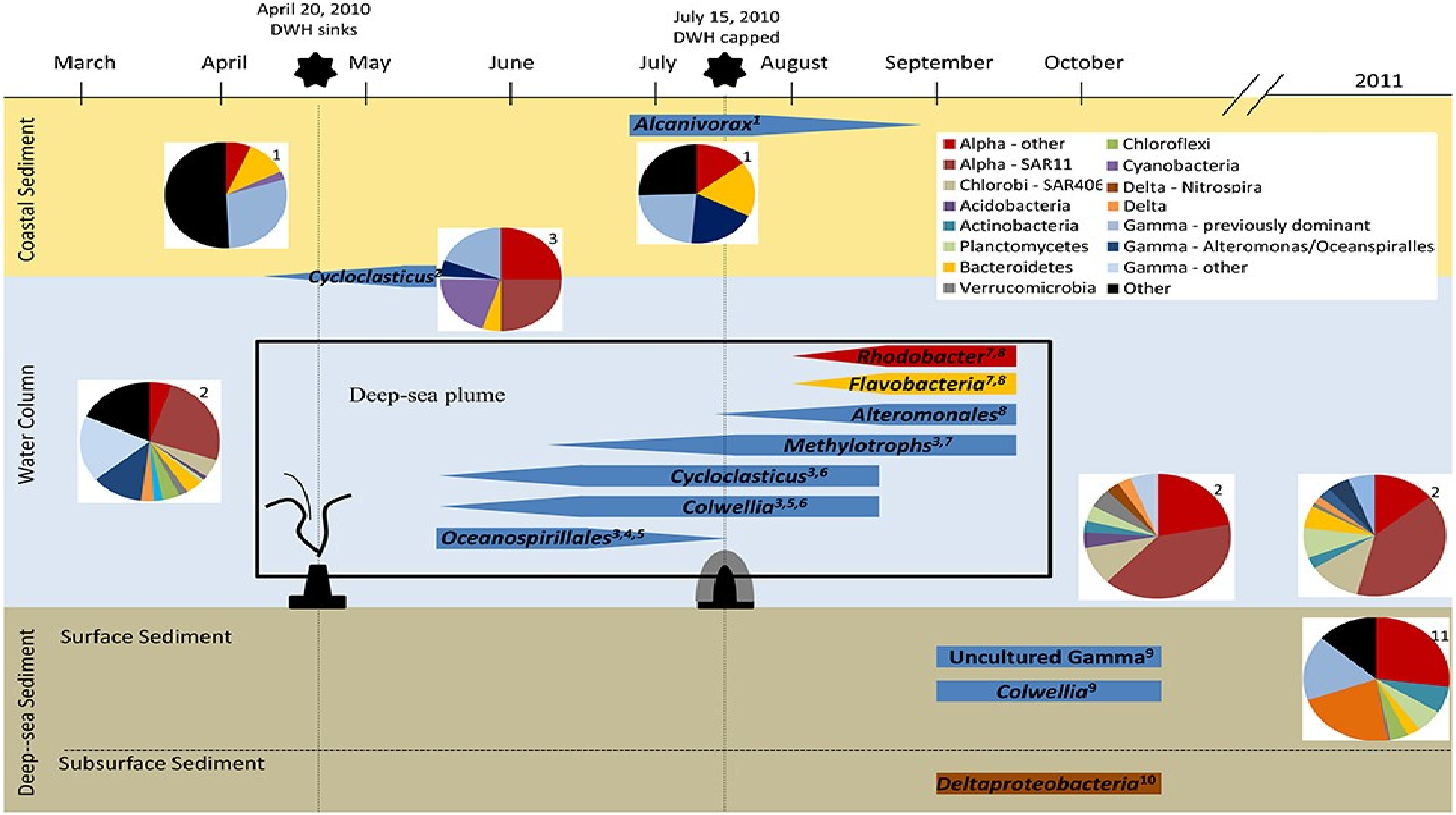
Table 2 Estimated costs of remediation strategies for hydrocarbon-polluted soils and sediments

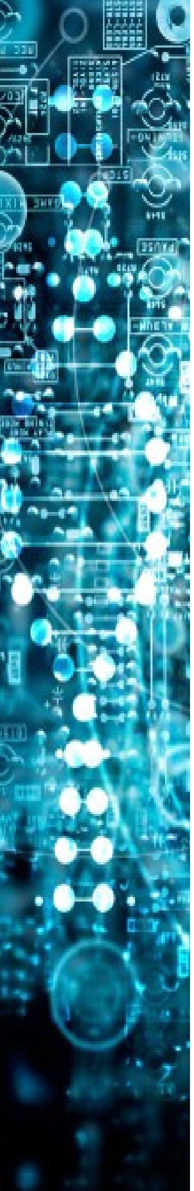
Remediation strategy	Treating site	Cost (US $/m^3)[a]
Biological		
Biostimulation	In situ	30–100
Bioaugmentation	In situ	30–100
Bioventing	In situ	79–970
Biopiles	Ex situ	130–260
Composting	Ex situ	630–757
Landfarming	Ex situ	30–70
Physicochemical		
Vapor extraction	In situ	405–1,485
Thermal desorption	Ex situ	44–252

[a] Data from the US Federal Remediation Technologies Roundtable (2014).

BP DWH Spill – 61 Billion USD

Naturally occurring degraders





Obligate HydrocarbonoClastic Bacteria

The ecology of a special group of **ubiquitous marine hydrocarbon-degrading bacteria** offers a model of microbial dynamics after oils spills.

Obligate hydrocarbonoclastic bacteria (OHCB) are an unusual ecological group that plays a key role in biodegradation of petroleum hydrocarbons in marine environments. OHCB are able to grow on a reduced spectrum of hydrocarbons.

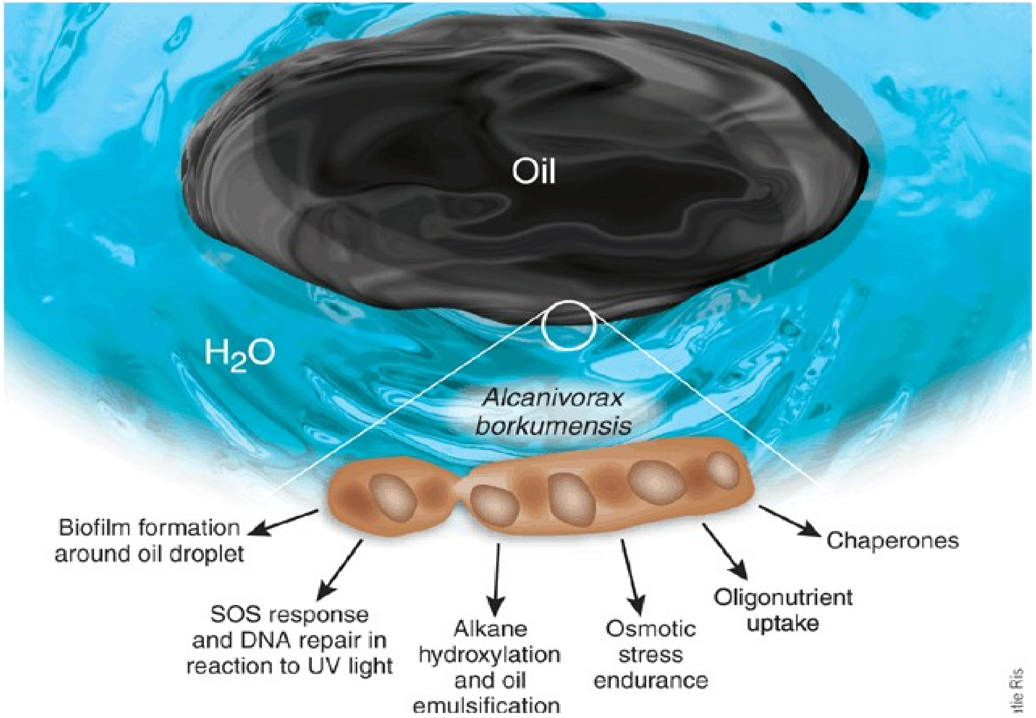
In non-polluted marine environments, OHCB are found in **extremely low numbers**, but after an oil pollution event, members of this group undergo a **bloom**. OHCB growth is favored in hydrocarbon-polluted seawater because they can breakdown substrates that are useless for most bacteria.

The model OHCB is ***Alcanivorax borkumensis*** SK2, able to degrade n-alkanes of chain-length up to C32, long-chain isoprenoids, phytane, pristine, and alkyl-aromatic hydrocarbons and to synthesize **biosurfactants** and **exopolysaccharides** probably involved in **biofilm formation**.

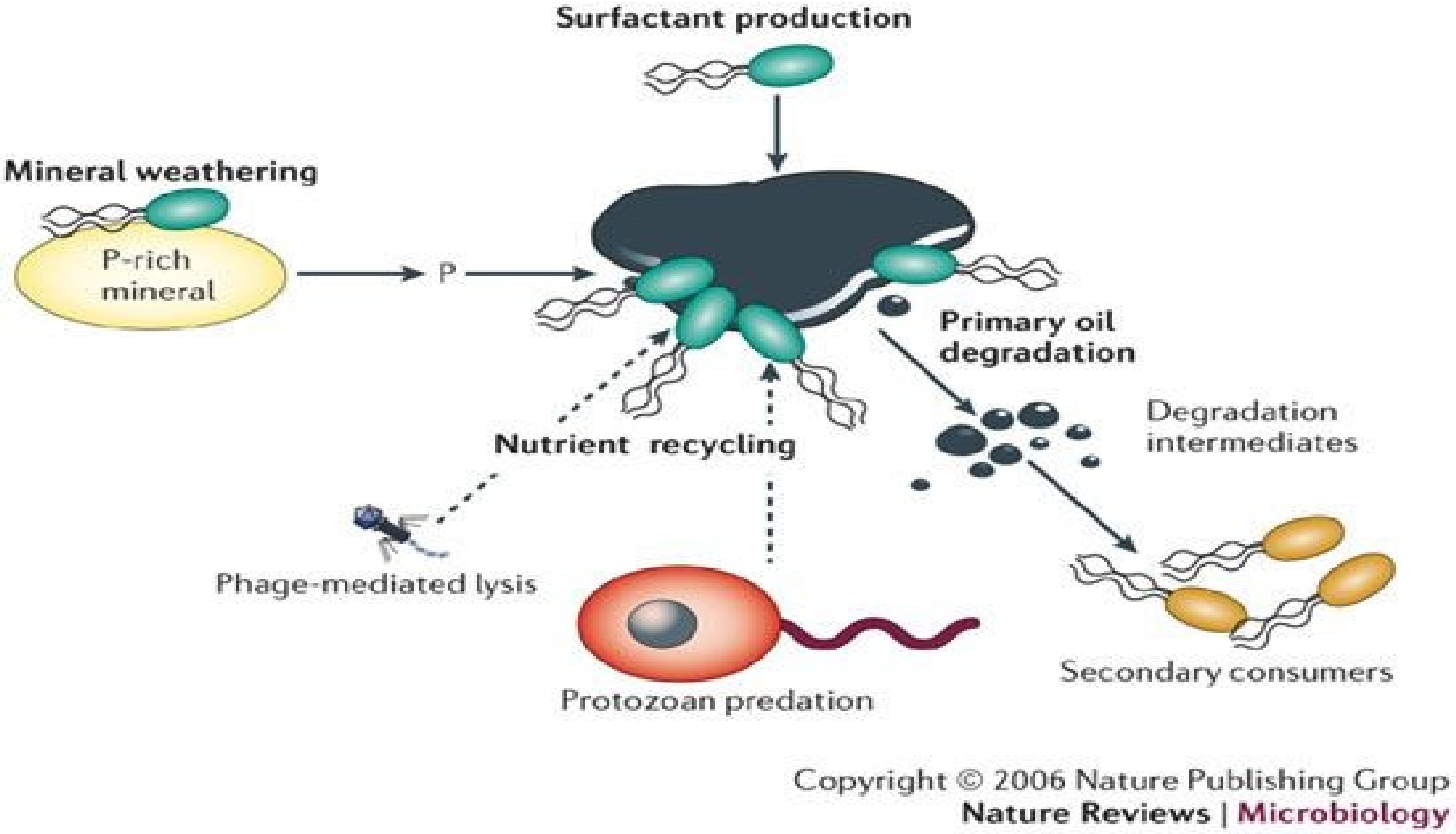
Alcanivorax borkumensis

A. borkumensis genome revealed **multiple systems for hydrocarbon degradation** pathways, i.e., two alkane hydroxylase systems, AlkB1 and AlkB2, and three P450 cytochromes.

The **absence** of genes belonging to **glucose breakdown** pathways highlights its amazing metabolic specialization.

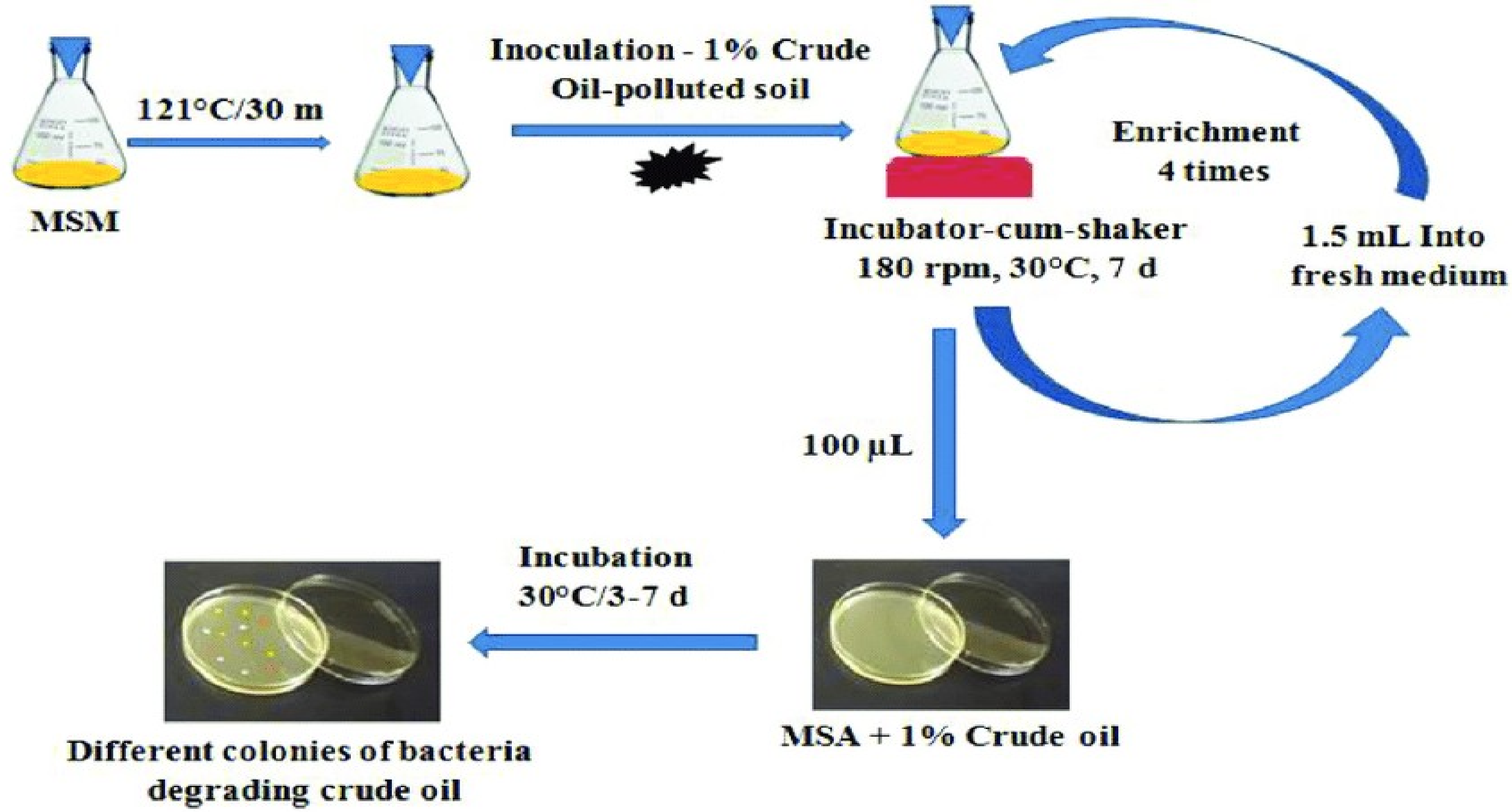


Community Response

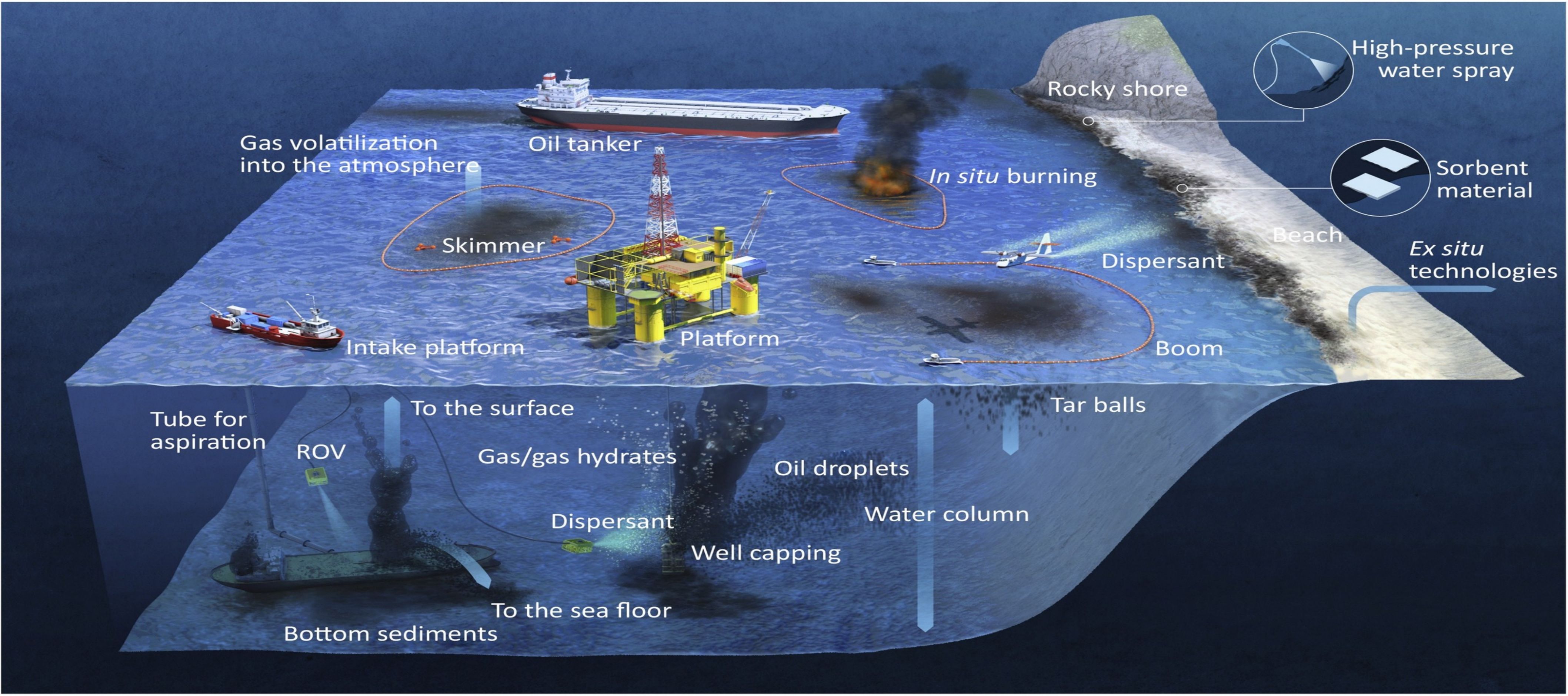


Head et al., 2006 NatRevMicrobiol

Enriching/Isolating oil degrading microbes



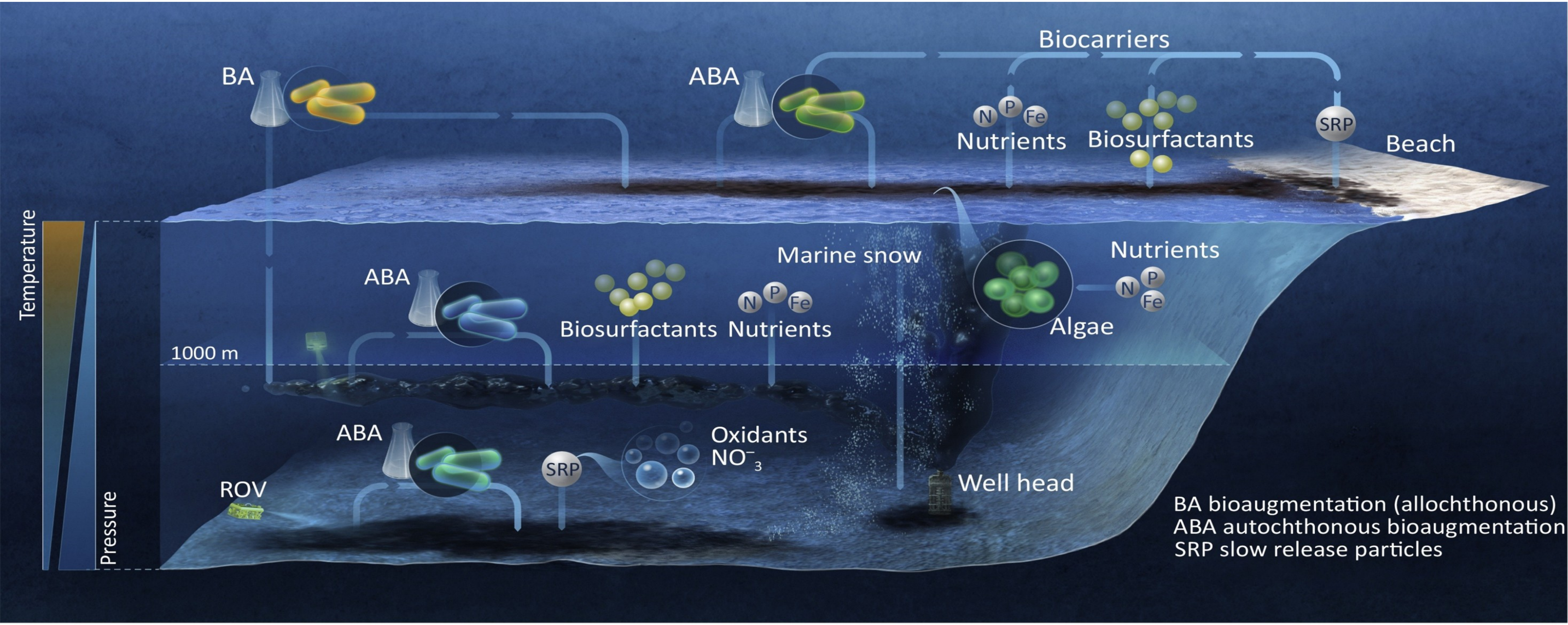
Oil spill response



Mapelli et al., 2017 TrendsBiotech

Trends in Biotechnology

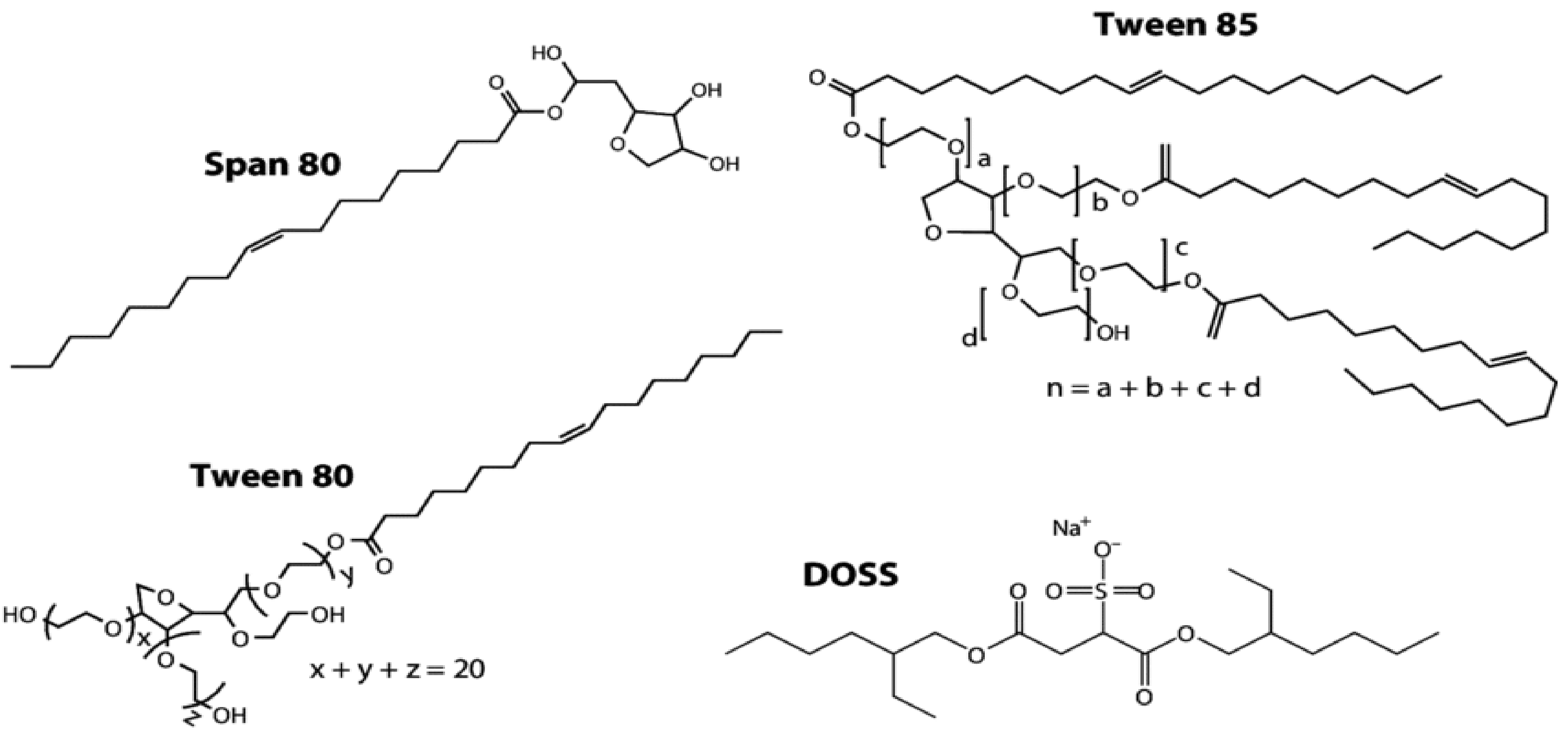
Hydrocarbon decontamination during spills



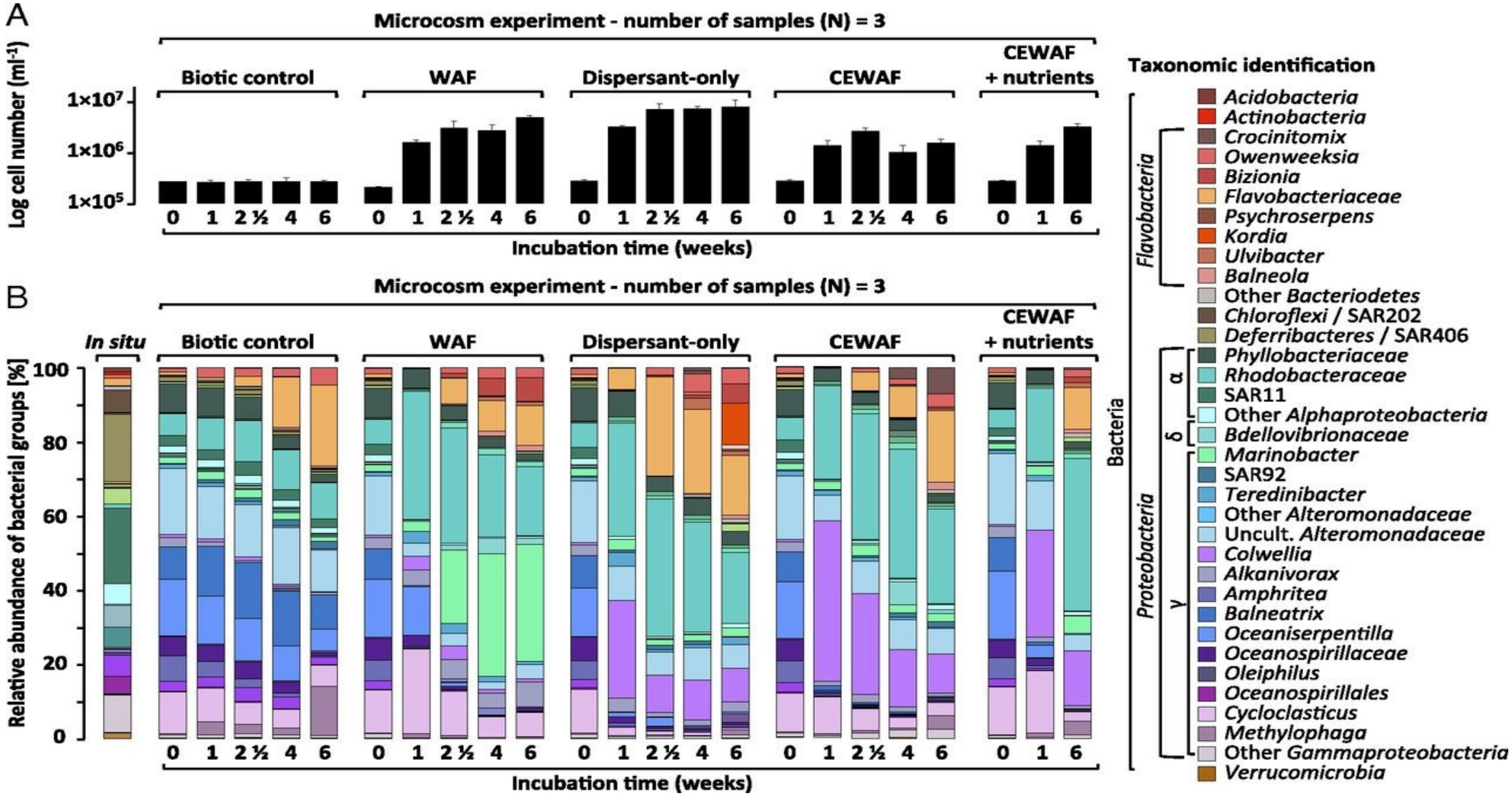
Trends in Biotechnology

Mapelli et al., 2017 TrendsBiotech

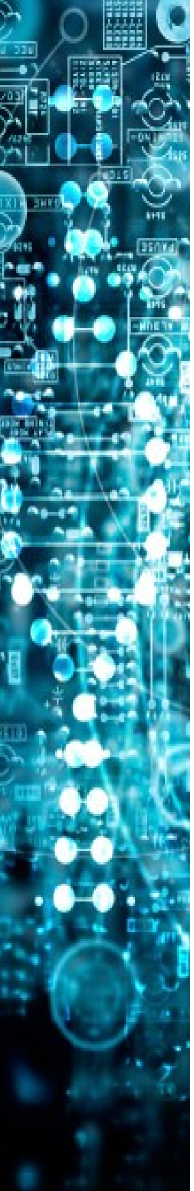
Unexpected effects of dispersant



Unexpected effects of dispersant



Hazen et al., 2010 Science



BIOMASS CONVERSION

Production from Biomass

*Biomass are defined as **organic products from biological material** such as plants, animals, microorganisms and municipal waste. They can be directly the bodies of the organisms or byproducts of other human-mediated processes.*

Biomass can be classified in many different types, depending from the provenience, the composition, the state (liquid, solid) and the lability.

Examples of Biomass

Plant oils or sugary /starchy parts of crops

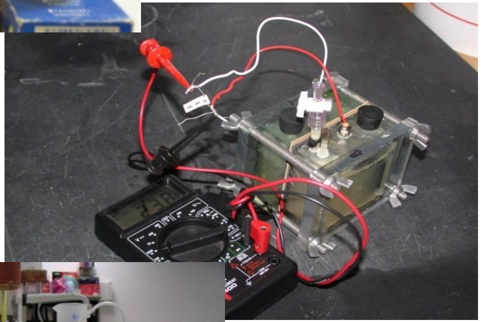
Trees, wood chippings, or straw

Waste cooking oil

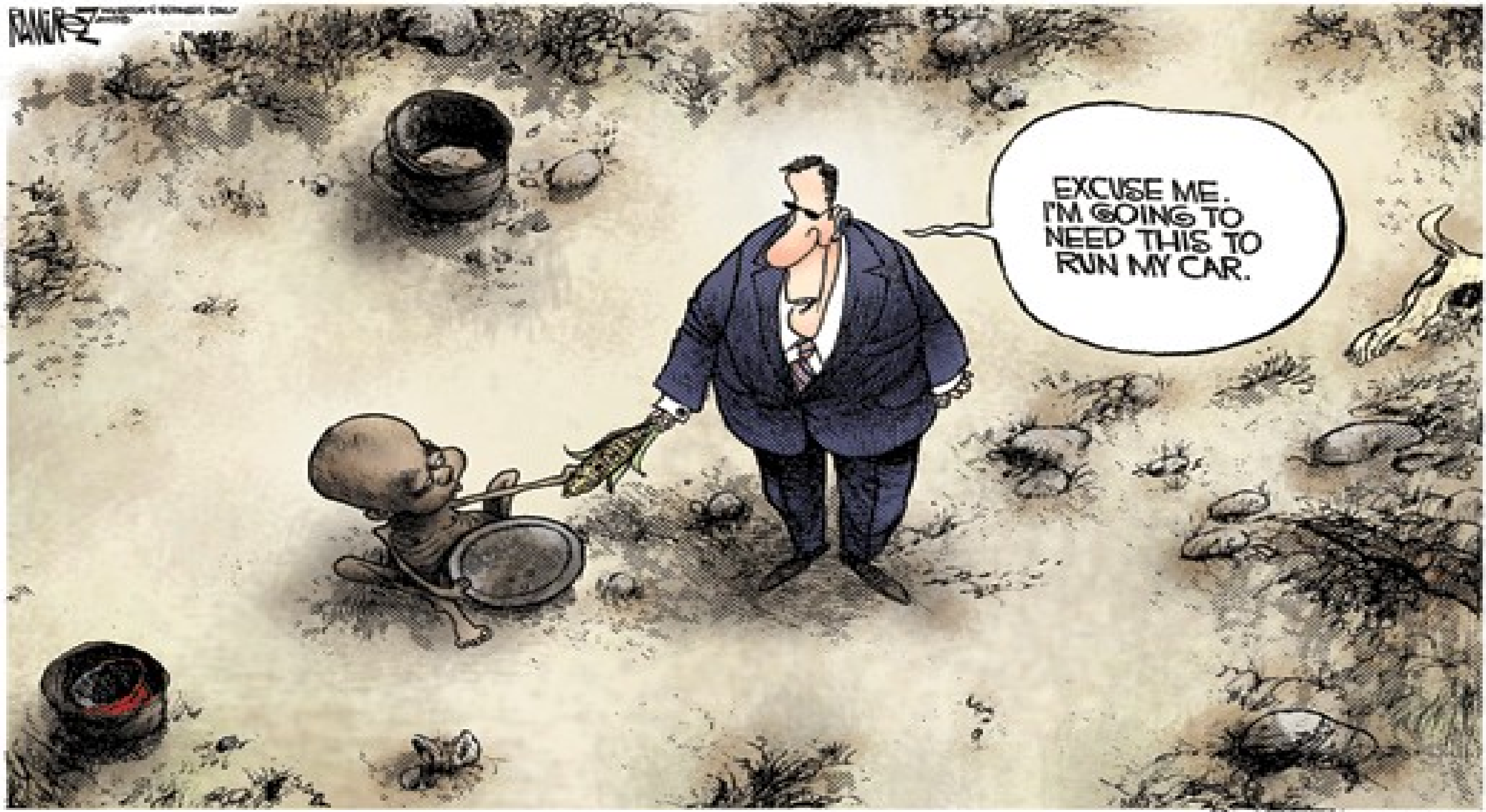
Animal waste

Algae oil

Methods of Biomass to Energy Conversion



- ***Thermal conversion***
  - *Combustion*
  - *Gasification*
  - *Pyrolysis*
- ***Chemical conversion***
  - *Transesterification (biodiesel)*
- ***Biological conversion***
  - *Fermentation (methanol, ethanol, butanol)*
  - *Anaerobic digestion (methane)*
  - *Anaerobic respiration (bio-battery)*


EXCUSE ME. I'M GOING TO NEED THIS TO RUN MY CAR.

Biogas

Anaerobic digestion *is a commercially proven technology and is widely used for recycling and treating wet organic waste and waste waters. It is a type of fermentation that converts* ***organic material*** *into* ***biogas****, which mainly consists of* ***methane*** *(approximately 60%) and carbon dioxide (approximately 40%) and is comparable to landfill gas.*

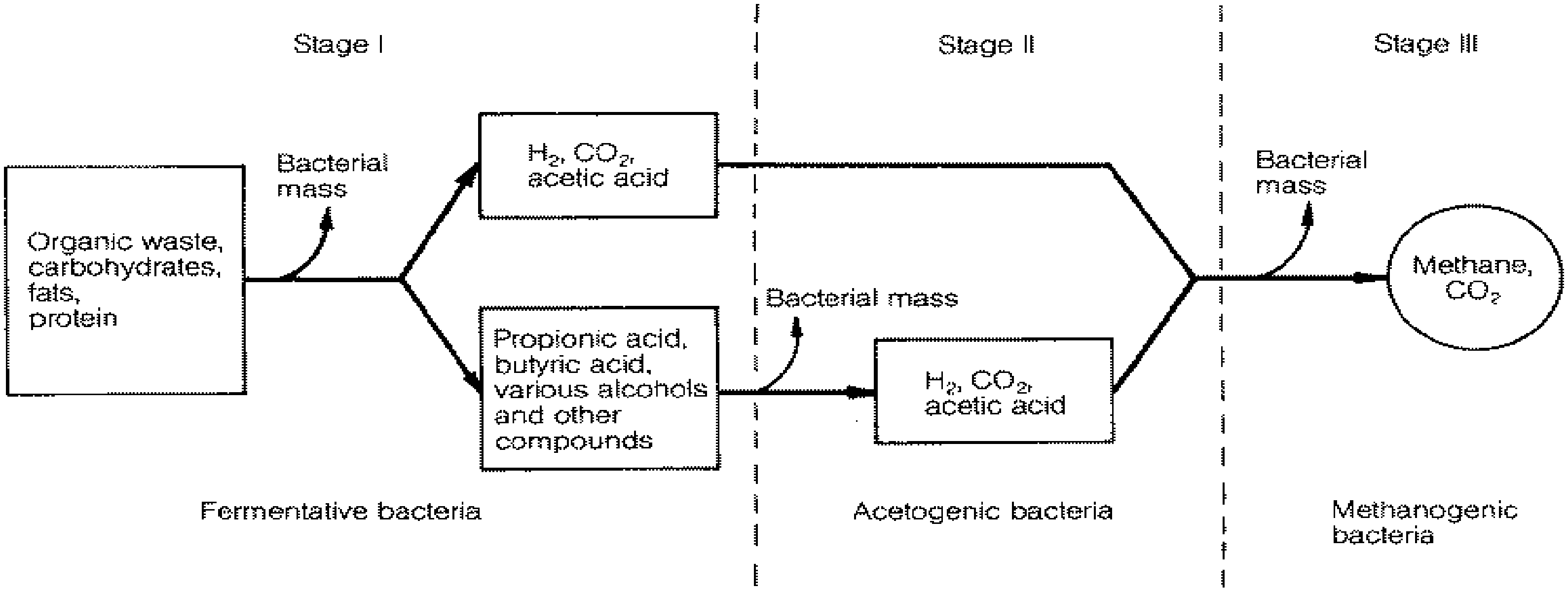
Virtually ***any biomass except lignin*** *(a major component of wood) can be converted to biogas—including animal and human wastes, sewage sludge, crop residues, industrial processing byproducts, and landfill material.*

The conversion of animal wastes and manure to methane/biogas can yield significant health and environmental benefits.

Biogas Production

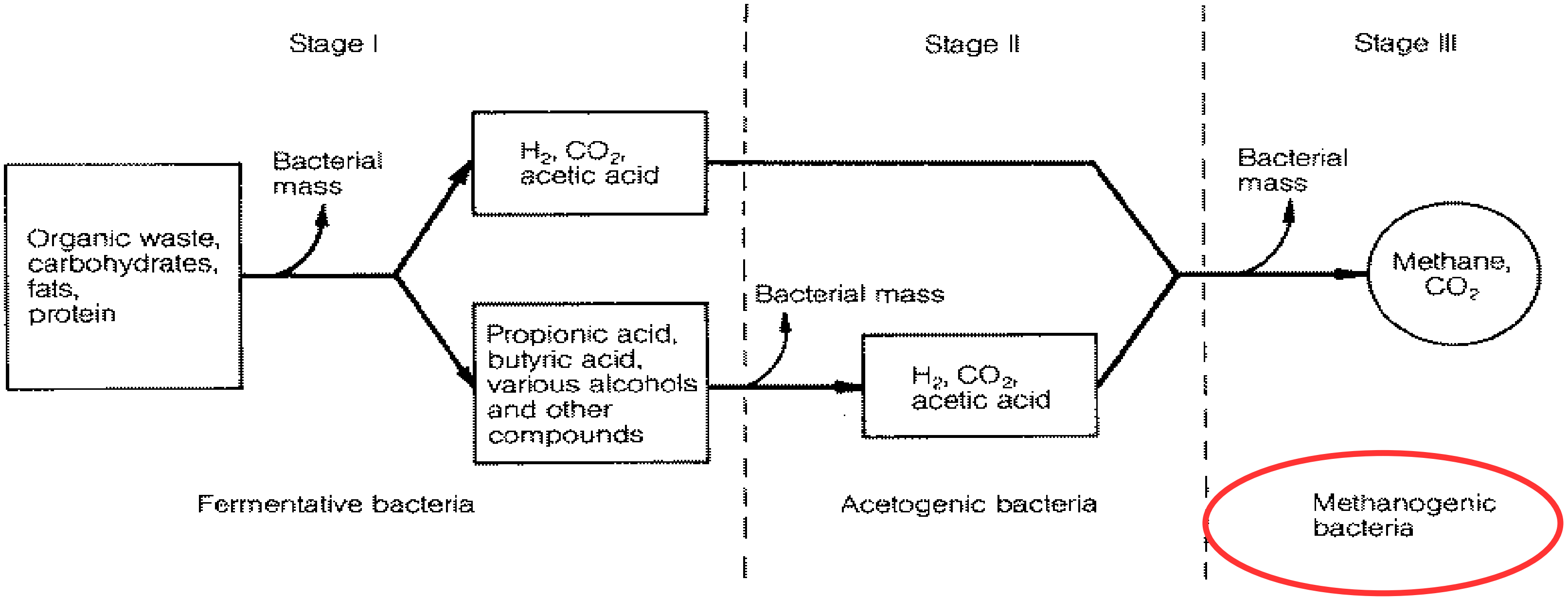
Biomass is fermented in a multistep process to produce secondary wastes (together with bio-fertilizers and other compounds) and methane (together with other compounds that need to be removed)

Biogas Microbiology



A complex consortia of microorganisms is able to convert waste into Biogas (mainly CH_4) for use in cogenerators and as energy source.

Biogas Microbiology



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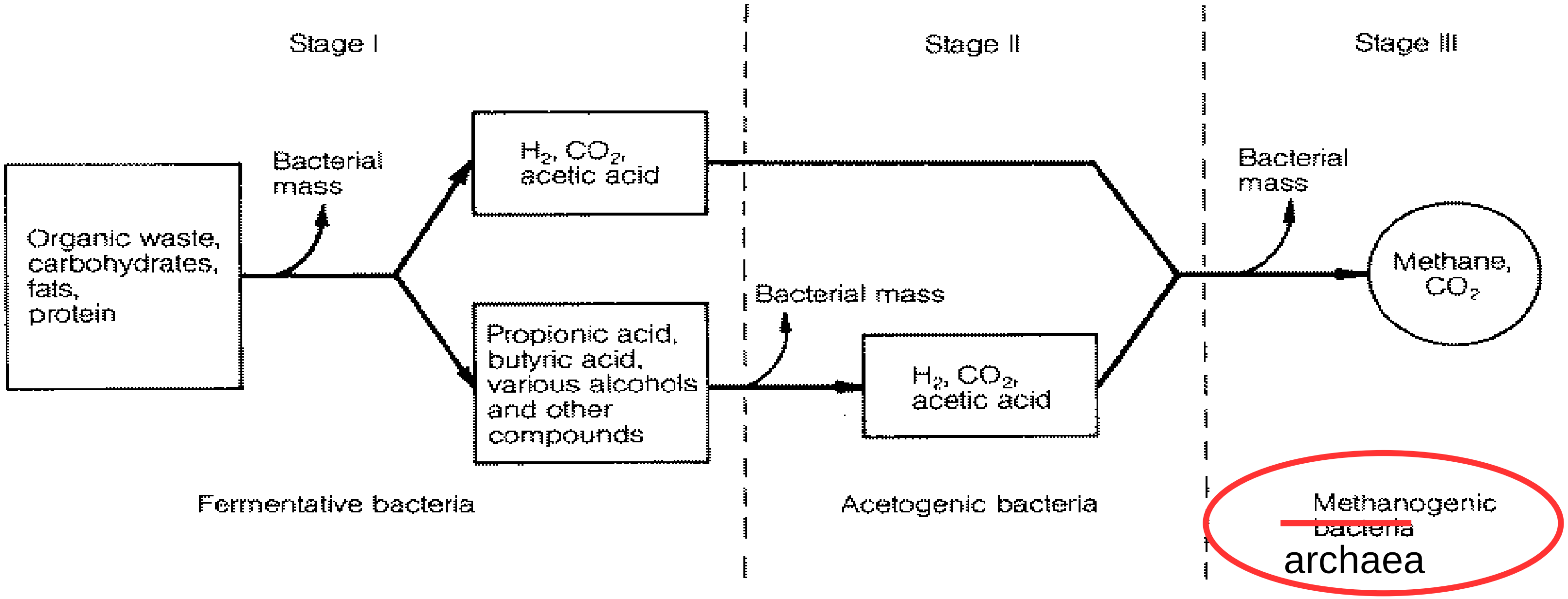
Biogas Microbiology



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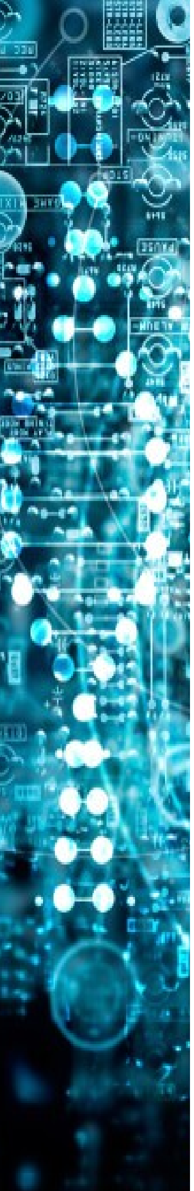
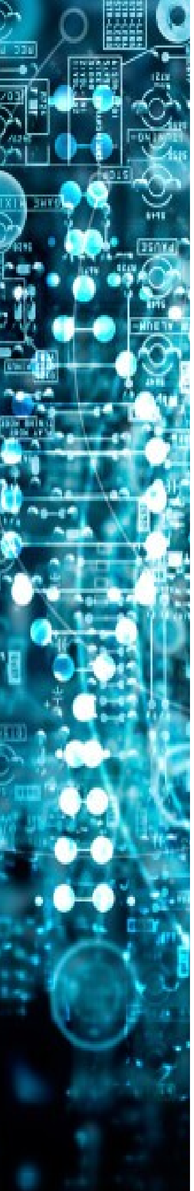


Biorefineries

An emerging concept to be aware of is ***biorefineries****. A biorefinery involves the* ***co-production*** *of a spectrum of* ***bio-based products*** *(food, feed, materials, chemicals)* ***and energy*** *(fuels, power, heat) from biomass.*

A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and value-added chemicals from biomass. The biorefinery concept is ***analogous to today's petroleum refinery****, which produces multiple fuels and products from petroleum.*

A biorefinery could, for example, produce one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel such as biodiesel or bioethanol. At the same time, it can generate electricity and process heat, for its own use and perhaps enough for sale of electricity to the local utility.



Biobatteries

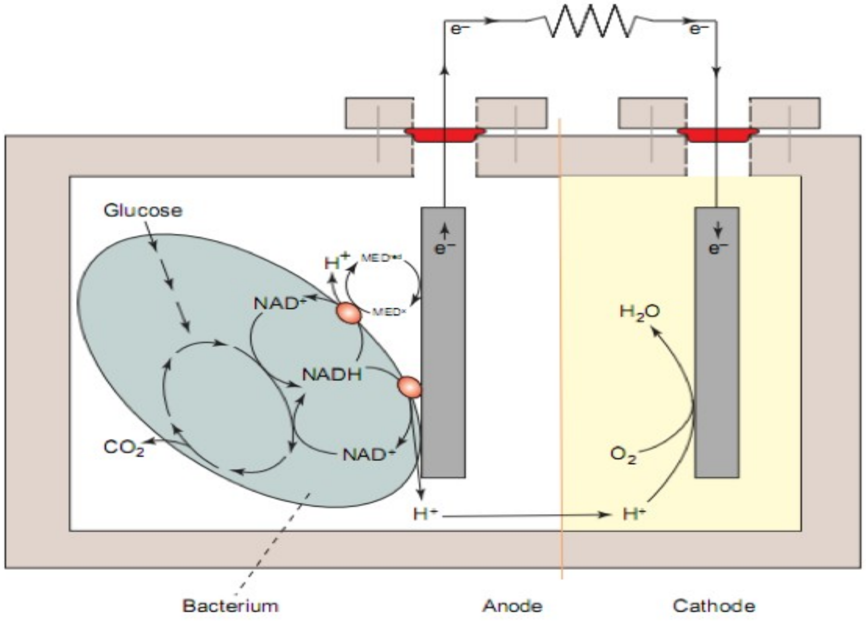
An emerging technology is the direct use of ***microbial metabolism*** *to produce* ***electrical currents****, called Biobatteries.*

This technology takes advantage of the ability of certain microbes to use a solid metal substrate as ***electron acceptor of their respiratory chain.*** *This effectively couples the degradation of an organic substrate to the capacity of producing an electrical current.*

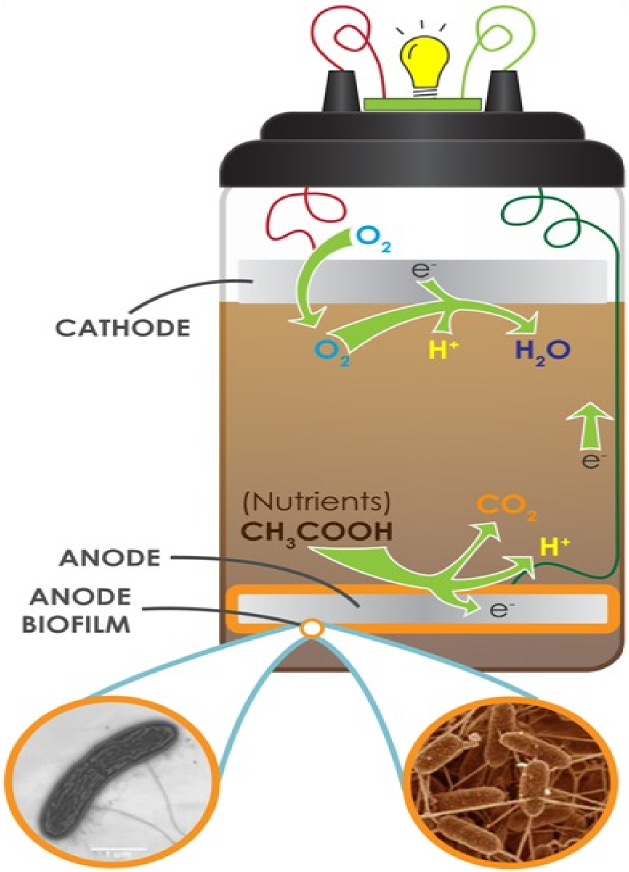
The technology is under development, however has the potential to be transformative, especially if coupled to waste biomass. Current biobatteries use sugars (glucose) as main source of energy.

Several prototypes and patents have already proven their ability to power small scale everyday electronic devices.

Biobatteries



TRENDS in Biotechnology



Electrons flow from an anode through a resistor to a cathode where electron acceptors are reduced. Protons flow across a proton exchange membrane (PEM) to complete the circuit.

Back to the Future, 1985

Bioplastics: mainly PHA and PHB

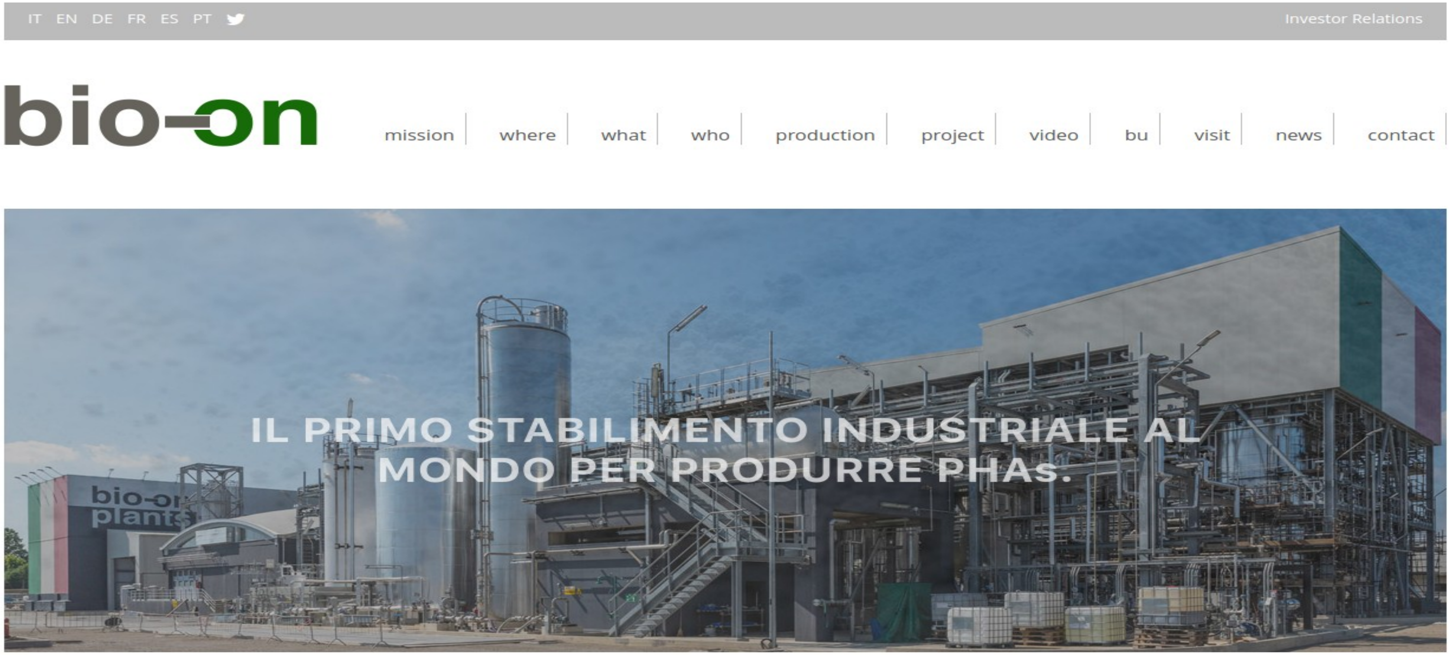
Bioplastics are plastics derived from **renewable biomass** sources, such as vegetable fats and oils, corn starch, straw, woodchips, food waste, etc.

Many different types exist: **cellulose exters**, **celluloid**, **nitrocellulose**, **polylactic acid** (from corn mainly), **PA11** (from vegetable oils), **polyethylene from bioethanol**, **polyurethanes** and **epoxies** (from microalgae oils).

Current focus is on a **biobased** AND **biodegradable** type of biopolymer:

Polyhydroxyalkanoates (PHA) area class of linear polyesters produced in nature by bacterial fermentation of sugar or lipids. They have characteristics similar to those of the petroplastic polypropylene.

Case Study: Bio-On Spa



www.bio-on.it

Case Study: Bio-On Spa

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il Resto del Carlino BOLOGNA

CRONACA SPORT COSA FARE EDIZIONI VIRUS MARCHE VENETO MASCHERINE GERIATRIA BURIONI MES

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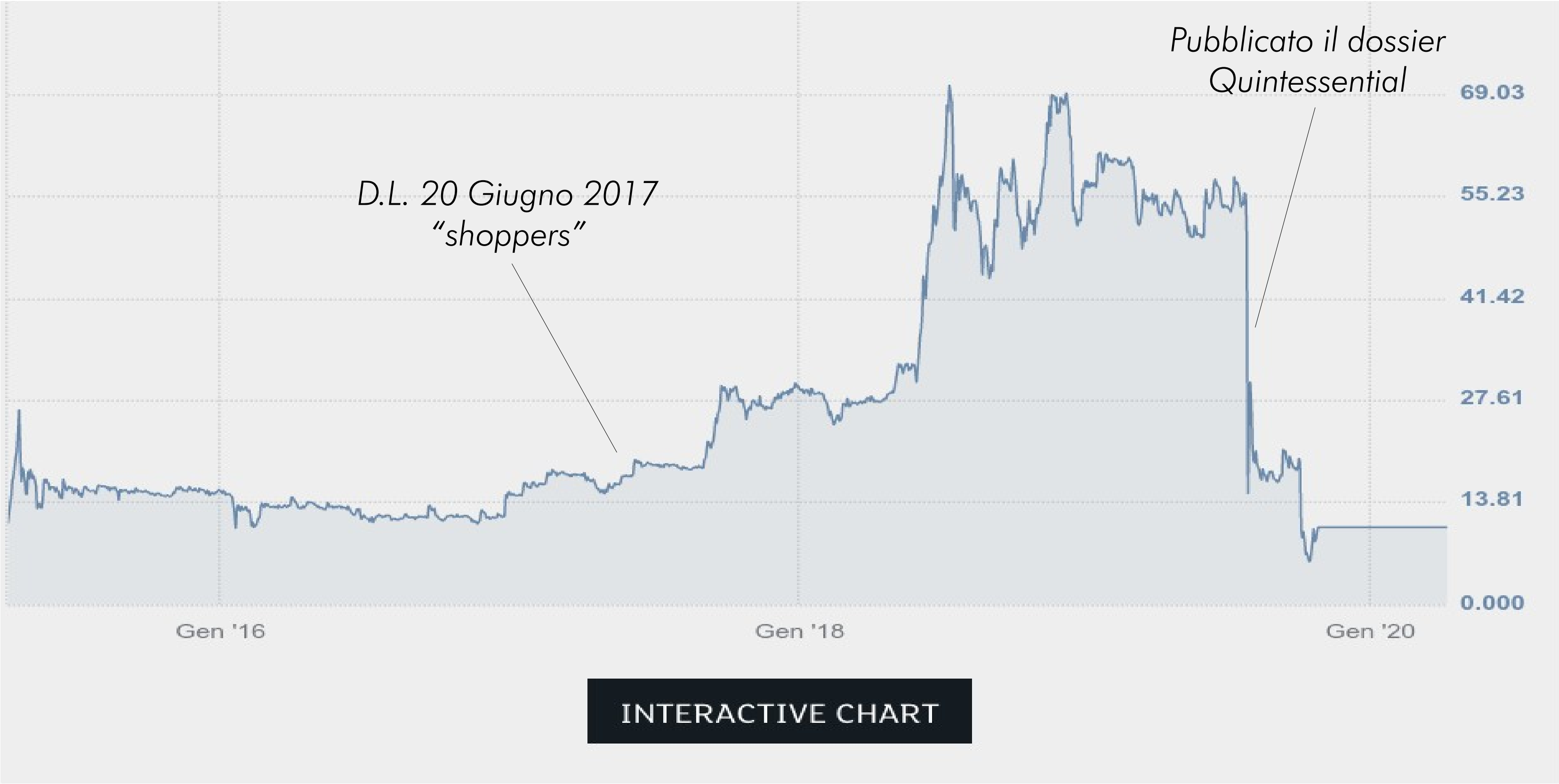
Pubblicato il **14 gennaio 2020**

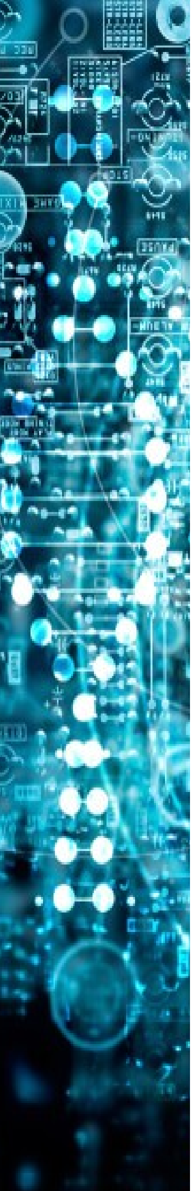
Bio on, parla il fondatore Astorri. "Una rivoluzione, perciò ci hanno fermato"

Intervista esclusiva all'ex presidente (indagato) dopo il fallimento: "Il potenziale tecnologico resta enorme. Vittime di un attacco speculativo ben preparato"

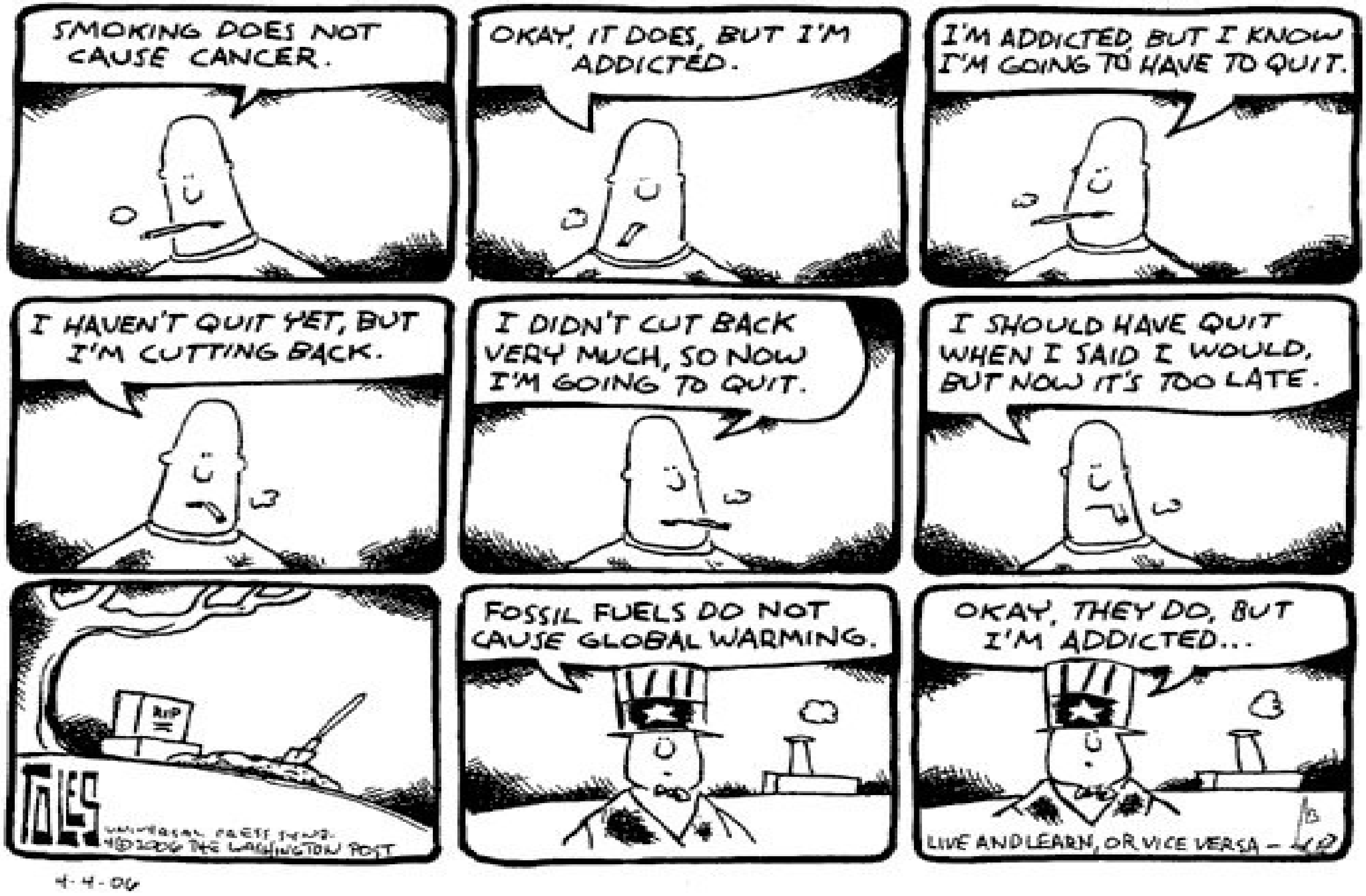
di NICOLA BIANCHI E RICCARDO RIMONDI

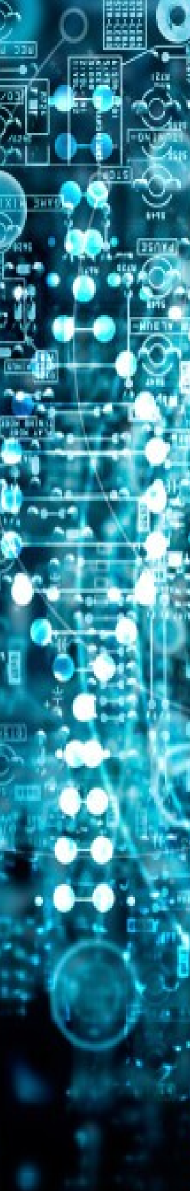
Case Study: Bio-On Spa





CLIMATE ENGINEERING


SMOKING DOES NOT CAUSE CANCER.
OKAY, IT DOES, BUT I'M ADDICTED.
I'M ADDICTED BUT I KNOW I'M GOING TO HAVE TO QUIT.
I HAVEN'T QUIT YET, BUT I'M CUTTING BACK.
I DIDN'T CUT BACK VERY MUCH, SO NOW I'M GOING TO QUIT.
I SHOULD HAVE QUIT WHEN I SAID I WOULD, BUT NOW IT'S TOO LATE.
RIP
TOLES
FOSSIL FUELS DO NOT CAUSE GLOBAL WARMING.
OKAY, THEY DO, BUT I'M ADDICTED...
LIVE AND LEARN, OR VICE VERSA –
4-4-06



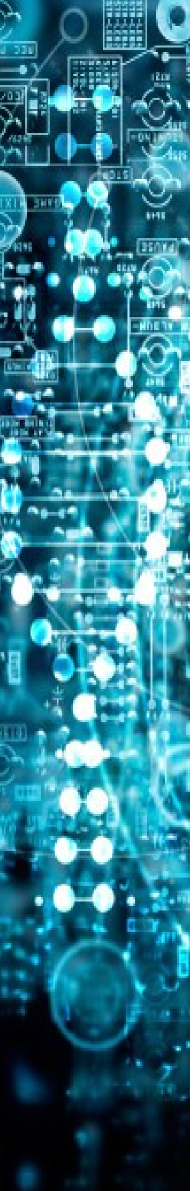
Climate Engineering: Geoengineering

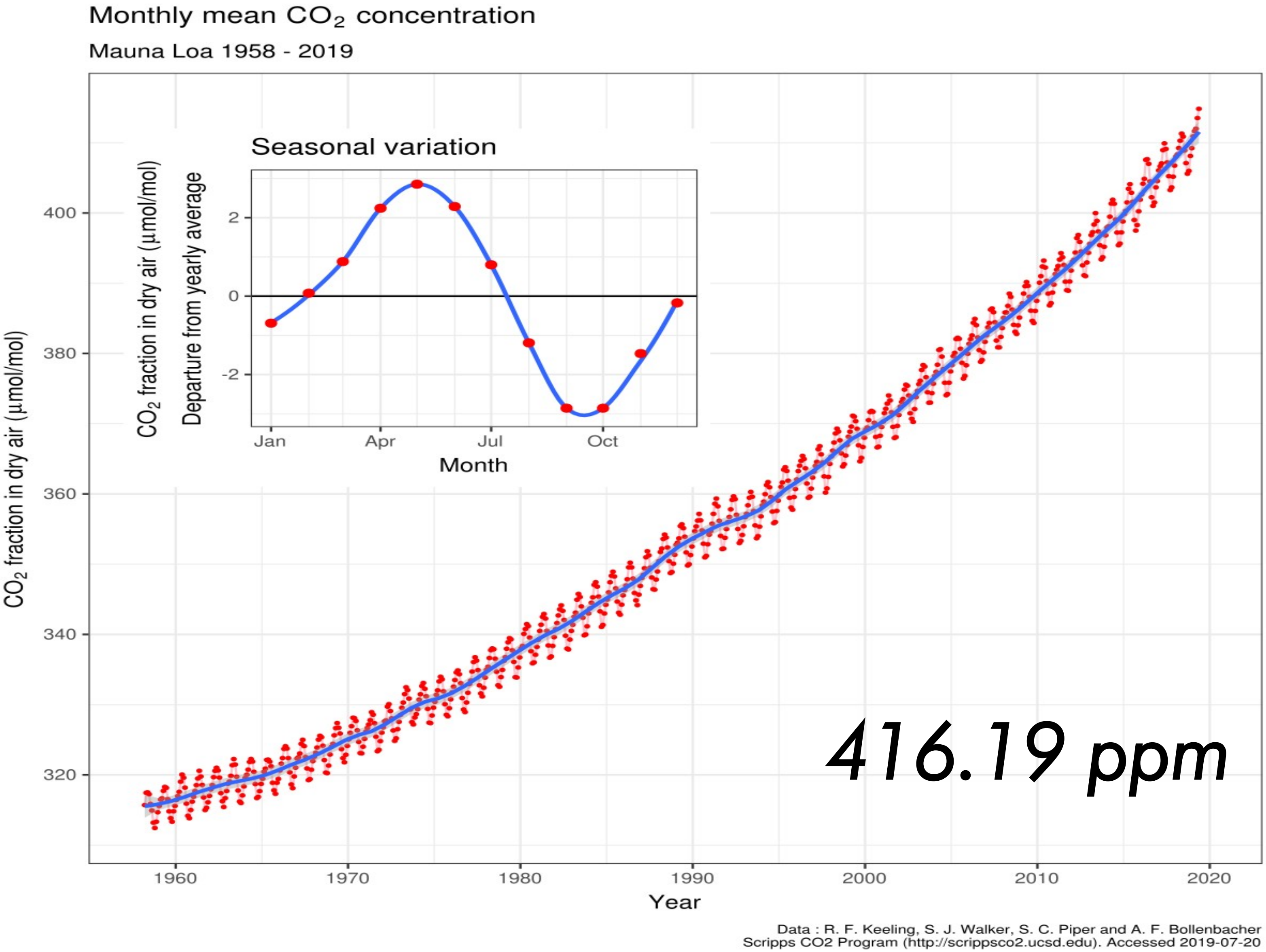
*Refers to actions **deliberately taken** in order to alter the natural functioning of processes that can **directly or indirectly** help with the **mitigation of the climate ~~change~~ crisis**, global warming and the increase of CO_2 in the atmosphere*

*Geoengineering is the deliberate modification of Earth's environment on a large scale "**to suit human needs and promote habitability**"*

Over the years it has focused on different aspect of the issue, tacking the problem with different technological approach

*These can be broadly divided in **Solar Radiation Management** and **Carbon Sequestration***

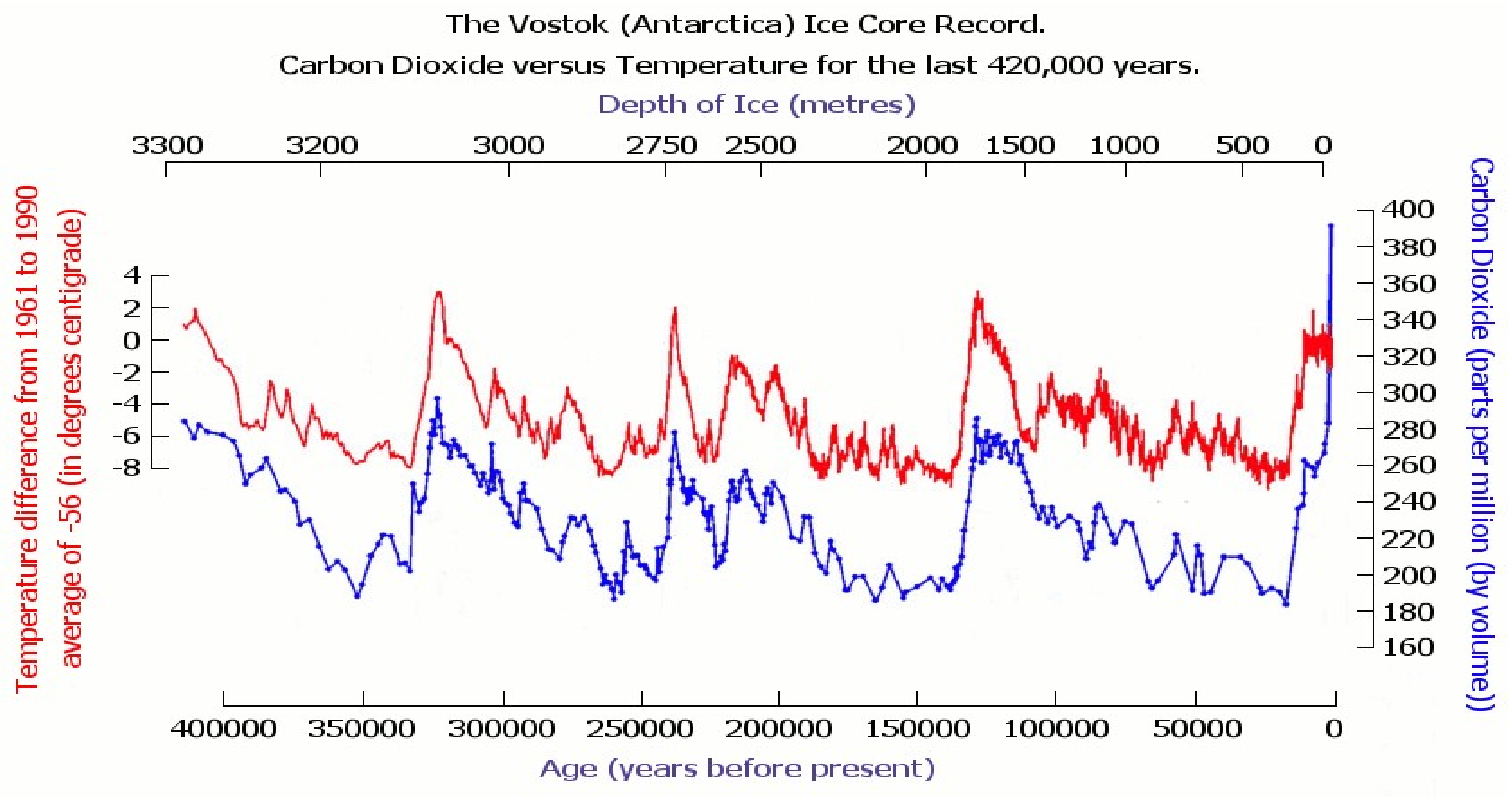


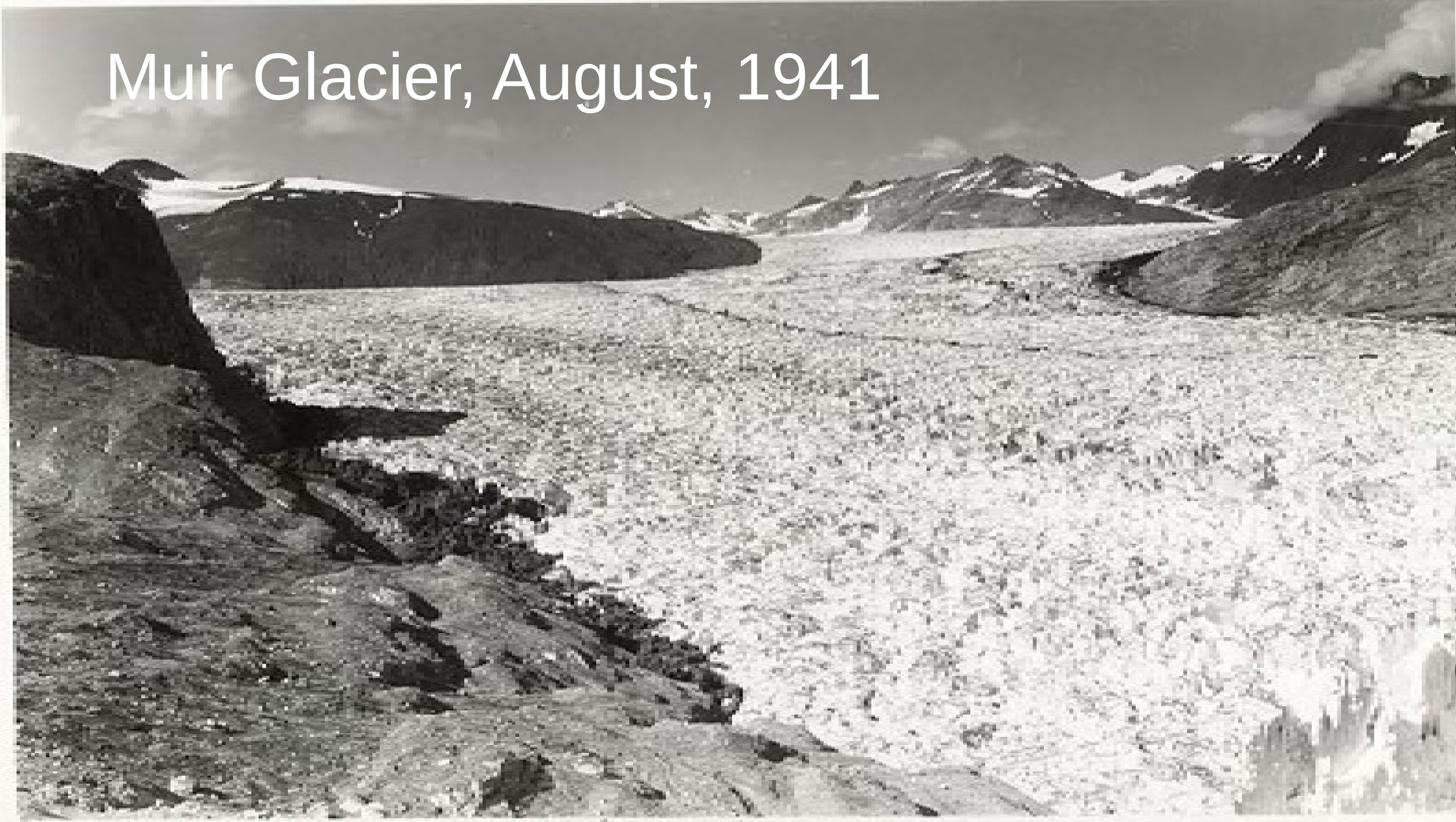


Monthly mean CO_2 concentration
Mauna Loa 1958 - 2019
Seasonal variation
CO_2 fraction in dry air (µmol/mol)
Departure from yearly average
2
0
-2
Jan
Apr
Jul
Oct
Month
400
380
360
340
320
1960
1970
1980
1990
2000
2010
2020
Year
Data : R. F. Keeling, S. J. Walker, S. C. Piper and A. F. Bollenbacher
Scripps CO2 Program (http://scrippsco2.ucsd.edu). Accessed 2019-07-20

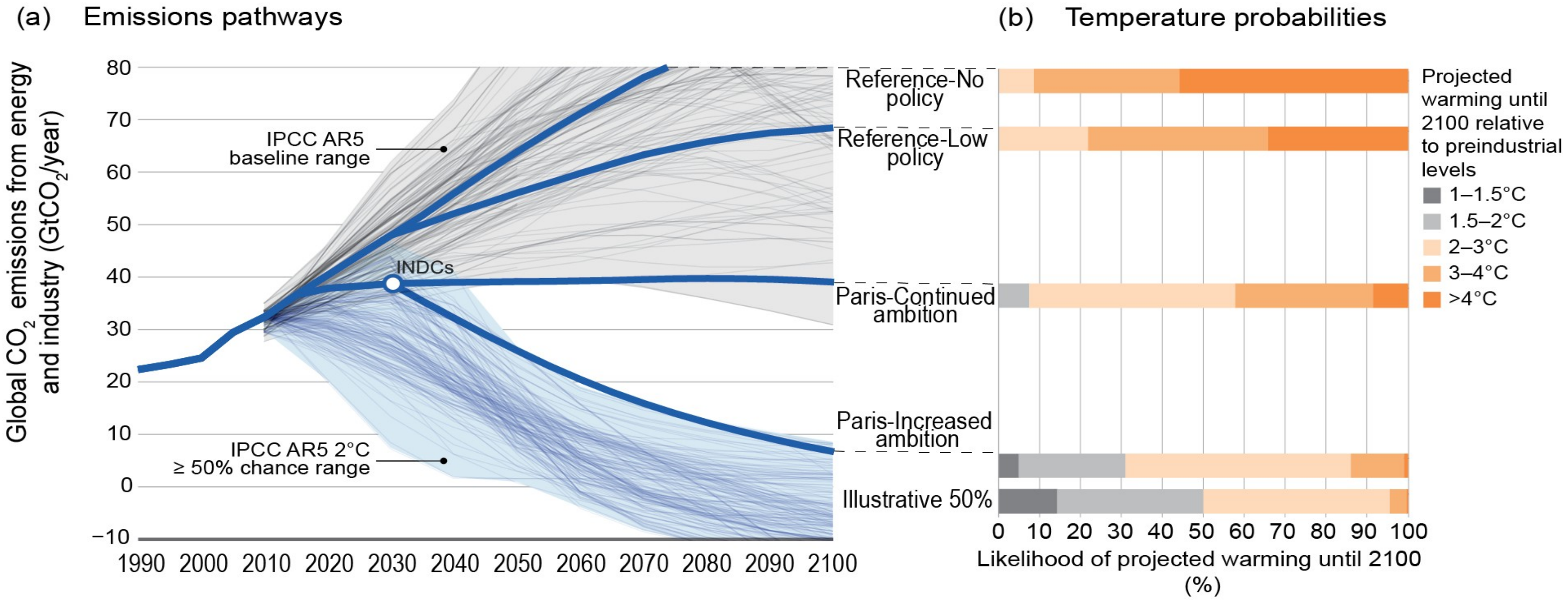
416.19 ppm

CO2 – Temperature correlations




Muir Glacier, August, 1941

Muir Glacier, August, 2004



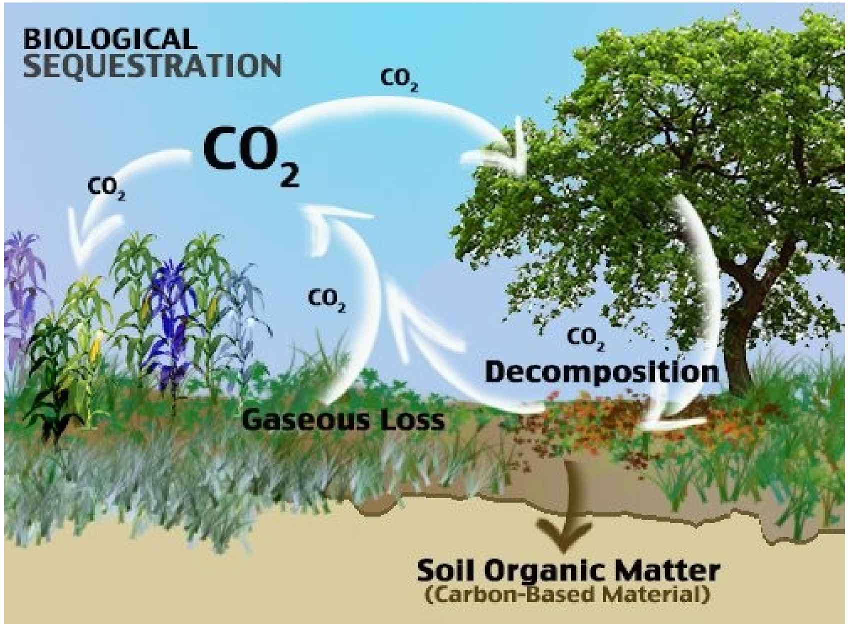
Wikipedia, Global CO2 emissions and probabilistic temperature outcomes of different policies

Biological Sequestration

Biological sequestration is the is the ***capture and storage*** *of the atmospheric greenhouse gas carbon dioxide by biological processes*

This may be by increased ***primary productivity*** *(reforestation, biological carbon pump) or by* ***preventive measures*** *(avoid deforestation)*

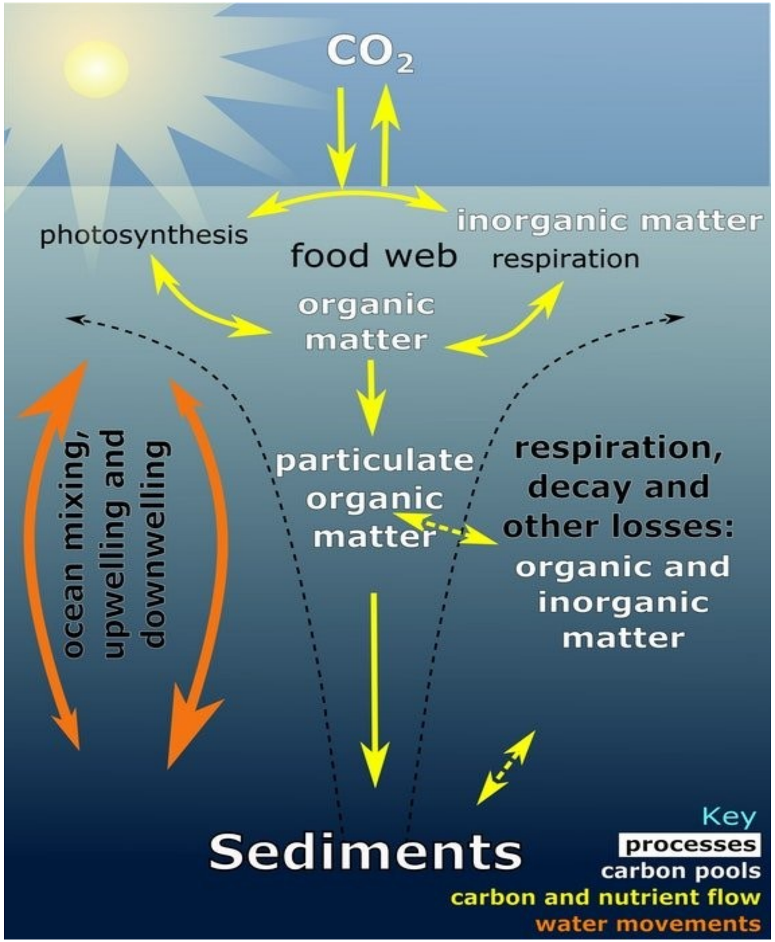
Storage can be achieved in different ways, such as through ***burrial*** *or* ***immobilization*** *in refractory fractions of organic matter*

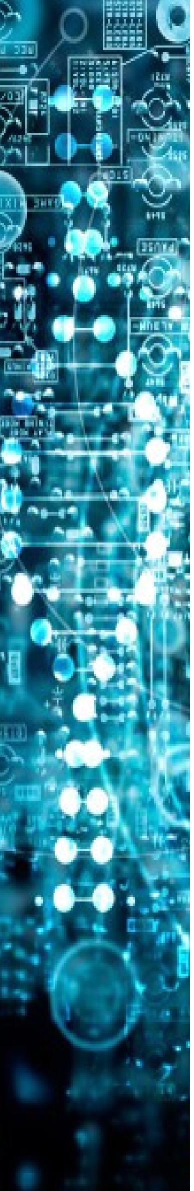


Biological Carbon Pump

*The **biological pump**, in its simplest form, is the ocean's biologically driven sequestration of carbon from the atmosphere to the **ocean interior** and **seafloor sediments***

*It is the part of the oceanic carbon cycle responsible for the sequestering organic matter formed mainly by phytoplankton during **photosynthesis** (soft-tissue pump), as well as the cycling of **calcium carbonate** ($CaCO_3$) formed into shells by certain organisms such as plankton and mollusks (carbonate pump)*





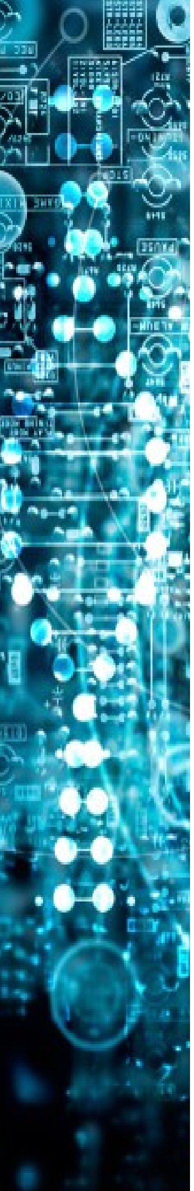
Carbonation of Rocks

Carbon, in the form of CO2 can be removed from the atmosphere by chemical processes, and stored in **stable carbonate mineral** forms. This process is known as 'carbon sequestration by mineral carbonation' or mineral sequestration.

The process involves reacting carbon dioxide with abundantly available metal oxides–either magnesium oxide (MgO) or calcium oxide (CaO)–to **form stable carbonates**.

These reactions are exothermic and **occur naturally** (e.g., the weathering of rock over geologic time periods).

Some rocks are **more prone to carbonation**, and therefore are primary target for carbon storage studies



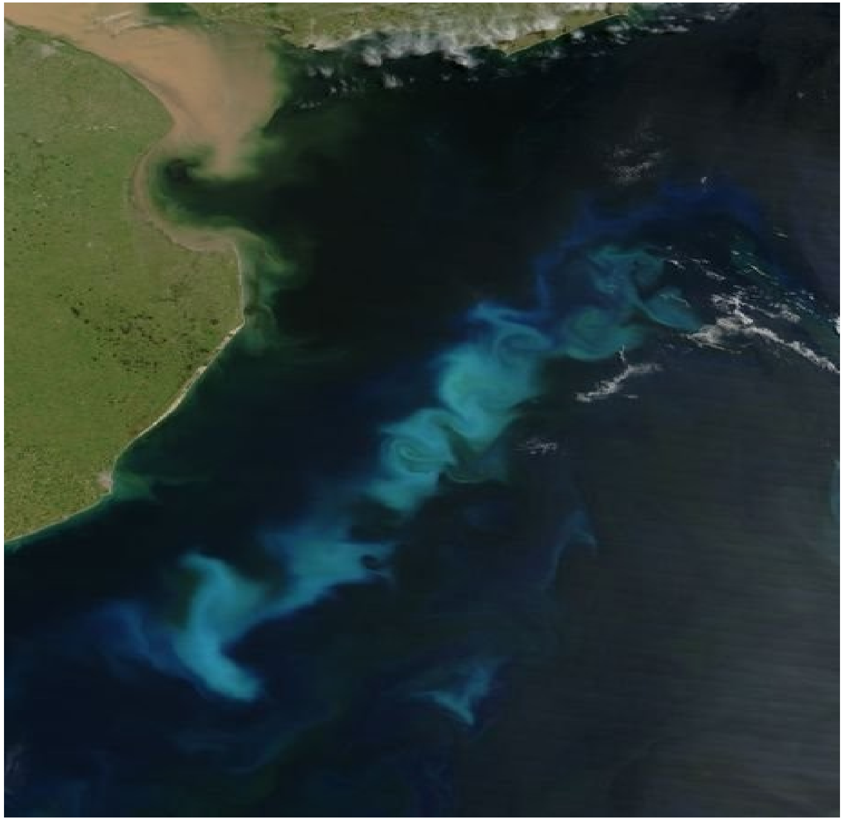
Carbon Sequestration: Ocean

Primary Productivity in the Ocean

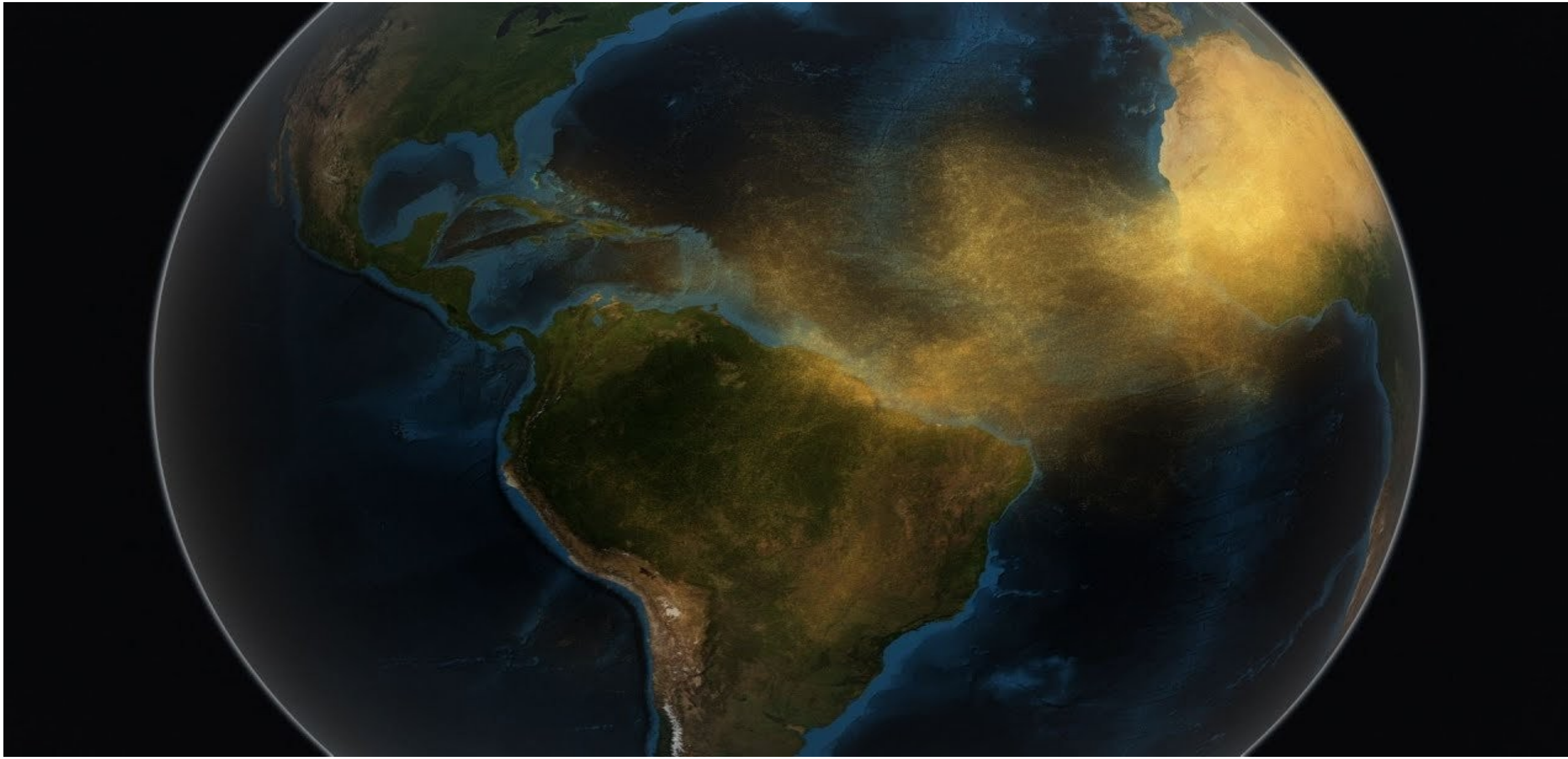
Primary productivity is limited in the ocean by the penetration of the **solar radiation**, **nutrient** availability and **iron** concentrations

Besides photosynthesis, plankton that **generate calcium or silica carbonate** skeletons, such as diatoms, coccolithophores and foraminifera, account for most direct carbon sequestration

When these organisms die 20-30% of their carbonate skeletons **sink to the seafloor** and get buried in sediments



Natural Iron Fertilization



“Give me a few oil tankers full of iron, and I’ll give you an ice age.”

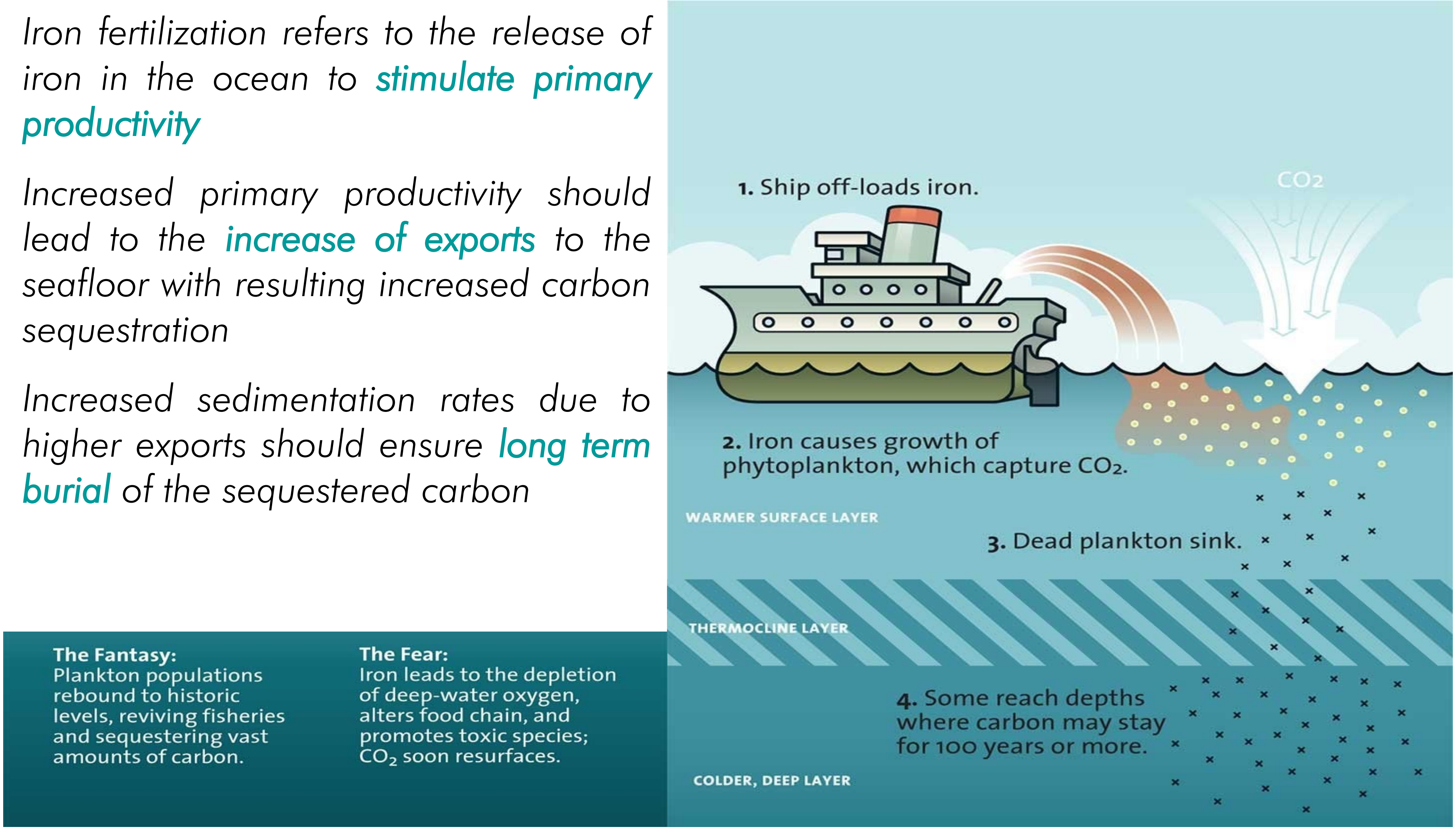
– John Martin, WHOI Scientist

Iron Fertilization

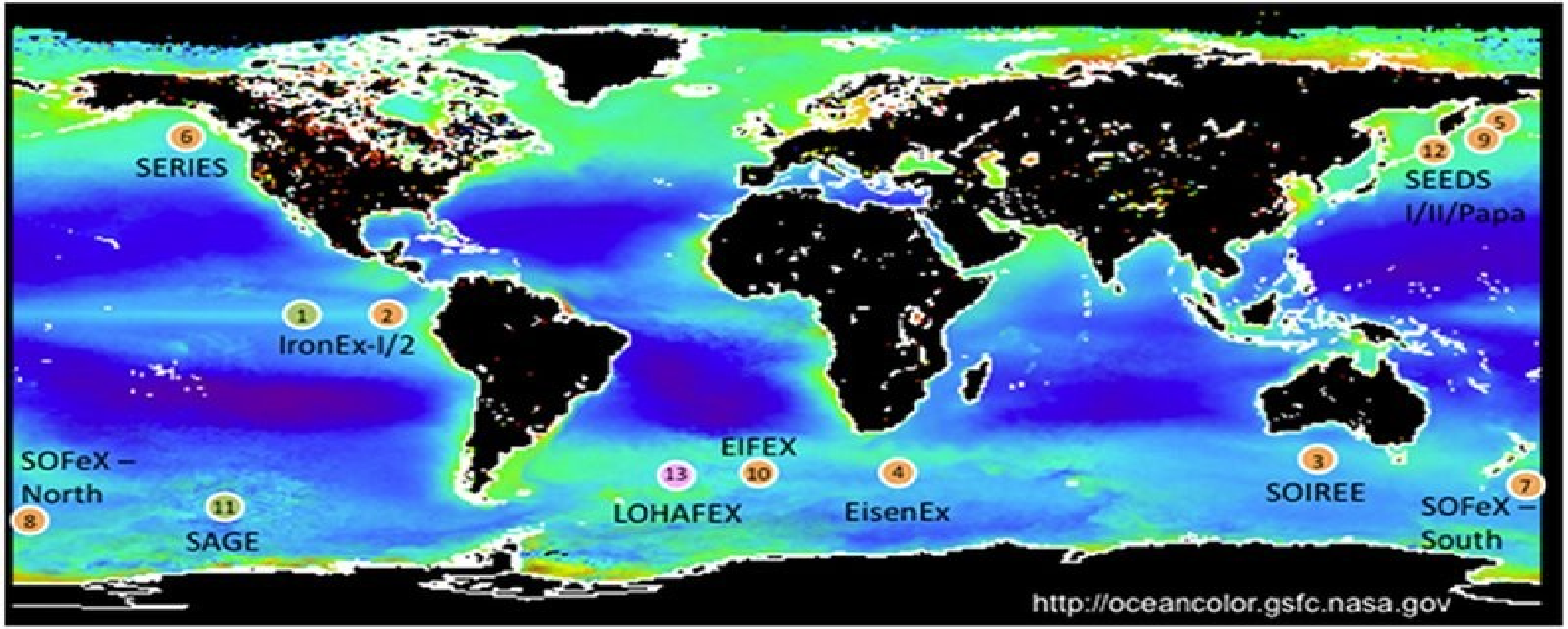
Iron fertilization refers to the release of iron in the ocean to **stimulate primary productivity**

Increased primary productivity should lead to the **increase of exports** to the seafloor with resulting increased carbon sequestration

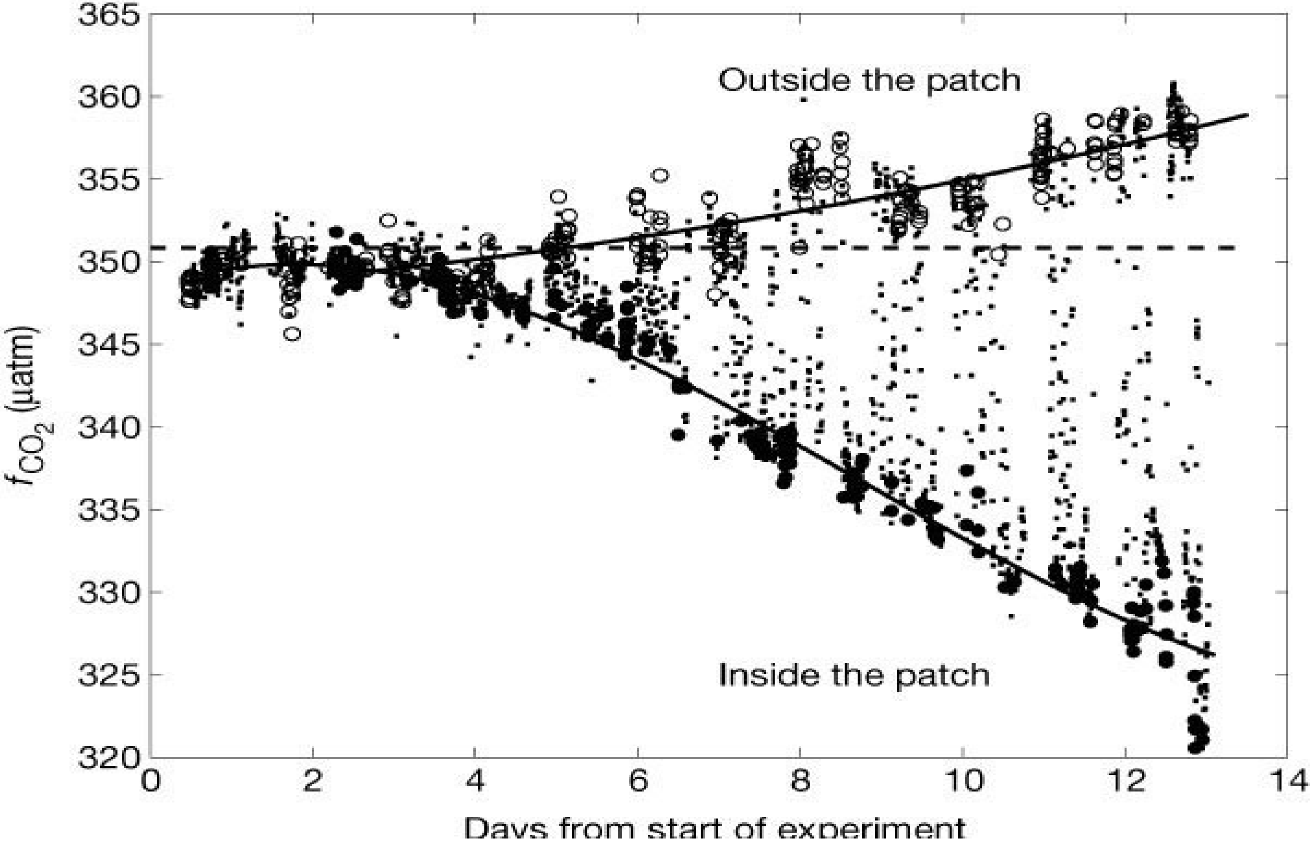
Increased sedimentation rates due to higher exports should ensure **long term burial** of the sequestered carbon



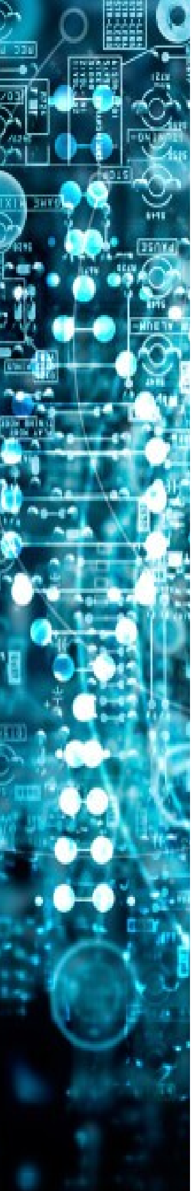
Iron Fertilization



Quantifiable reduction in atmospheric CO_2 in "patches" of iron fertilization. SOFEX Experiment



Watson et al, 2000 Nature

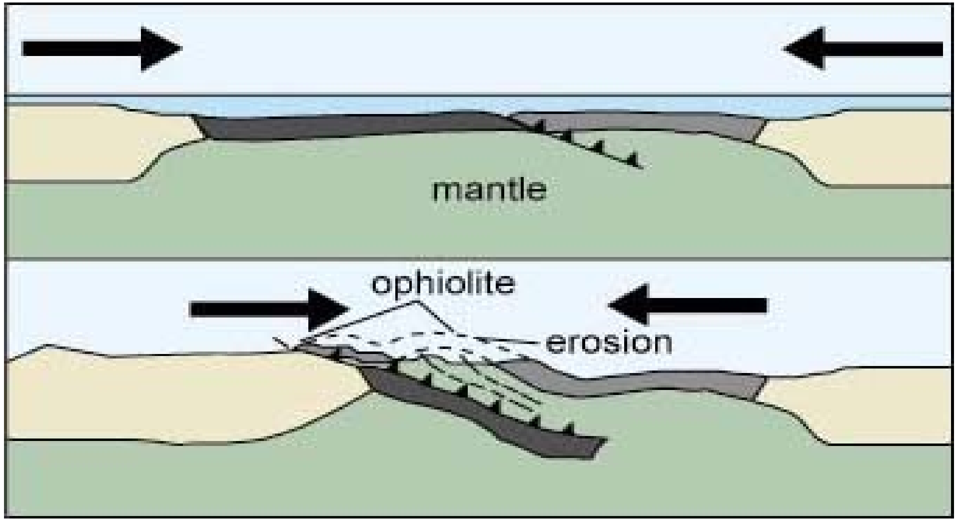


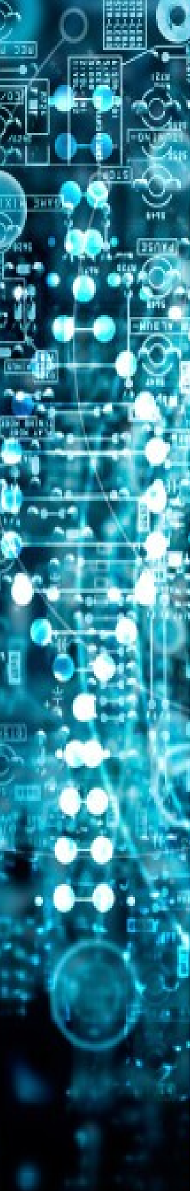
Carbon Sequestration: Underground

Natural Carbon Sequestration

*An **ophiolite** is a section of the Earth's oceanic crust and the underlying upper mantle that has been uplifted and exposed above sea level and often emplaced onto continental crustal rocks*

Made of mantle rocks (peridotite) rich in iron and magnesium, they react with water and CO_2, sequestering carbon into carbonate





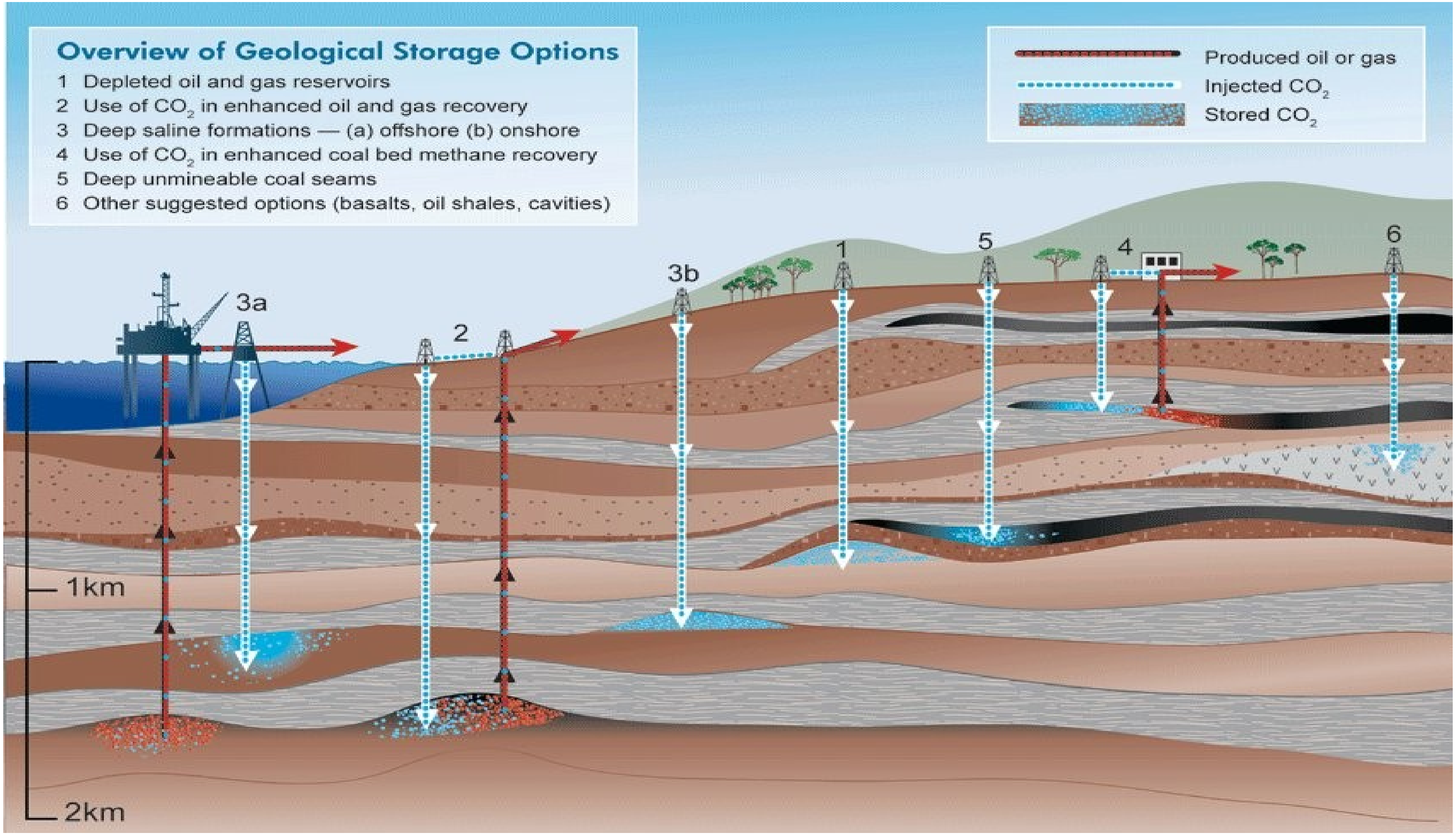
Manmade Carbon Sequestration

Geological sequestration refers to the storage of CO2 underground in depleted oil and gas reservoirs, saline formations, or deep, un-minable coal beds

Once CO2 is captured from a gas or coal-fired power plant, it would be compressed to ≈100 bar so that it would be a supercritical fluid. In this fluid form, the CO2 would be easy to transport via pipeline to the place of storage.

The CO2 would then be injected deep underground, typically around 1 km, where it would be stable for hundreds to millions of years.

Carbon Sequestration

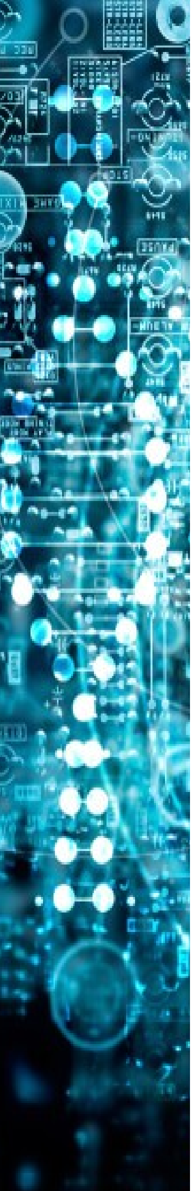


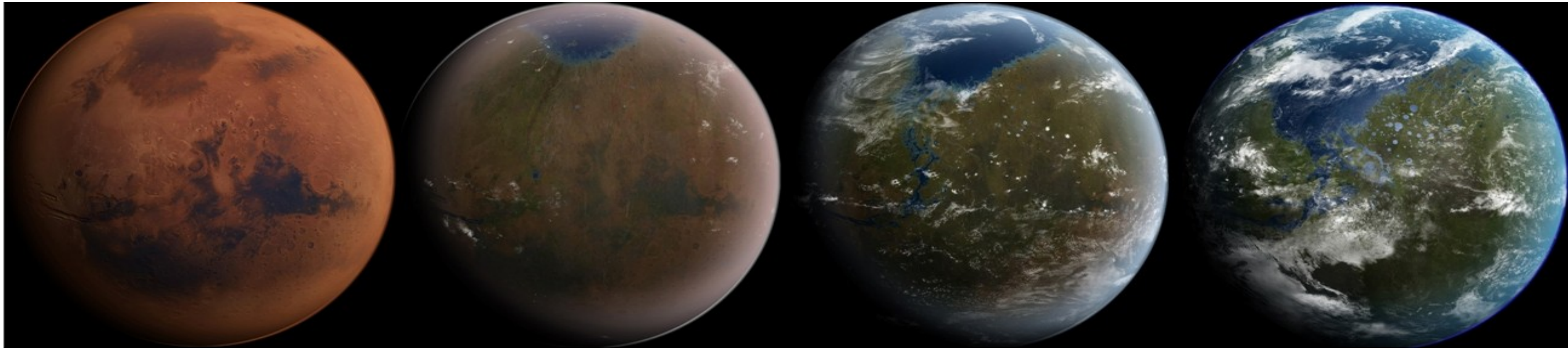
Geoengineering: not just this planet

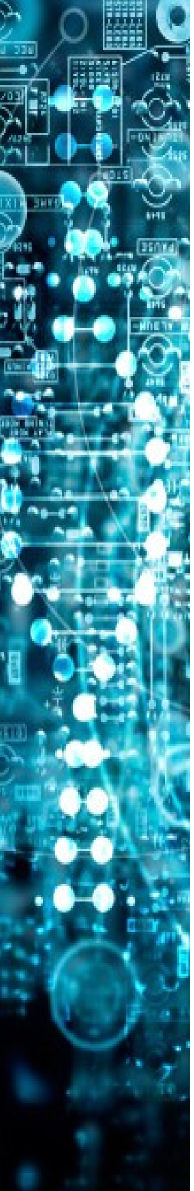
Geoengineering concept can also be applied to ***extraterrestrial planets***

In this case they are often collectively referred to as ***Terraforming***

A number of project exists for example on the possible terraforming of Mars







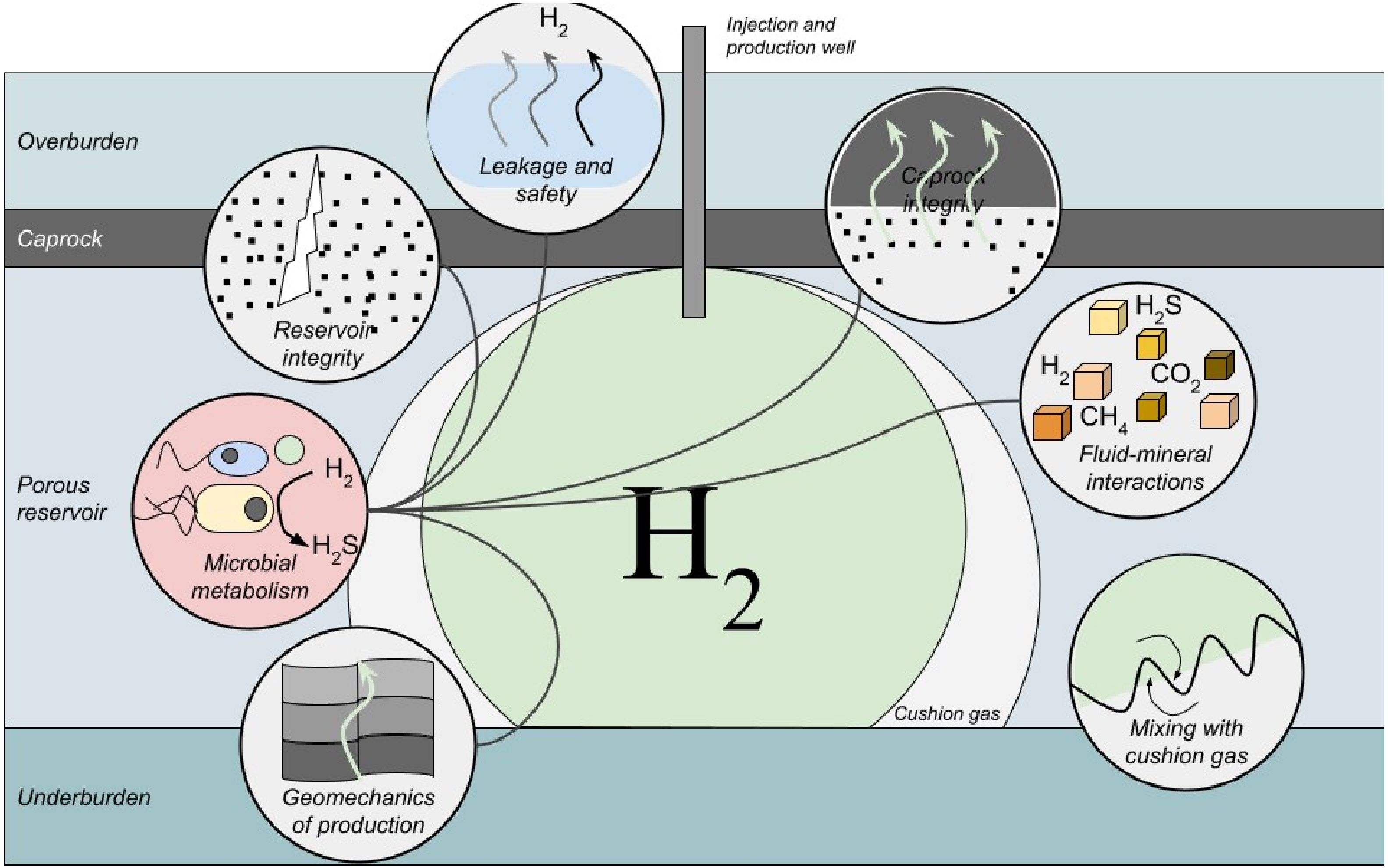
UNDERGROUND HYDROGEN STORAGE

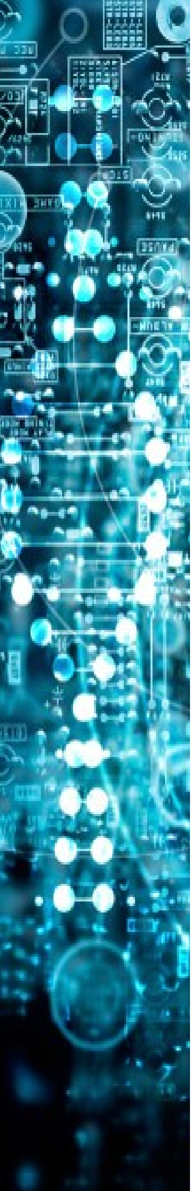
Underground Hydrogen Storage

Renewable energies (RE) will play a key role in decarbonization of our society. However they are for their nature intermittent and not uniformly distributed.

Converting excess energy from RE into hydrogen is a key technology that will allow storage and transportation to meet the societal demands. For safety reason hydrogen is better stored underground

Underground Hydrogen Storage





BIOLEACHING AND BIOMINING

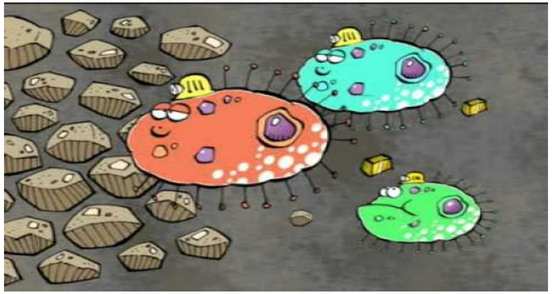
Bioleaching and Biomining

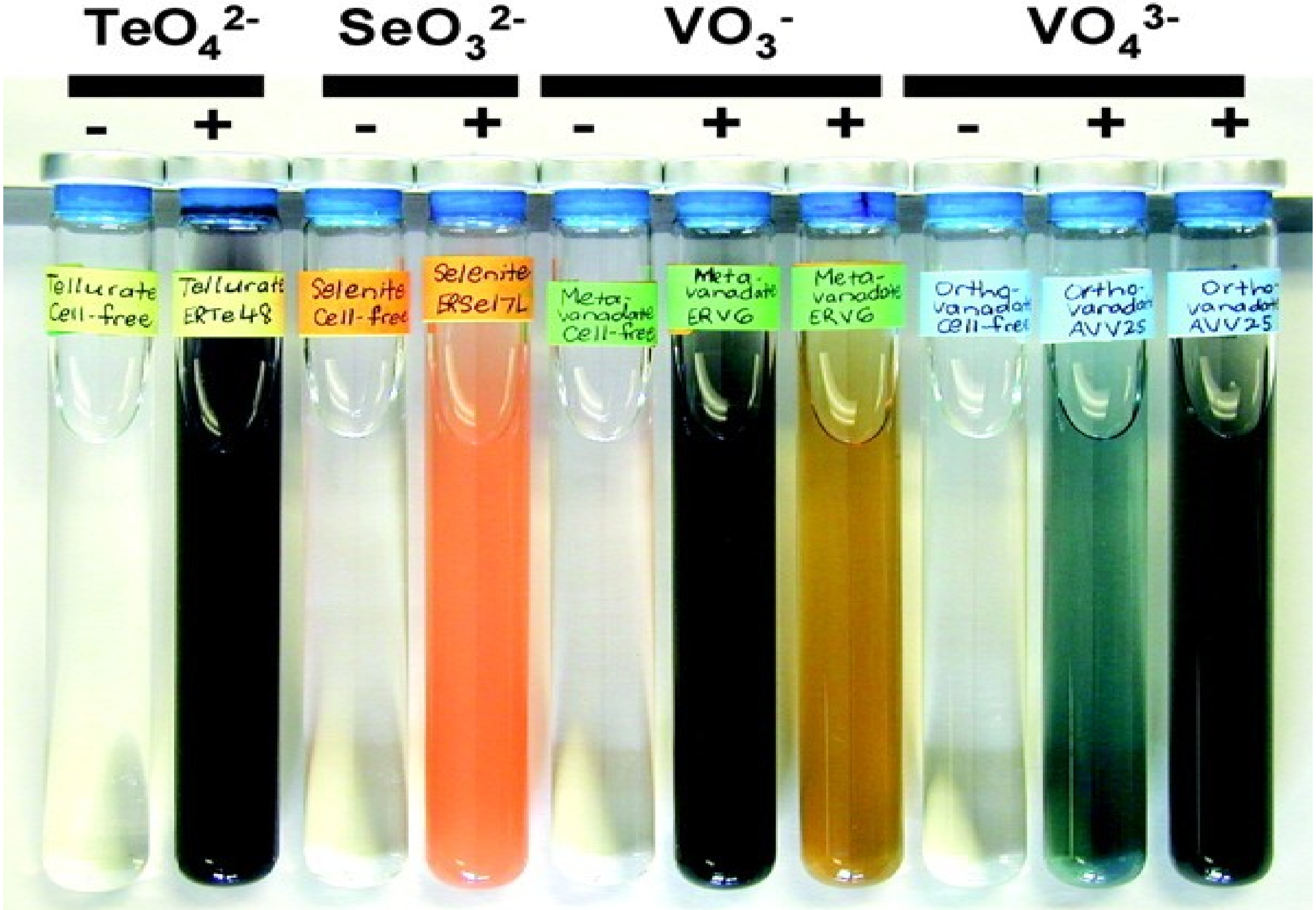
Bioleaching and Biomining are subdivision of **Biohydrometallurgy**, a branch of hydrometallurgy that deals with the employment of biotechnology in hydrometallurgy.

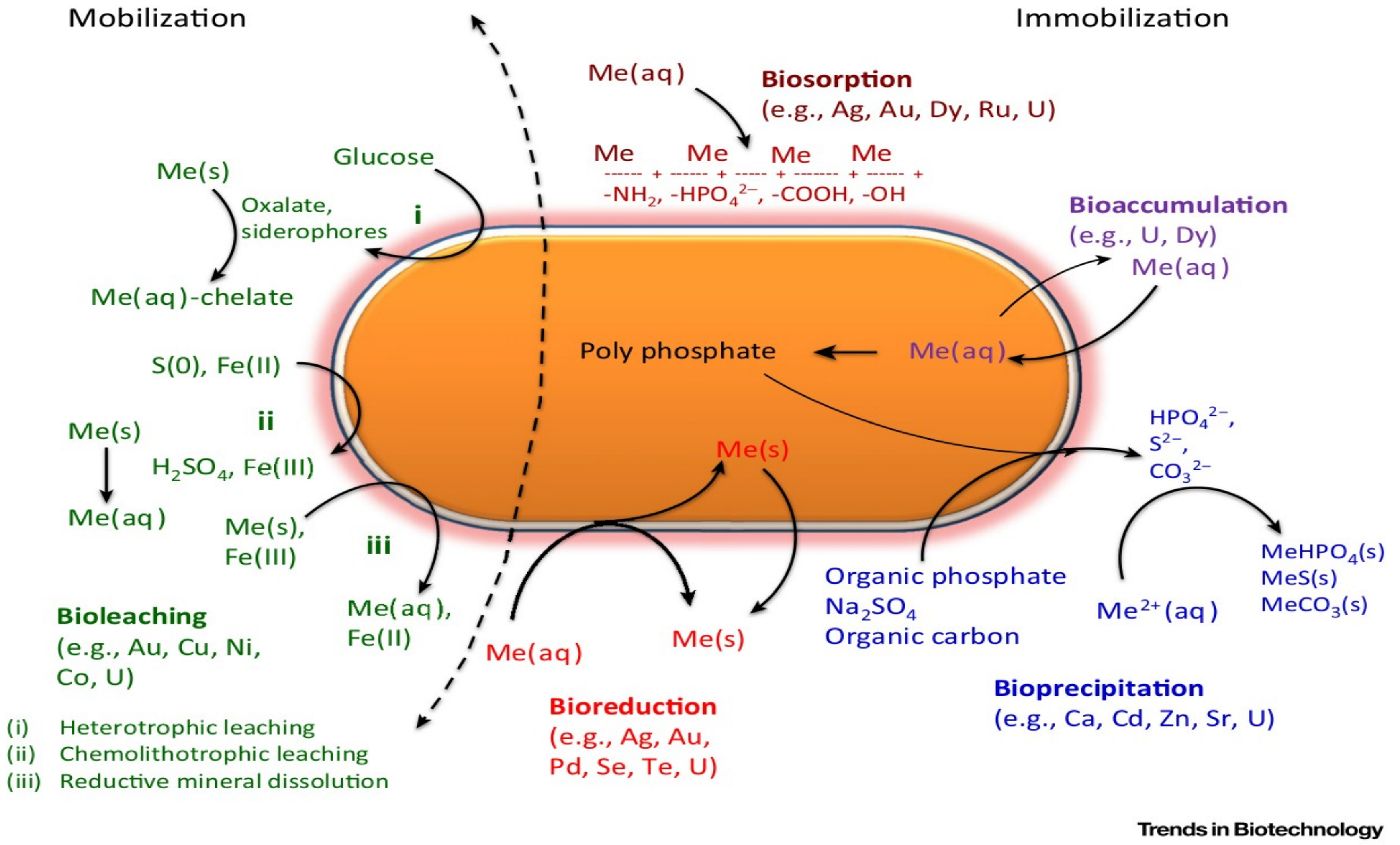
Biomining is the generic term that refers to the use of **biotechnology in mining operations**. The most used form of biomining is bioleaching

Bioleaching is the **solubilization** of metals from their ores through the use of living organisms.

Bioleaching is currently used to recover **copper, zinc, lead, arsenic, antimony, nickel, molybdenum, gold, silver,** and **cobalt**.




TeO_4^{2-}
SeO_3^{2-}
VO_3^{-}
VO_4^{3-}
- + - + - + + - + +
Tellurate Cell-free
Tellurate ERTe48
Selenite Cell-free
Selenite ERSe17L
Meta-vanadate Cell-free
Meta-vanadate ERV6
Meta-vanadate ERV6
Ortho-vanadate Cell-free
Ortho-vanadate AVV25
Ortho-vanadate AVV25



Nancharaiah et al. 2016 Trends in Biotechnology

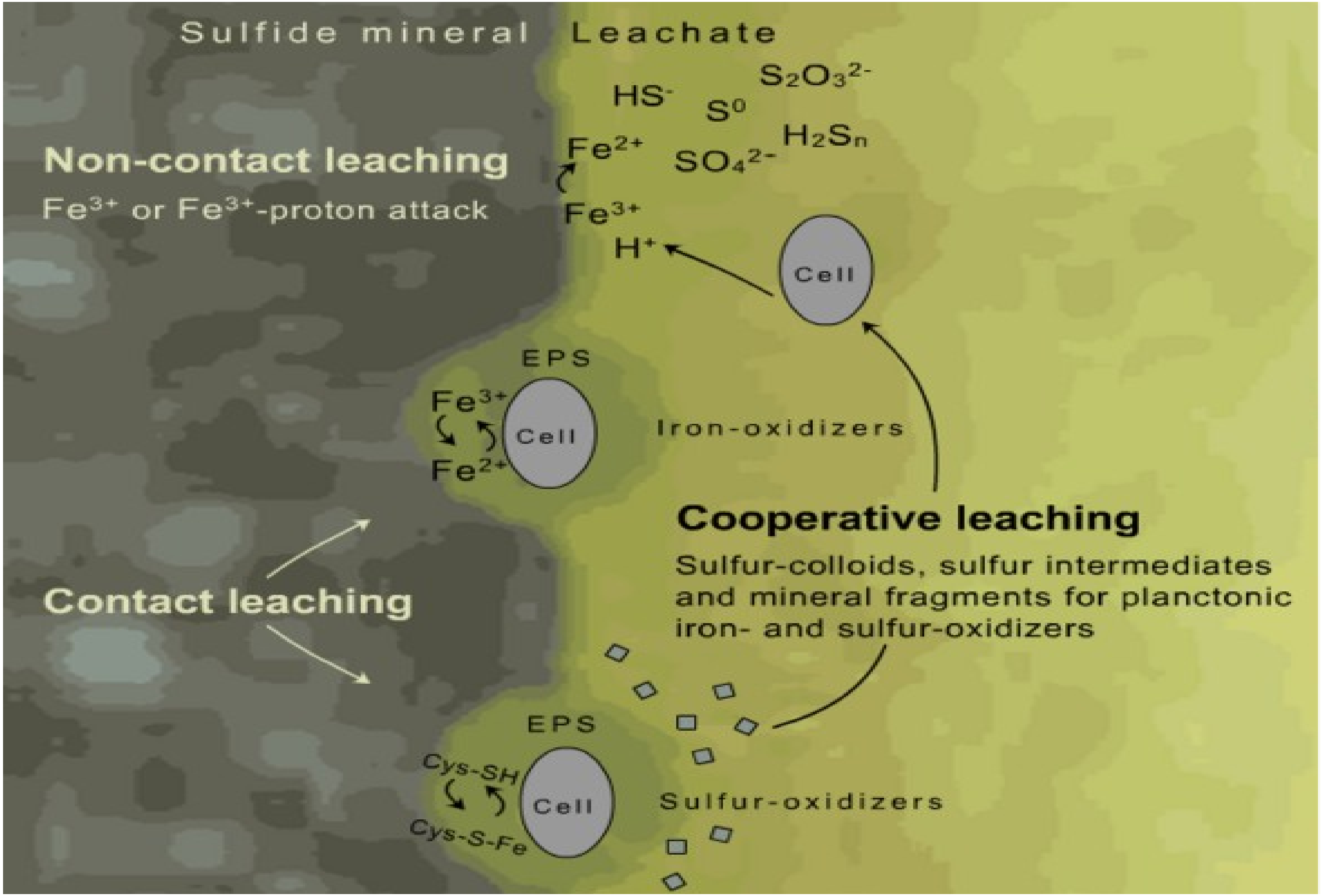
Bioleaching for Biomining

Until 50 years ago, nobody was aware that bacteria played an active part in ore extraction process. Despite the lack of knowledge, bioleaching had been **unknowingly used in medieval times** to extract and recover metals.

The modern era of biomining began within the discovery of a bacterium able to catalyse the oxidation of Fe^{3+} to Fe^{2+} in low pH (Thiobacillus ferrooxidans, renamed **Acidithiobacillus ferrooxidans**) and accelerate the oxidative dissolution of pyrite (FeS_2), the most abundant sulfide mineral in the lithosphere.

By the **mid-1960s the bioleaching** of run-of-mine copper waste rocks in mines operated by the (then) Noranda corporation in the USA started.

Today microbe-aware mining turn billions of tons of low-value copper ore into pure copper. United States, Canada, Chile, Australia, and South Africa produce **>25% of the total copper** production through bioleaching. More than **10% of gold** and **3% of cobalt** and **nickel** are biotechnologically produced.



Sulfide mineral
Leachate
$S_2O_3^{2-}$
HS^-
S^0
H_2S_n
Fe^{2+}
SO_4^{2-}
Non-contact leaching
Fe^{3+} or Fe^{3+}-proton attack
Fe^{3+}
H^+
Cell
EPS
Fe^{3+}
Cell
Fe^{2+}
Iron-oxidizers
Cooperative leaching
Sulfur-colloids, sulfur intermediates and mineral fragments for planctonic iron- and sulfur-oxidizers
Contact leaching
EPS
Cys-SH
Cell
Cys-S-Fe
Sulfur-oxidizers

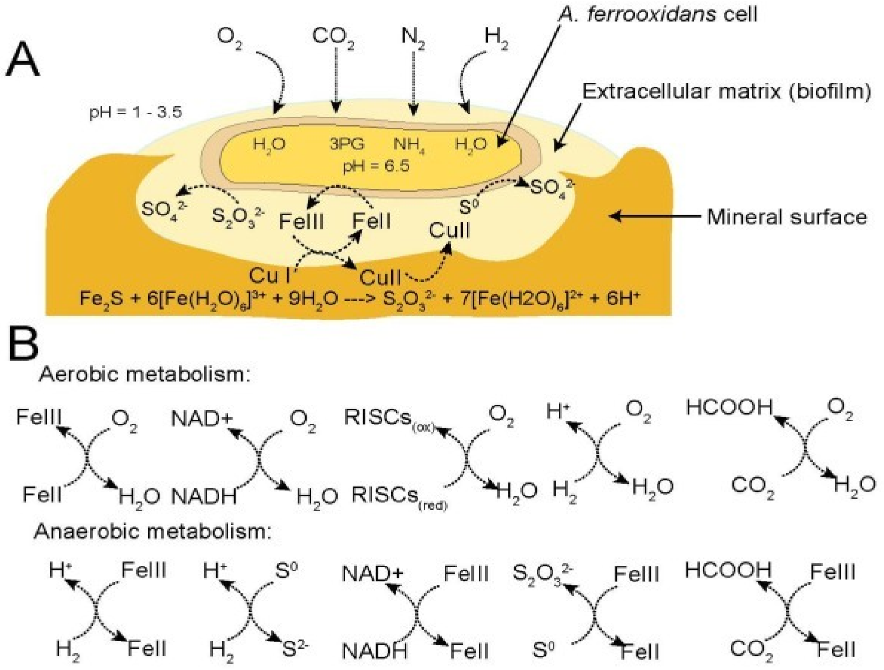
Acidithiobacillus ferrooxidans

Acidithiobacillus ferrooxidans (formely *Thiobacillus*) is a Gram-negative, **Gammaproteobacterium** that thrives optimally at 30°C and pH 2, but can grow at pH 1 or lower.

It is **abundant in natural environments** associated with pyritic ore bodies, coal deposits, and their acidified drainages.

It is capable of coupling **Fe^{2+}**, **elemental sulfur** and **thiosulfate oxidation** to oxygen respiration.

It is an important member of **microbial consortia** used to recover copper via a process known as bioleaching or biomining.



Valdes et al. 2008 BMC Genomics

Bioleaching of Chalcopyrite

Chalcopyrite bioleaching is a multistep process, involving both direct and indirect bioleaching

(1) $CuFeS_2 + 4Fe^{3+} \rightarrow Cu^{2+} + 5Fe^{2+} + 2S^0$ *spontaneous/microbial*

(2) $4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$ *iron oxidizers*

(3) $2S^0 + 3O_2 + 2H_2O \rightarrow 2SO_4^{2-} + 4H^+$ *sulfur oxidizers*

In general, sulfides are first oxidized to elemental sulfur, whereas disulfides are oxidized to give thiosulfate, and the processes above can be applied to other sulfidic ores.

Bioleaching of non-sulfidic ores such as pitchblende also uses ferric iron as an oxidant (e.g., $UO_2 + 2Fe^{3+} \rightarrow UO_2^{2+} + 2Fe^{2+}$). In this case, the sole purpose of the bacterial step is the regeneration of Fe^{3+}.

Copper mine aerial view

Environmental issues: Mine Drainage Fluids

Aside from the commercial use of microbiology to facilitate mining operations, microbiology also interacts with mining wastes, often in unwanted manners.

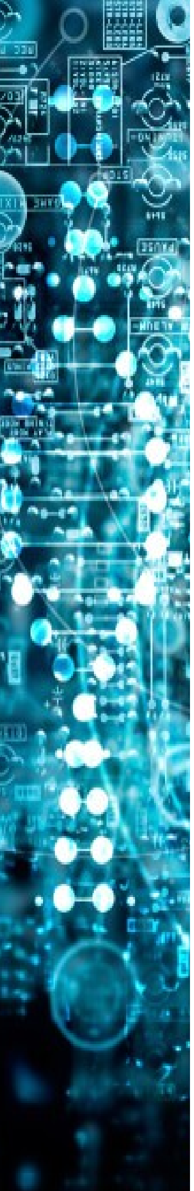
The most abundant mining waste in many case are the ***Mine Drainage Fluids****. These are composed by high amounts of* ***sulfide, heavy metals and very low pH****.*

Mine Drainage Fluids are responsible for the vast majority of the mining accidents and spills threatening neighboring ecosystems

The microbiology of Mine Drainage Fluids has been extensively studied, and the body of knowledge collected can help both ***biomining*** *operations as well as* ***bioremediation*** *efforts.*

Mine Drainage Fluids

Mine Drainage Fluids



Recovery of e-wastes

Electronic waste or e-waste describes discarded electrical or electronic devices.

Up to **60 elements** can be found in complex electronics. In the United States alone, an estimated **70% of heavy metals in landfills** comes from discarded electronics.

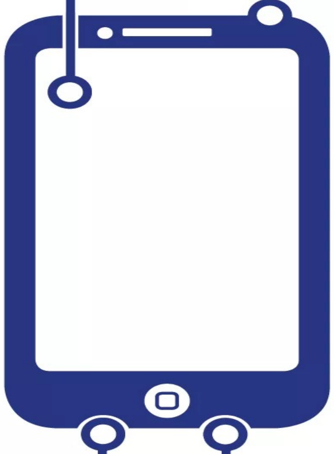
The short lifespan and rapid technology turnover makes electronics one of the **fast growing special waste** of the future.

Additionally many of the **elements are considered endangered**, and their recovery will become of primary importance for the sustainability of our society.

Informal processing of e-waste in **developing countries** can lead to **adverse human health effects** and **environmental pollution**.

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ALKALI METAL · ALKALINE EARTH METAL · TRANSITION METAL · GROUP 13 · GROUP 14 · GROUP 15 · GROUP 16 · HALOGEN · LANTHANIDE



SCREEN

49 In Indium · 8 O Oxygen · 50 Sn Tin

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

13 Al Aluminium · 14 Si Silicon · 8 O Oxygen · 19 K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

39 Y Yttrium · 57 La Lanthanum · 65 Tb Terbium · 59 Pr Praseodymium · 63 Eu Europium · 66 Dy Dysprosium · 64 Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

29 Cu Copper · 47 Ag Silver · 79 Au Gold · 73 Ta Tantalum

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

28 Ni Nickel · 66 Dy Dysprosium · 59 Pr Praseodymium · 65 Tb Terbium · 60 Nd Neodymium · 64 Gd Gadolinium

Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

14 Si Silicon · 8 O Oxygen · 51 Sb Antimony · 33 As Arsenic · 15 P Phosphorus · 31 Ga Gallium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

50 Sn Tin · 82 Pb Lead

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

BATTERY

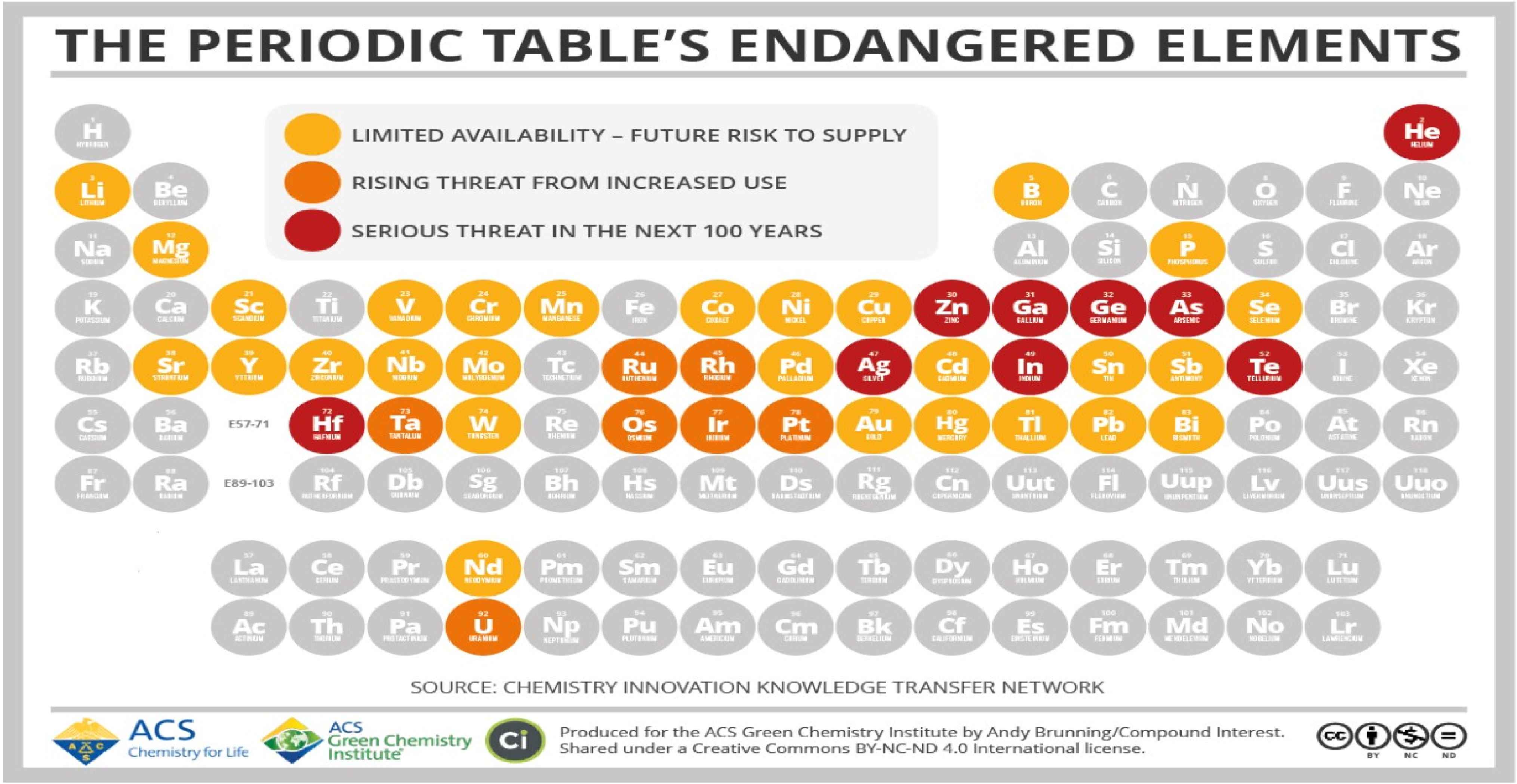
3 Li Lithium · 27 Co Cobalt · 8 O Oxygen · 6 C Carbon · 13 Al Aluminium

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

6 C Carbon · 12 Mg Magnesium · 35 Br Bromine · 28 Ni Nickel

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.



THE PERIODIC TABLE'S ENDANGERED ELEMENTS
LIMITED AVAILABILITY – FUTURE RISK TO SUPPLY
RISING THREAT FROM INCREASED USE
SERIOUS THREAT IN THE NEXT 100 YEARS
H He
Li Be B C N O F Ne
Na Mg Al Si P S Cl Ar
K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn Ga Ge As Se Br Kr
Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd In Sn Sb Te I Xe
Cs Ba E57-71 Hf Ta W Re Os Ir Pt Au Hg Tl Pb Bi Po At Rn
Fr Ra E89-103 Rf Db Sg Bh Hs Mt Ds Rg Cn Uut Fl Uup Lv Uus Uuo
La Ce Pr Nd Pm Sm Eu Gd Tb Dy Ho Er Tm Yb Lu
Ac Th Pa U Np Pu Am Cm Bk Cf Es Fm Md No Lr
SOURCE: CHEMISTRY INNOVATION KNOWLEDGE TRANSFER NETWORK
ACS Chemistry for Life
ACS Green Chemistry Institute
Ci
Produced for the ACS Green Chemistry Institute by Andy Brunning/Compound Interest.
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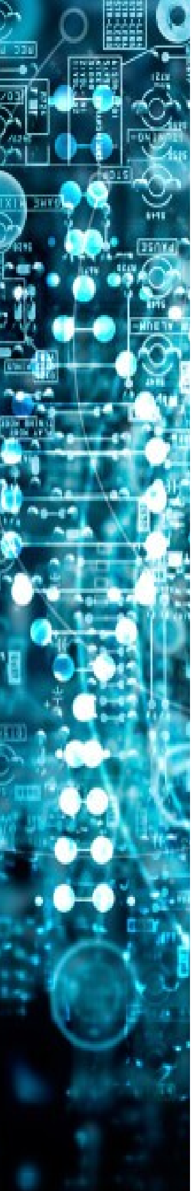
BY NC ND



BIOENGINEERING

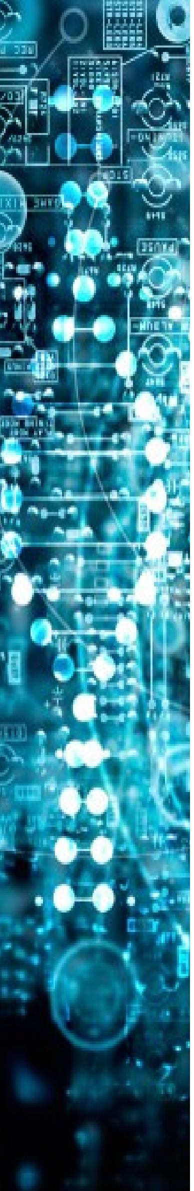
A timeline of CRISPR discovery

1987 – Ishino ***accidentally cloned part of a CRISPR*** *together with the E. coli gene. The function of the clustered repeats was unknown at the time*

1993 – Van Soolingen and colleagues reported in two papers clusters of interrupted direct repeats in Mycobacterium tuberculosis used their diversity to devise a named ***spoligotyping*** *(still in use) to investigate M. tuberculosis diversity*

2001 – Mojica and Jansen, working on Haloferax, reported the presence of the cluster in many microbes and ***proposed the acronym CRISPR***

2002 – Tang showed that CRISPR repeat from Archaeoglobus fulgidus were ***transcribed into long RNA*** *subsequently processed into small RNAs. At the same time Jansen described the* ***CRISPR-associated systems genes***



2005 *– Three independent research groups showed that some CRISPR spacers are* ***derived from phage DNA*** *and extrachromosomal DNA such as plasmids and Mojica proposed a role of CRISPR-Cas in microbial immunity. All were rejected from high profile journals*

2010 *– The first experimental evidence that CRISPR was an* ***adaptive immune system*** *was published*

2012 *– Doudna and Charpentier (UC Berkeley, USA)* ***re-engineered the Cas9*** *endonuclease manageable two-component system. By manipulating the guide RNA, the artificial Cas9 system could be programmed to target any DNA. Two more teams, Šikšnys (Vilnius University, Lithuania) and Zhang (MIT, USA)*

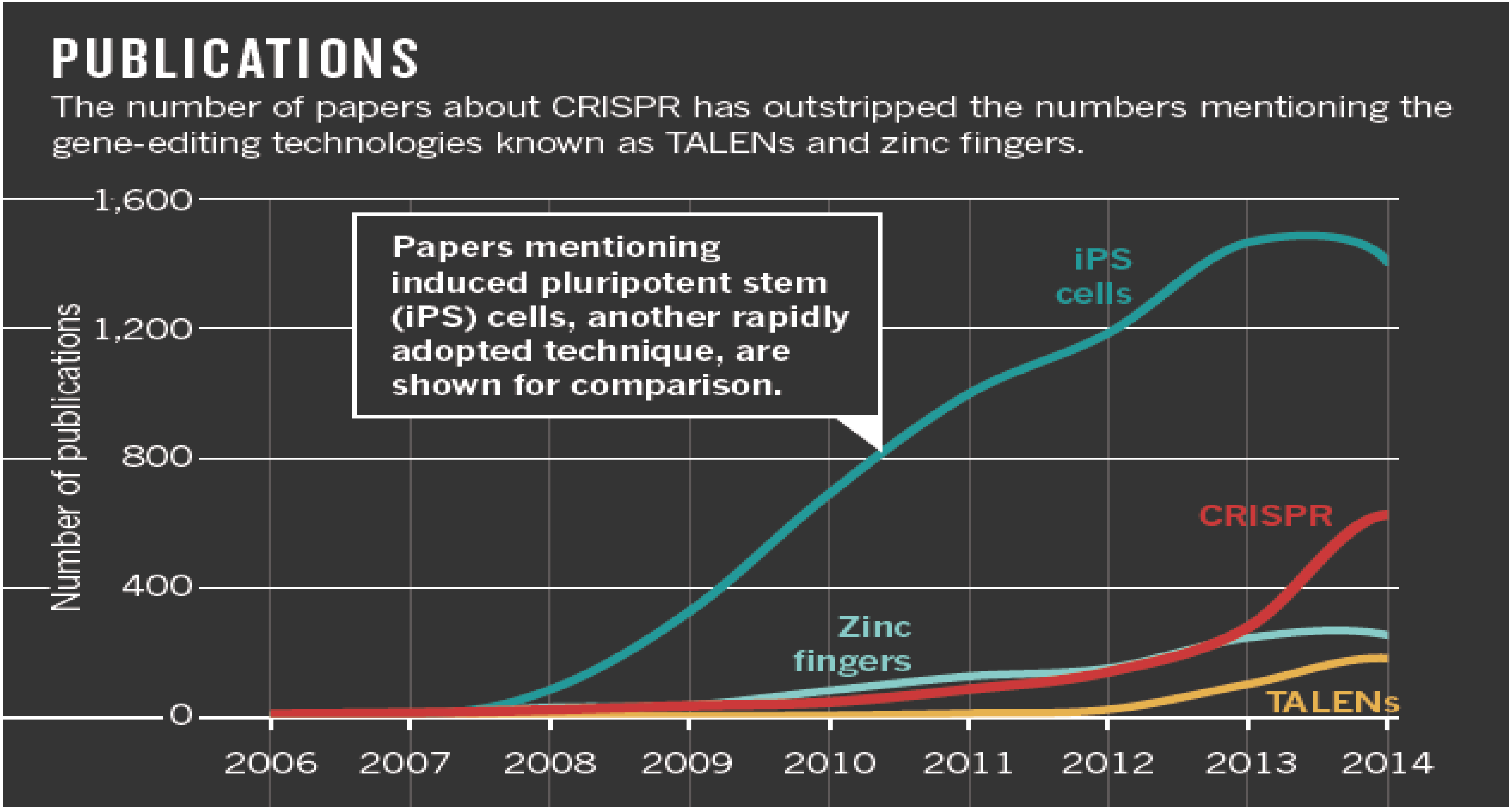
2013 *– Two groups simultaneously described* ***genome editing in human cell cultures*** *using CRISPR-Cas9 for the first time*

By the end of ***2014*** *some* ***1,000 research papers*** *had been published that mentioned CRISPR*

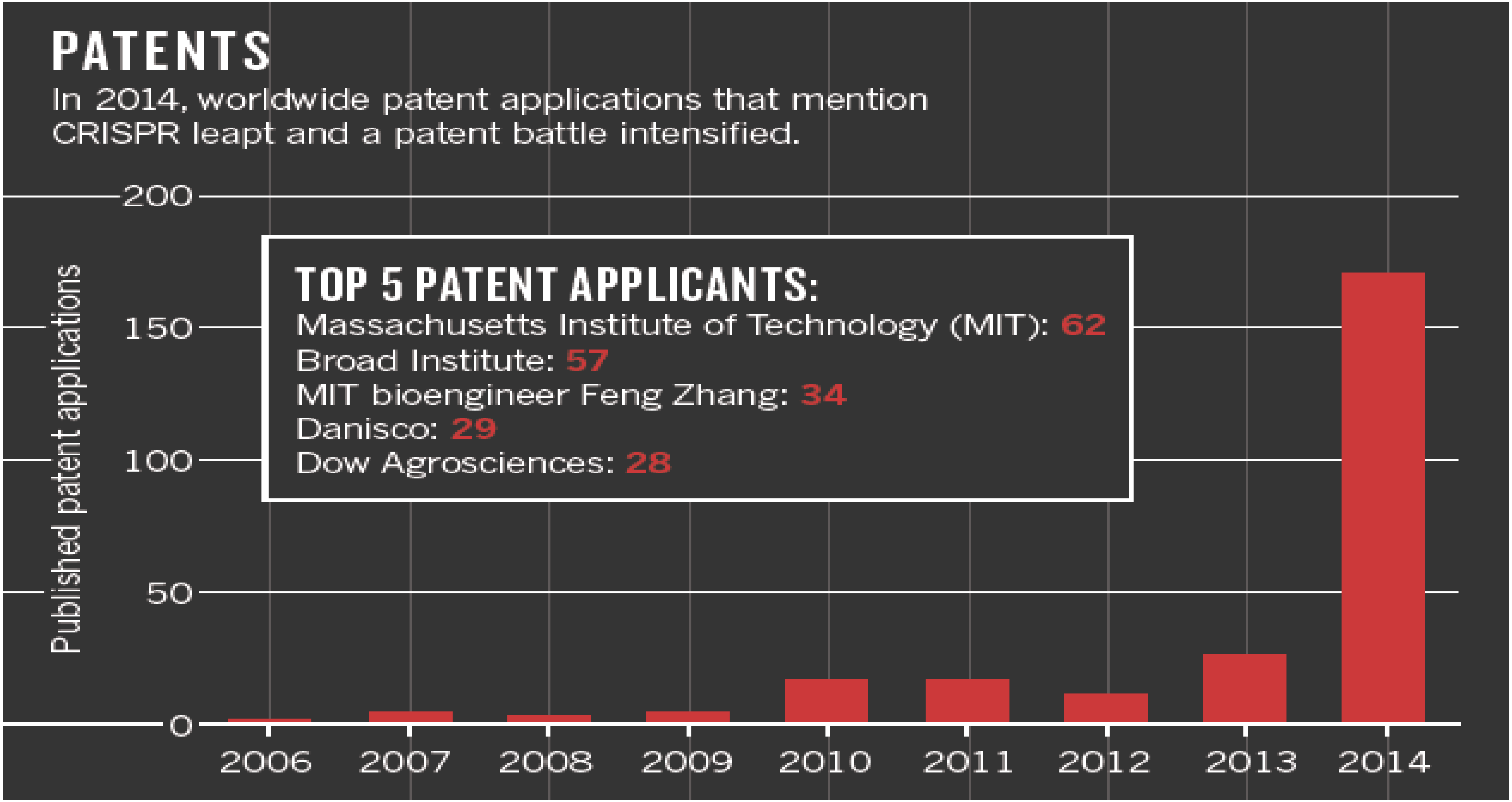
SCIENTIFIC AMERICAN
RELEASING THE BOTTLENECK WITH CRISPR-CAS9
The CRISPR Journal
Inaugural Issue!
Genome Editing B.C. (Before CRISPR)
Multiplex Editing in Wheat
The CRISPR Patent Landscape
20p
Britain's first and only concise quality newspaper
i
The essential daily briefing
What if JFK had lived? By Stephen King
Genetic revolution that can eradicate disease
'Jaw-dropping' breakthrough lets scientists delete faulty parts of the human genome
Discovery has potential for treating cancer, HIV, Down's syndrome and Huntington's
'A triumph with huge implications for science,' declares Nobel Prize winner
Killer pet bulldog was stray found in the park
c&en
CHEMICAL & ENGINEERING NEWS
Can CRISPR break through?
Playing the drug delivery game to turn gene editing into a therapy P.28
ACS
C&EN
CHEMICAL & ENGINEERING NEWS
DISRUPTING PRIONS
BOSTON IN PHOTOS
EDITING THE GENOME
CRISPR/Cas9 takes gene manipulation into a new era P.14
Science
CRISPR PIGS
Science
2015
BREAKTHROUGH of the YEAR
CRISPR
nature
SEEK AND DESTROY
PAM sequences recruit and activate Cas9 endonuclease in CRISPR/Cas9 genome-editing tool
TAKING CHARGE
STILL IN THE DARK
SEE RADIO IN A NEW LIGHT
ISSUES
IN SCIENCE AND TECHNOLOGY
Summit on Human Gene Editing
Human Gene Therapy
Mary Ann Liebert, Inc. publishers
New Scientist Live Last chance to book
Home | News | Health
372
SHORT SHARP SCIENCE 25 January 2017
Gene editing has saved the lives of two children with leukaemia
BIOLOGIC SCIENCE NEWS
Human embryo edited with CRISPR-Cas9 leads to birth of twins, in world first

CRISPR-Cas *is a* ***vertically transmitted adaptive immune system*** *against phage infection present in a large number of Bacteria and Archaea*

CRISPR-Cas *is a* ***tool for targeted genetic engineering*** *(or gene editing) extremely diffused in modifying eukaryotic genomes*



Ledford, 2015 *Nature*



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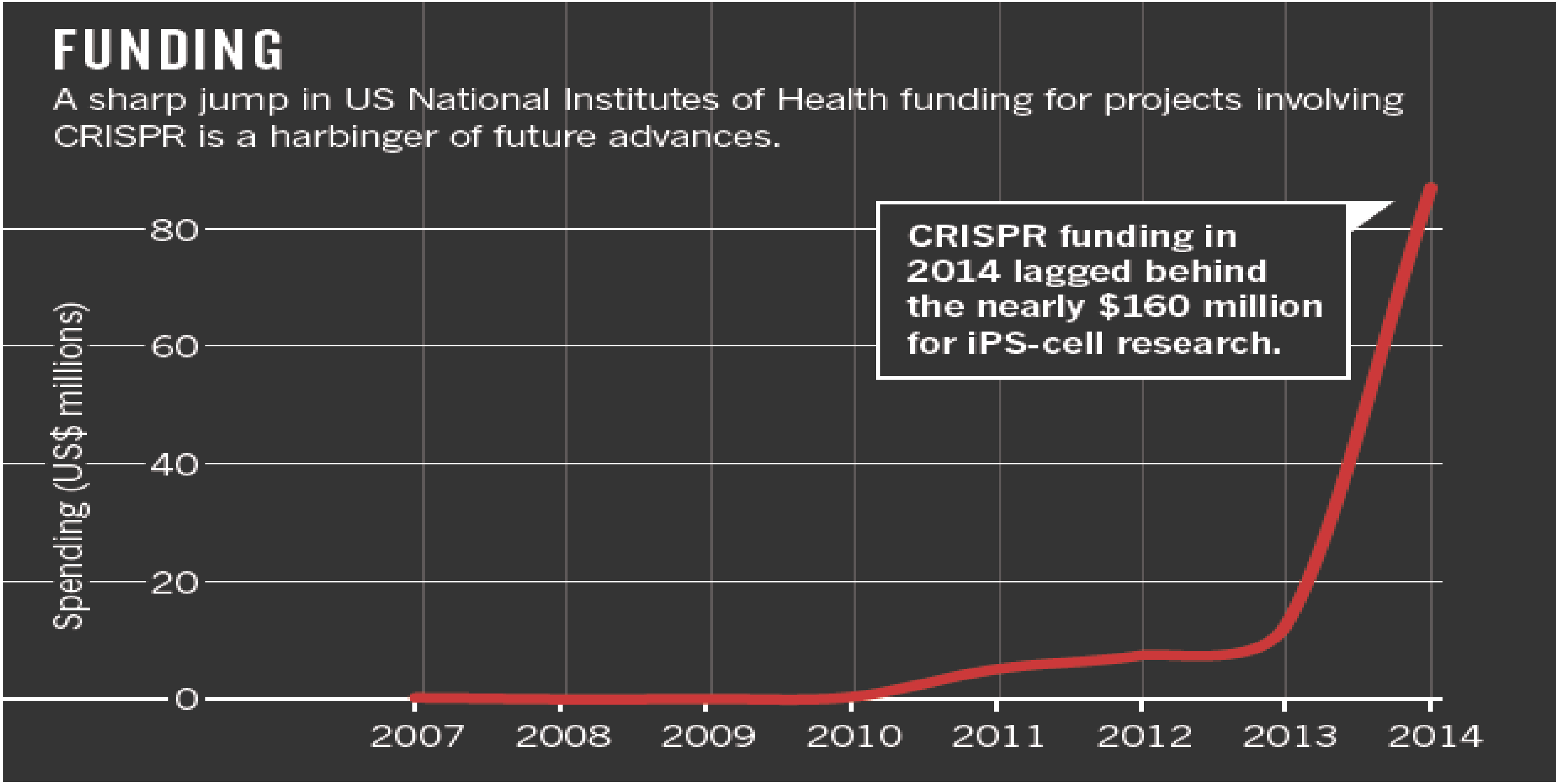


Ledford, 2015 *Nature*

"It seems appropriate to remember here that the great motor of molecular biology during the 20th century, molecular cloning, was made possible by restriction endonucleases and plasmid vectors, both derived from serendipitous discoveries of prokaryotic cell biology features involved in self/nonself discrimination as well. The lesson here to scientists, science policy makers and mankind at large is that **the only way forward is enlarging evenly the sphere of knowledge supporting fundamental research***. In words of Louis Pasteur: 'There does not exist a category of science to which one can give the name applied science. There are science and the applications of science, bound together as the fruit of the tree which bears it'."*

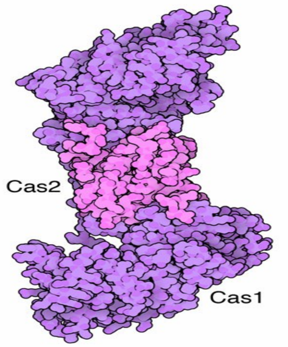
Mojica and Rodriguez-Valera, 2016 FEBS Journal

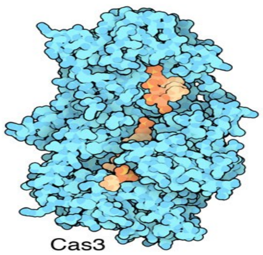
CRISPR-associated system

*CRISPR repeat-spacer arrays are generally associated to protein coding genes called **cas genes**. A complete CRISPR-Cas locus has at least one gene belonging to the cas core.*

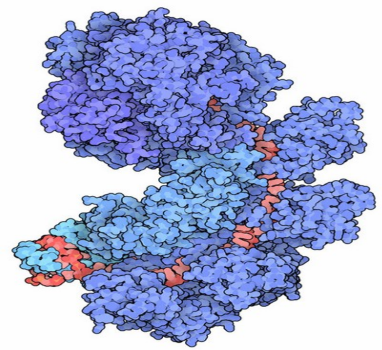
*Collectively the **93 cas genes** are grouped into **35 families** based on sequence similarity of the encoded proteins. 11 of the 35 families form the cas core.*

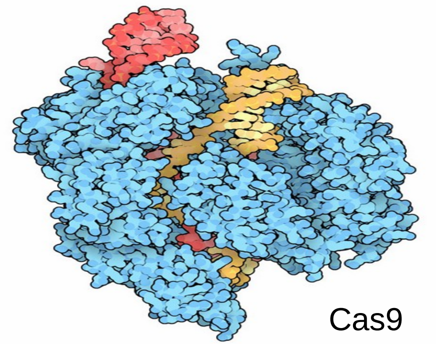
*CRISPR-Cas systems fall into two classes. **Class 1** systems use a complex of **multiple Cas proteins** to degrade foreign nucleic acids. **Class 2** systems use a **single large Cas protein** for the same purpose (see www.rcsb.org)*





Cascade





Cas9

Coevolution

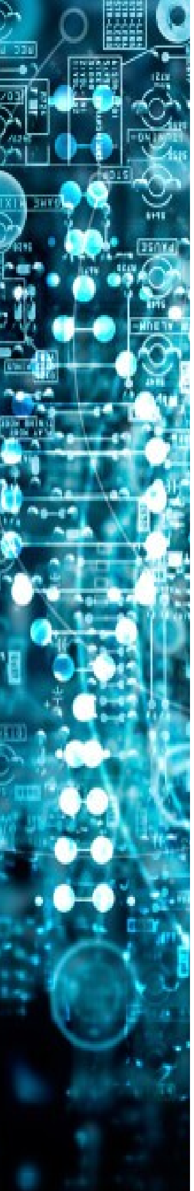
CRISPR sequences revealed coevolution *of host and viral genomes.*

The basic model of CRISPR evolution is newly incorporated spacers driving phages to mutate their genomes to avoid the bacterial immune response, creating diversity in both the phage and host populations.

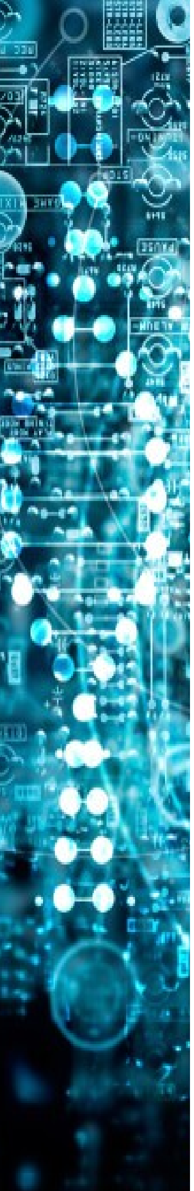
To fight off a phage infection, the sequence of the CRISPR spacer *must correspond perfectly* *to the sequence of the target phage gene.*

Deviant Art, Tentaculus

“Now, here, you see, it takes all the running you can do, to keep in the same place.” - Alice: Through the Looking Glass



BIOACTIVE COMPOUNDS



JOURNAL OF BACTERIOLOGY, Aug. 1969, p. 289–297 Vol. 98, No. 1

Printed in U.S.A.

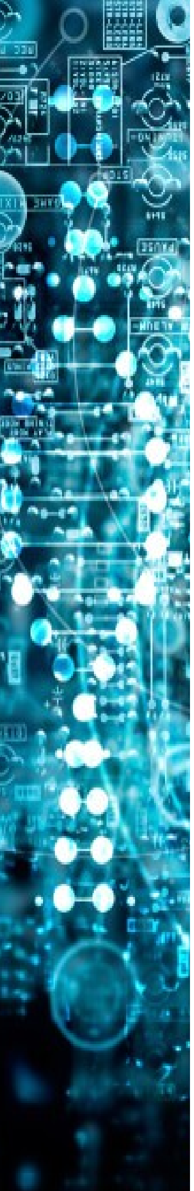
Thermus aquaticus gen. n. and sp. n., a Non-sporulating Extreme Thermophile

THOMAS D. BROCK AND HUDSON FREEZE

Department of Microbiology, Indiana University, Bloomington, Indiana 47401

Received for publication 15 January 1969

The isolation of a new thermophilic bacterium, *Thermus aquaticus* gen. n. and sp. n., is described. Successful enrichment requires incubation at 70 to 75 C, and the use of nutrient media relatively dilute with respect to the organic components. Strains of *T. aquaticus* have been isolated from a variety of thermal springs in Yellowstone National Park and from a thermal spring in California. The organism has also been isolated from man-made thermal habitats, such as hot tap water, in geographical locations quite distant from thermal springs. Isolates of *T. aquaticus* are gram-negative nonsporulating nonmotile rods which frequently form long filaments at supraoptimal temperatures or in the stationary phase. All isolates form a yellow cellular pigment, probably a carotenoid. A characteristic structure formed by all isolates is a large sphere, considerably larger than a spheroplast. These large spheres, as well as lysozyme-induced spheroplasts, are resistant to osmotic lysis. Deoxyribonucleic acid base compositions of four strains were determined by CsCl density gradient ultracentrifugation and found to be between 65.4 and 67.4 moles per cent guanine plus cytosine. The growth of all isolates tested is inhibited by fairly low concentrations of cycloserine, streptomycin, penicillin, novobiocin, tetracycline, and chloramphenicol. Nutritional studies on one strain showed that it did not require vitamins or amino acids, although growth was considerably faster in enriched than in synthetic medium. Several sugars and organic acids served as carbon sources, and either NH_4^+ or glutamate could serve as nitrogen source. The organism is an obligate aerobe and has a *p*H optimum of 7.5 to 7.8. The optimum temperature for growth is 70 C, the maximum 79 C, and the minimum about 40 C. The generation time at the optimum is about 50 min. The possible relationships of this new genus to the myxobacteria, flexibacteria, and flavobacteria are discussed.



1967 Brooks explained: "Bacteria are able to grow [...] at any temperature at which there is liquid water, even in pools which are above the boiling point."

In 1976 the thermostable enzyme DNA polymerase was first isolated from Thermus aquaticus

In 1983 the Taq enzyme became the cornerstone of Kary Mullis invention of the Polymerase Chain Reaction (PCR) for which he won the Noble Prize in 1993

Thermostable polymerase enzymes derived from Taq are now an industry worth ca. 400 Million euro/year

PCR and polymerases are key technologies for biological, genetics, biomedicine and biotechnology research, a global business of hundred billions of euro

***Bioprospecting** is defined as a systematic and organized search for useful products derived from bioresources including plants, microorganisms, animals, etc., that can be developed further for commercialization and overall benefits of the society.*

From: Medicinal Spices and Vegetables from Africa, 2017

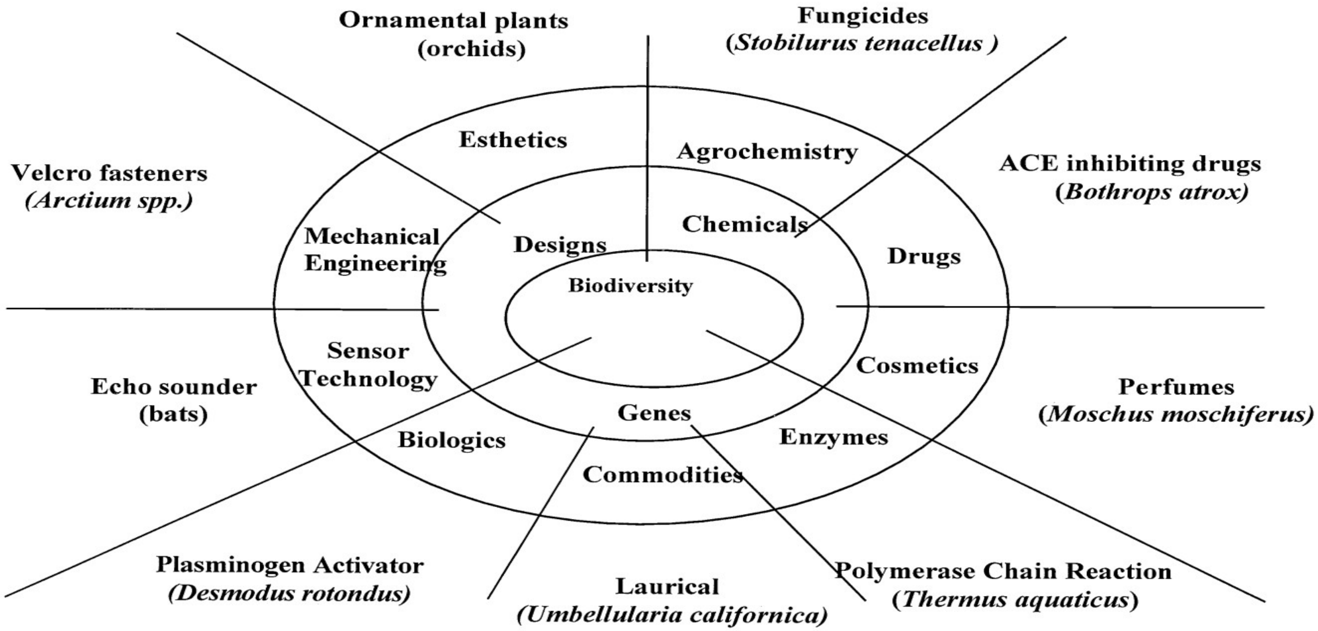
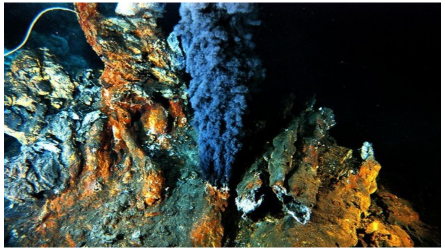


FIGURE 1 The three principal sources of inspirations from biodiversity and their applications. Product examples are described in the text (with variations derived from Nader and Hill, 1999).

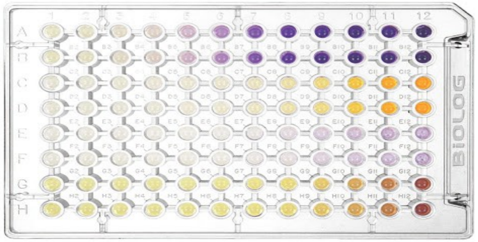
Bioprospecting program	Global health issues	Sources	Parameters of species selection	Complementary approaches	Products to obtain in a bioprospecting program
Terrestrial	Antimicrobial resistance	Plants	Ethnopharmacology	Metagenomics	Pharmaceuticals
Freshwater origin	Cardiovascular diseases	Fungi	Chemotaxonomy	Protemics	Chemical scaffolds
Marine	Cancer	Animals	Ecological chemistry	Metabolomics	Bioprocesses
Polar regions	Malnutrition	Algae	Random search	Combinatorial chemistry	Formulations
Extreme environments	Mental diseases	Insects	Bioassay-guided isolation	Medicinal chemistry	Genetic modified organisms
	Pollution	Ciliates		Organic synthesis	
	Emerging infectious diseases	Bacteria			
		Archaea			
		Microbial endophytes			
		Marine organisms			

Table 1: Parameters for to be considered in a rational bioprospecting program.

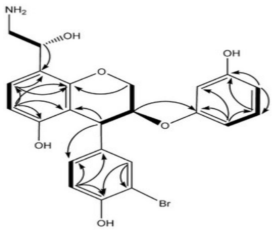
Juan, 2017 J Microb Biochem Technol



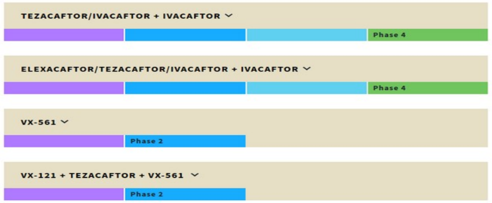
Access Biological Resources



Screen for Activity



Isolate and Characterize



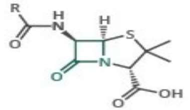
Test in Controlled Trials

DIFFERENT CLASSES OF ANTIBIOTICS - AN OVERVIEW

Key: COMMONLY ACT AS BACTERIOSTATIC AGENTS, RESTRICTING GROWTH & REPRODUCTION | COMMONLY ACT AS BACTERICIDAL AGENTS, CAUSING BACTERIAL CELL DEATH

ß-LACTAMS

MOST WIDELY USED ANTIBIOTICS IN THE NHS



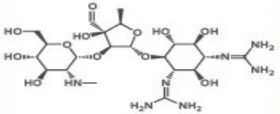
All contain a beta-lactam ring

EXAMPLES
Penicillins (shown) such as amoxicillin and flucloxacillin; *Cephalosporins* such as cefalexin.

MODE OF ACTION
Inhibit bacteria cell wall biosynthesis.

AMINOGLYCOSIDES

FAMILY OF OVER 20 ANTIBIOTICS



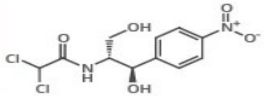
All contain aminosugar substructures

EXAMPLES
Streptomycin (shown), neomycin, kanamycin, paromomycin.

MODE OF ACTION
Inhibit the synthesis of proteins by bacteria, leading to cell death.

CHLORAMPHENICOL

COMMONLY USED IN LOW INCOME COUNTRIES



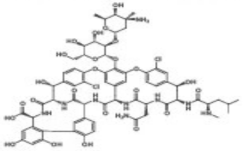
Distinct individual compound

MODE OF ACTION
Inhibits synthesis of proteins, preventing growth.

No longer a first line drug in any developed nation (except for conjunctivitis) due to increased resistance and worries about safety.

GLYCOPEPTIDES

COMMON 'DRUGS OF LAST RESORT'



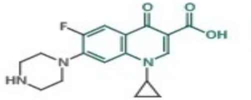
Consist of carbohydrate linked to a peptide formed of amino acids

EXAMPLES
Vancomycin (shown), teicoplanin.

MODE OF ACTION
Inhibit bacteria cell wall biosynthesis.

QUINOLONES

RESISTANCE EVOLVES RAPIDLY



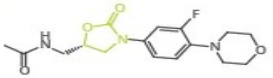
All contain fused aromatic rings with a carboxylic acid group attached

EXAMPLES
Ciprofloxacin (shown), levofloxacin, trovafloxacin.

MODE OF ACTION
Interfere with bacteria DNA replication and transcription.

OXAZOLIDINONES

POTENT ANTIBIOTICS COMMONLY USED AS 'DRUGS OF LAST RESORT'



All contain 2-oxazolidone somewhere in their structure

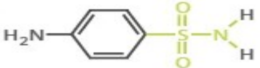
EXAMPLES
Linezolid (shown), posizolid, tedizolid, cycloserine.

MODE OF ACTION
Inhibit synthesis of proteins by bacteria, preventing growth.

DISCOVERY 1930 1940 1950 1960 1970 1980

SULFONAMIDES

FIRST COMMERCIAL ANTIBIOTICS WERE SULFONAMIDES



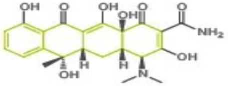
All contain the sulfonamide group

EXAMPLES
Prontosil, sulfanilamide (shown), sulfadiazine, sulfisoxazole.

MODE OF ACTION
Do not kill bacteria but prevent their growth and multiplication. Cause allergic reactions in some patients.

TETRACYCLINES

BECOMING LESS POPULAR DUE TO DEVELOPMENT OF RESISTANCE



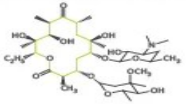
All contain 4 adjacent cyclic hydrocarbon rings

EXAMPLES
Tetracycline (shown), doxycycline, limecycline, oxytetracycline.

MODE OF ACTION
Inhibit synthesis of proteins by bacteria, preventing growth.

MACROLIDES

SECOND MOST PRESCRIBED ANTIBIOTICS IN THE NHS



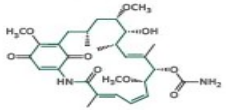
All contain a 14-, 15-, or 16-membered macrolide ring

EXAMPLES
Erythromycin (shown), clarithromycin, azithromycin.

MODE OF ACTION
Inhibit protein synthesis by bacteria, occasionally leading to cell death.

ANSAMYCINS

CAN ALSO DEMONSTRATE ANTIVIRAL ACTIVITY



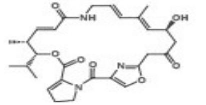
All contain an aromatic ring bridged by an aliphatic chain.

EXAMPLES
Geldanamycin (shown), rifamycin, naphthomycin.

MODE OF ACTION
Inhibit the synthesis of RNA by bacteria, leading to cell death.

STREPTOGRAMINS

TWO GROUPS OF ANTIBIOTICS THAT ACT SYNERGISTICALLY



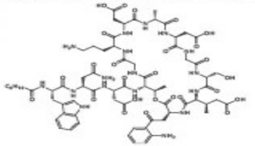
Combination of two structurally differing compounds, from groups denoted A & B

EXAMPLES
Pristinamycin IIA (shown), Pristinamycin IA.

MODE OF ACTION
Inhibit the synthesis of proteins by bacteria, leading to cell death.

LIPOPEPTIDES

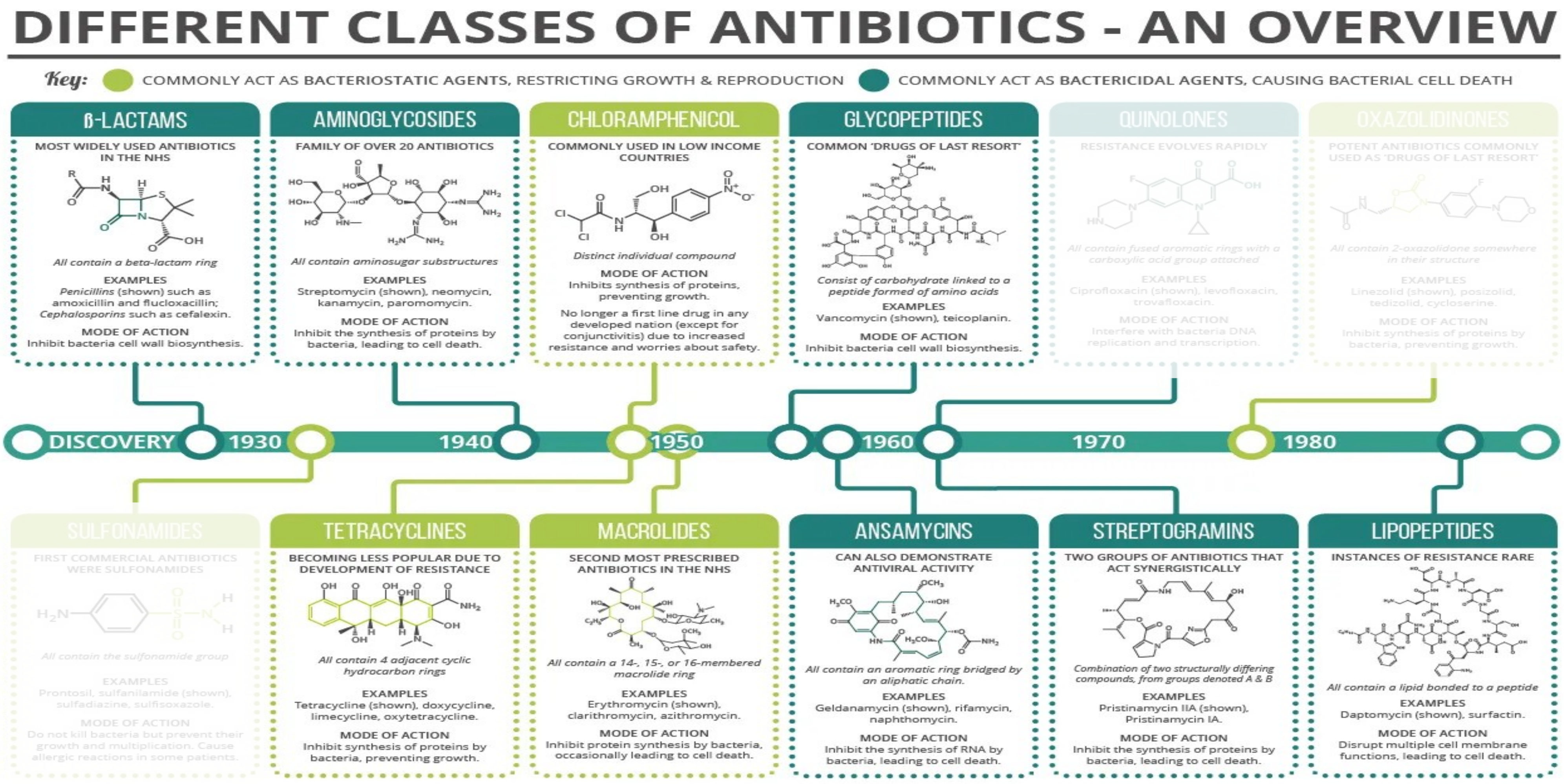
INSTANCES OF RESISTANCE RARE



All contain a lipid bonded to a peptide

EXAMPLES
Daptomycin (shown), surfactin.

MODE OF ACTION
Disrupt multiple cell membrane functions, leading to cell death.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COMMONLY USED IN LOW INCOME COUNTRIES
Distinct individual compound
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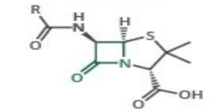

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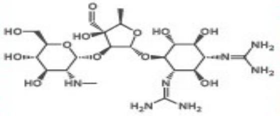

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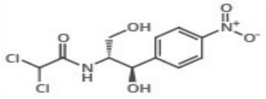

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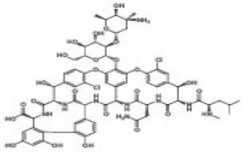
GLYCOPEPTIDES

COMMON 'DRUGS OF LAST RESORT'



Consist of carbohydrate linked to a peptide formed of amino acids

EXAMPLES
Vancomycin (shown), teicoplanin.

MODE OF ACTION
Inhibit bacteria cell wall biosynthesis.

QUINOLONES

RESISTANCE EVOLVES RAPIDLY

All contain fused aromatic rings with a carboxylic acid group attached

EXAMPLES
Ciprofloxacin (shown), levofloxacin, trovafloxacin.

MODE OF ACTION
Interfere with bacteria DNA replication and transcription.

OXAZOLIDINONES

POTENT ANTIBIOTICS COMMONLY USED AS 'DRUGS OF LAST RESORT'

All contain 2-oxazolidone somewhere in their structure

EXAMPLES
Linezolid (shown), posizolid, tedizolid, cycloserine.

MODE OF ACTION
Inhibit synthesis of proteins by bacteria, preventing growth.

DISCOVERY 1930 1940 1950 1960 1970 1980

SULFONAMIDES

FIRST COMMERCIAL ANTIBIOTICS WERE SULFONAMIDES

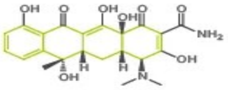
All contain the sulfonamide group

EXAMPLES
Prontosil, sulfanilamide (shown), sulfadiazine, sulfisoxazole.

MODE OF ACTION
Do not kill bacteria but prevent their growth and multiplication. Cause allergic reactions in some patients.

TETRACYCLINES

BECOMING LESS POPULAR DUE TO DEVELOPMENT OF RESISTANCE



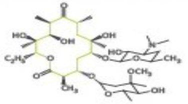
All contain 4 adjacent cyclic hydrocarbon rings

EXAMPLES
Tetracycline (shown), doxycycline, limecycline, oxytetracycline.

MODE OF ACTION
Inhibit synthesis of proteins by bacteria, preventing growth.

MACROLIDES

SECOND MOST PRESCRIBED ANTIBIOTICS IN THE NHS



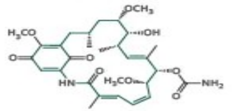
All contain a 14-, 15-, or 16-membered macrolide ring

EXAMPLES
Erythromycin (shown), clarithromycin, azithromycin.

MODE OF ACTION
Inhibit protein synthesis by bacteria, occasionally leading to cell death.

ANSAMYCINS

CAN ALSO DEMONSTRATE ANTIVIRAL ACTIVITY



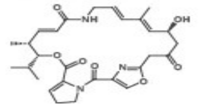
All contain an aromatic ring bridged by an aliphatic chain.

EXAMPLES
Geldanamycin (shown), rifamycin, naphthomycin.

MODE OF ACTION
Inhibit the synthesis of RNA by bacteria, leading to cell death.

STREPTOGRAMINS

TWO GROUPS OF ANTIBIOTICS THAT ACT SYNERGISTICALLY



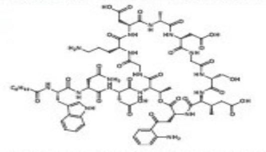
Combination of two structurally differing compounds, from groups denoted A & B

EXAMPLES
Pristinamycin IIA (shown), Pristinamycin IA.

MODE OF ACTION
Inhibit the synthesis of proteins by bacteria, leading to cell death.

LIPOPEPTIDES

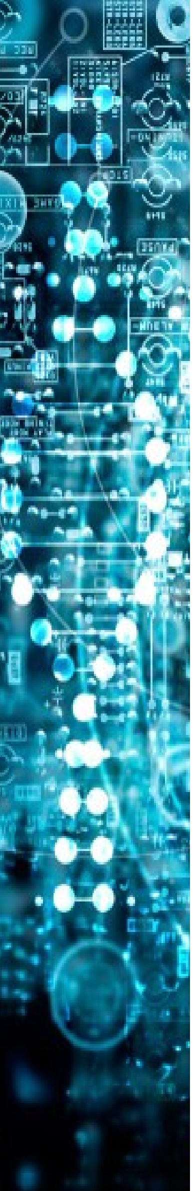
INSTANCES OF RESISTANCE RARE



All contain a lipid bonded to a peptide

EXAMPLES
Daptomycin (shown), surfactin.

MODE OF ACTION
Disrupt multiple cell membrane functions, leading to cell death.



EXPLO(R/IT)ATION OF BIOLOGICAL RESOURCES

The New York Times https://www.nytimes.com/2006/11/28/science/28yell.html

The Search for Private Profit in the Nation's Public Parks

Yellowstone National Park has more than 200 continuing experiments by outside scientists.
Anne Sherwood for The New York Times

By Jim Robbins

Nov. 28, 2006

YELLOWSTONE NATIONAL PARK, Wyo. — In the 1980s, a researcher at the Cetus Corporation named Kary Mullis was searching for a way to speed the replication of DNA. Enzymes used to amplify the genetic code broke down when they were heated. Dr. Mullis had the idea of using a heat-resistant enzyme called Taq

*Taq, isolated from Thermus aquaticus in the Yellowstone National Park, made billions of dollar in profit, of which none went to the public park services. It is referred to as "**the great Taq rip-off**".*

Researchers working in National Parks are now required to sign "benefits sharing" agreements that would send a portion of later profits back to the Park Service.

Who owns biological diversity?

"Until the 1970s, biodiversity was considered to be part of the "common heritage of humankind." Under this regime, biological resources are treated as belonging to the public domain and are not owned by any individual, group, or state."

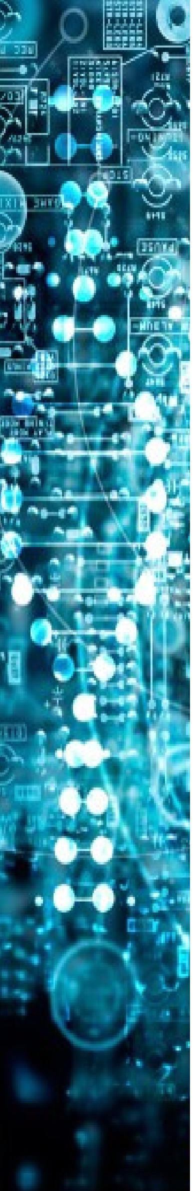
"The last three decades have seen a significant change in the regime governing access to biodiversity. From a common heritage of mankind, biodiversity is evolving into a resource under the sovereignty of nation states and is subject to intellectual property rights (IPRs)."

Illegal Bioprospecting and Biopiracy

*The **Convention on Biological Diversity** (CBD; http://www.biodiv.org) was signed in 1992 and came into force in 1993*

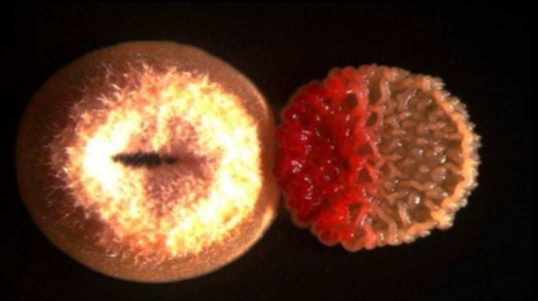
*The **Nagoya Protocol on Access and Benefit-sharing** (Nagoya Protocol, https://www.cbd.int/abs) entered into force on 12 October 2014*

Gepts 2004, Plant Physiol

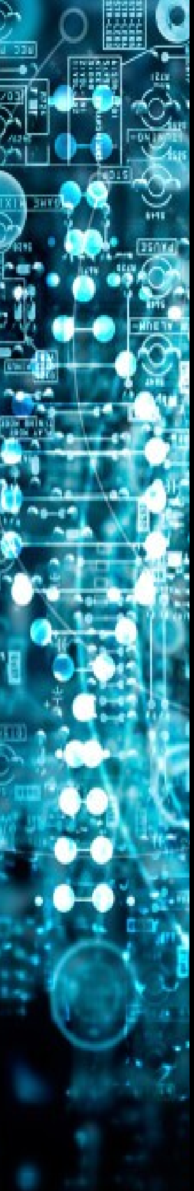


THE HIDDEN ROLE OF SOCIAL INTERACTION IN MICROORGANISMS

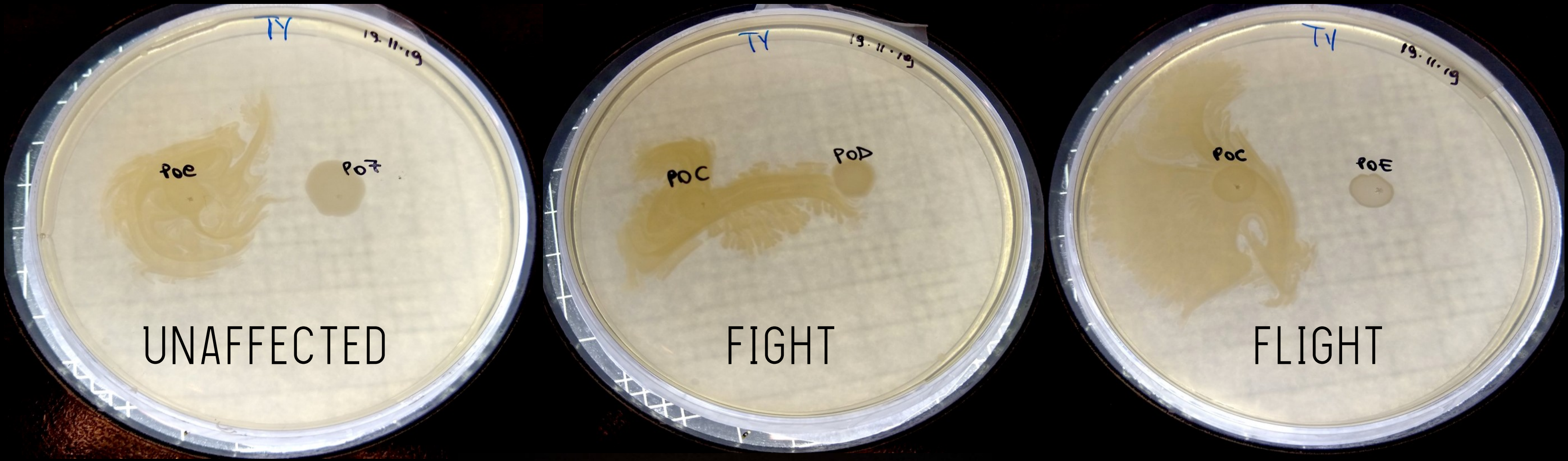
Competitive cocultures to stimulate alternative phenotypes in wild-type microorganisms: fight or flight

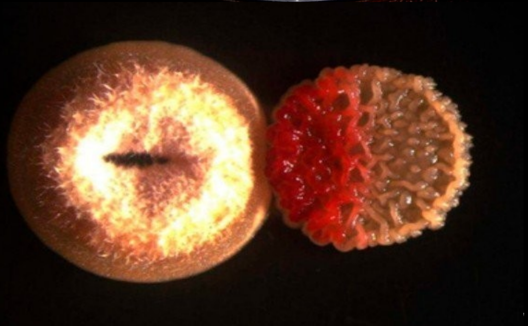


Competitive interaction alter the expression of secondary metabolites



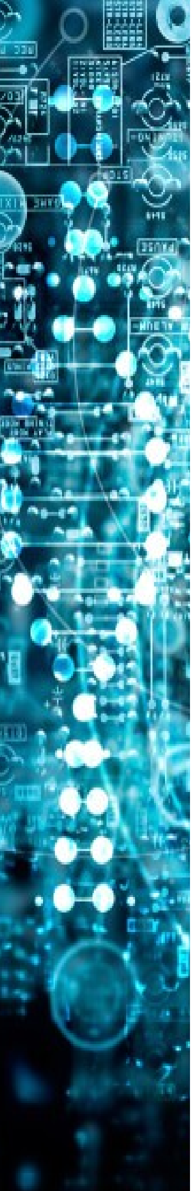
Competitive cocultures to stimulate alternative phenotypes in wild-type microorganisms: fight or flight



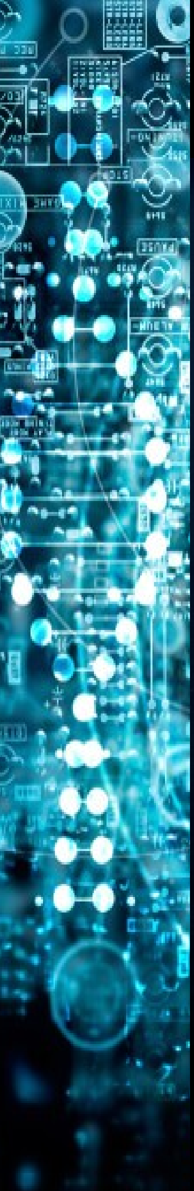


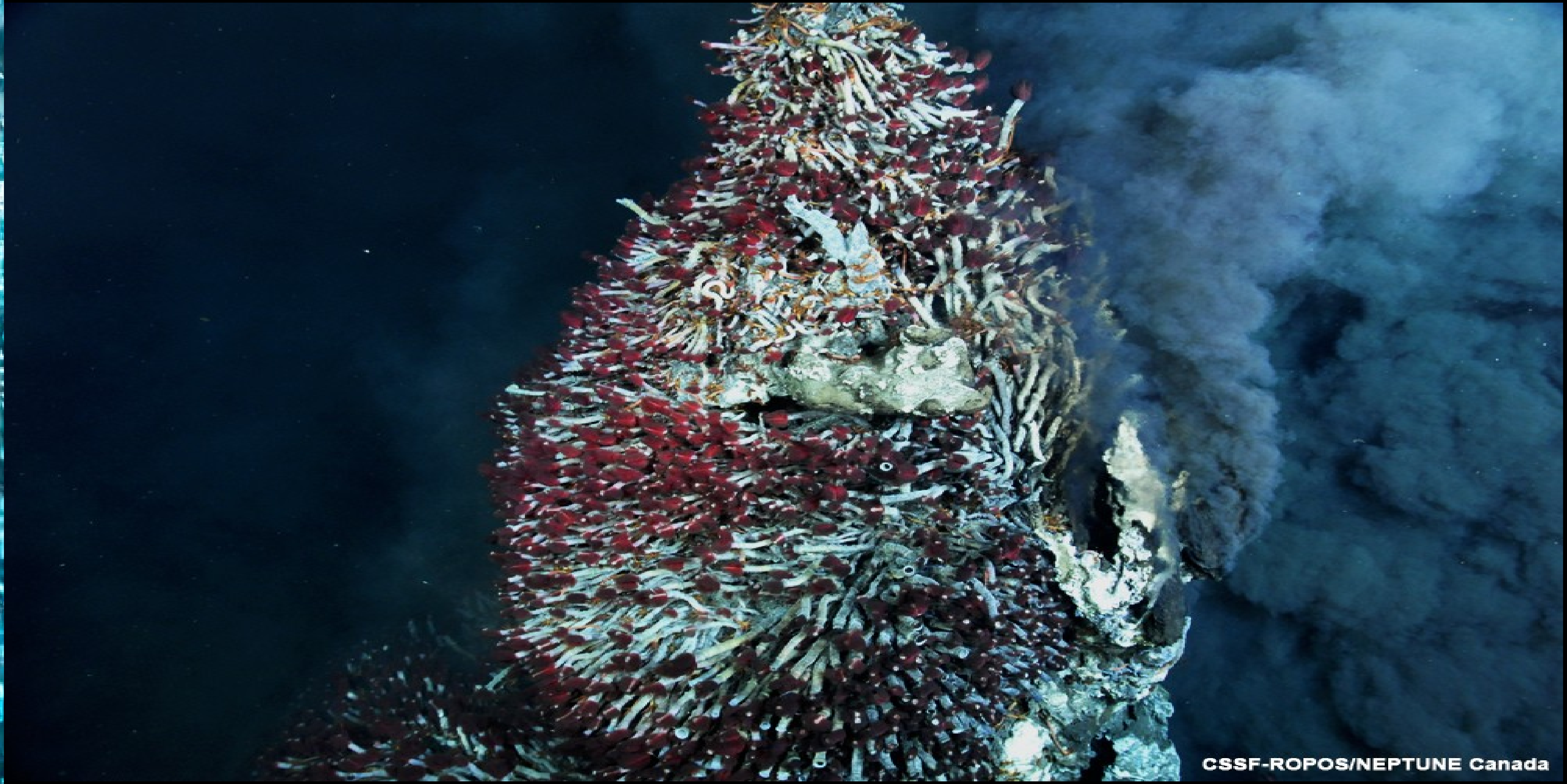
Competitive interaction after the expression of secondary metabolites

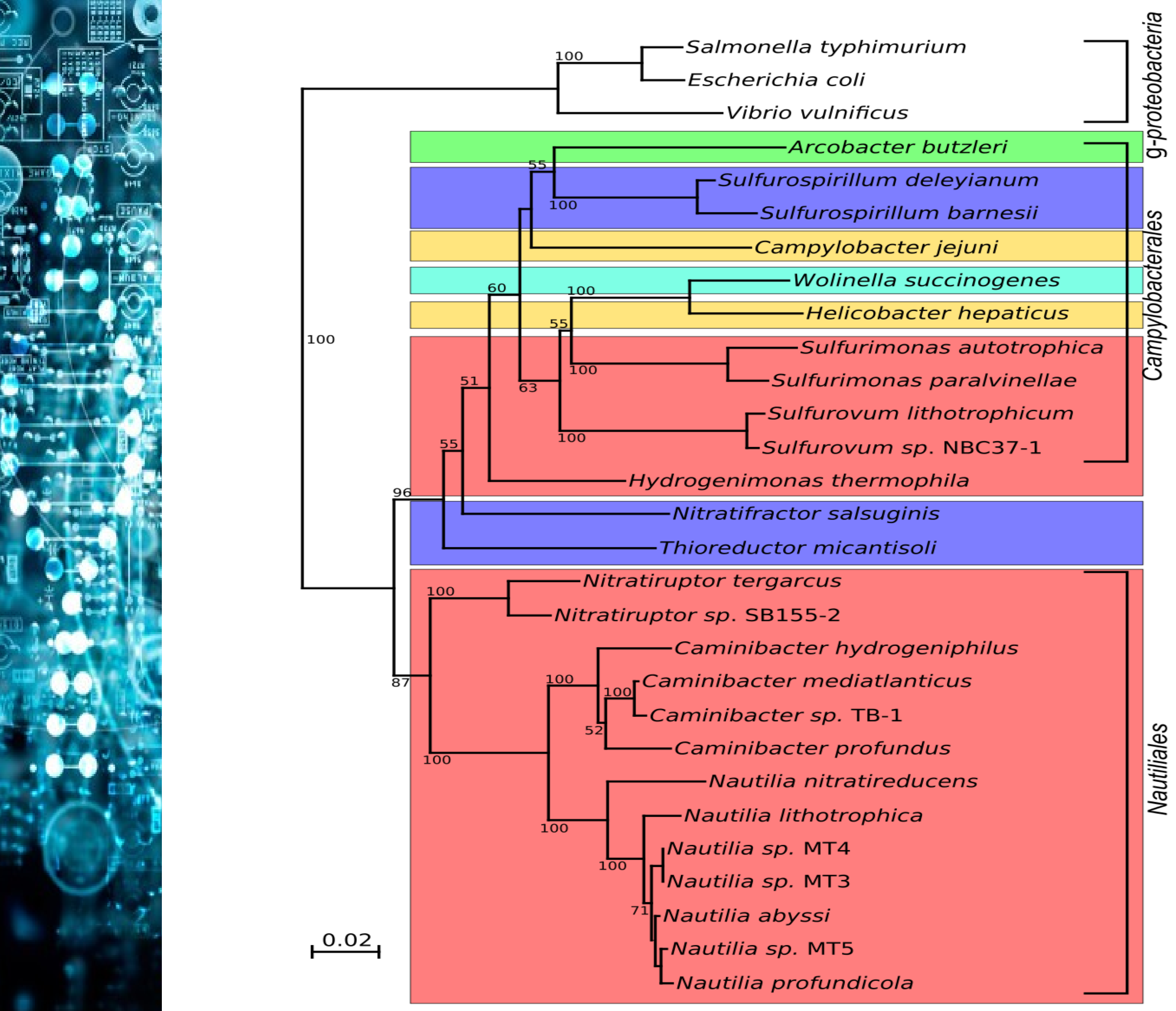
Martina Cascone



BEYOND THE OBVIOUS:
WHERE DO PATHOGENS COME FROM?




CSSF-ROPOS/NEPTUNE Canada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Escherichia coli
Vibrio vulnificus
g-proteobacteria
Arcobacter butzleri
Sulfurospirillum deleyianum
Sulfurospirillum barnesii
Campylobacter jejuni
Wolinella succinogenes
Helicobacter hepaticus
Sulfurimonas autotrophica
Sulfurimonas paralvinellae
Sulfurovum lithotrophicum
Sulfurovum sp. NBC37-1
Hydrogenimonas thermophila
Nitratifractor salsuginis
Thioreductor micantisoli
Campylobacterales
Nitratiruptor tergarcus
Nitratiruptor sp. SB155-2
Caminibacter hydrogeniphilus
Caminibacter mediatlanticus
Caminibacter sp. TB-1
Caminibacter profundus
Nautilia nitratireducens
Nautilia lithotrophica
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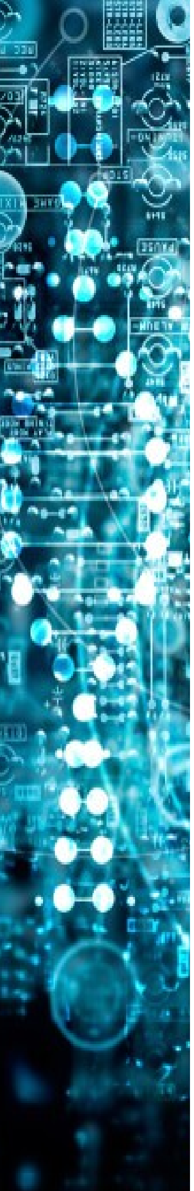
Nautilia profundicola
Nautiliales
0.02



From extreme environments to human pathogens: an evolutionary journey

Donato Giovannelli and Costantino Vetriani (Earth-Life Science Institute, Japan and Rutgers University, USA)

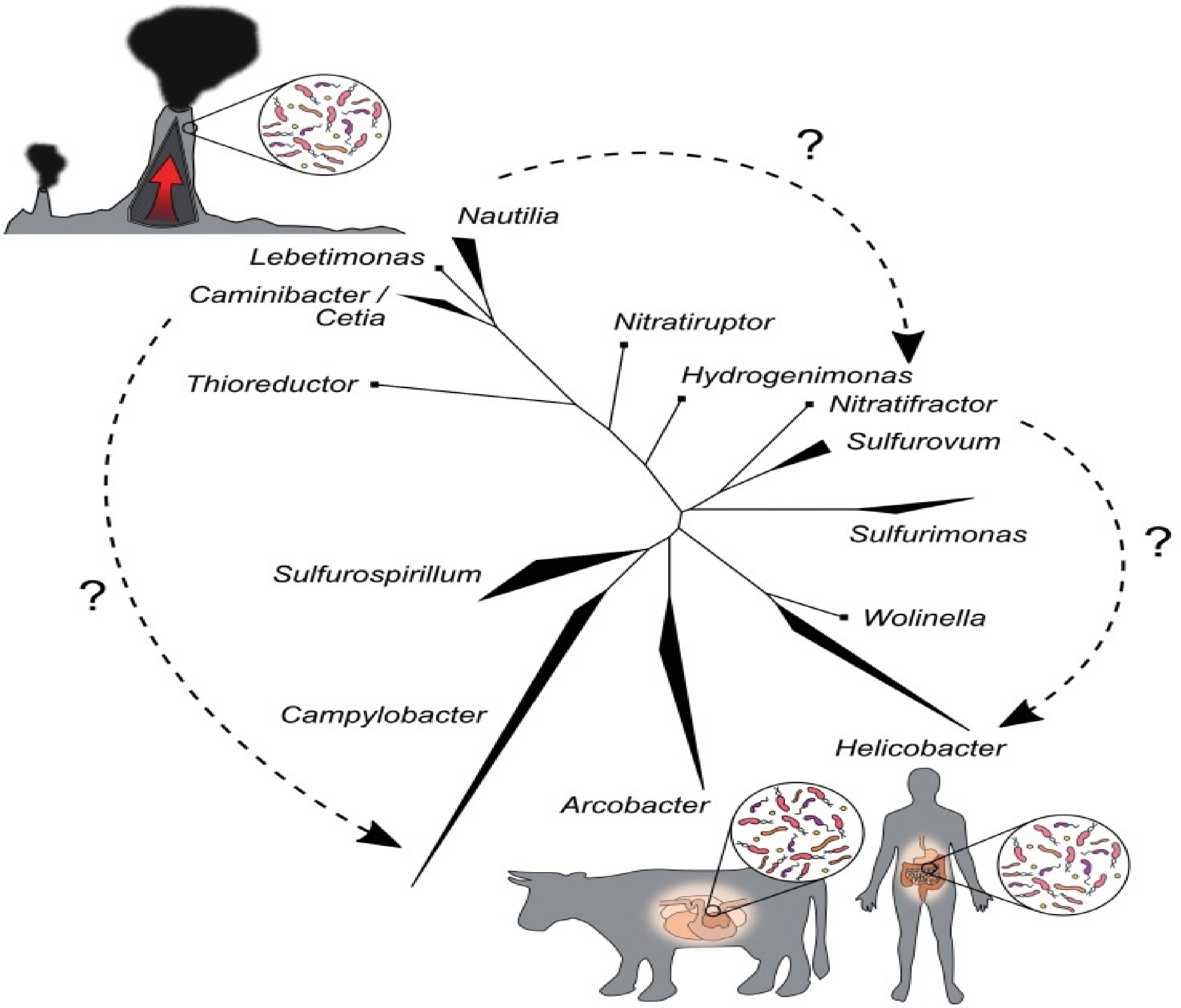
IThe history of our planet is underpinned by roughly 4 billion years of microbial evolution. From its emergence in a (probably) hot and anoxic environment, microbial life has evolved to colonize every available niche on our planet, including the inside and outside of other organisms. Yet, the emergence and evolution of microbial metabolism remains a major unsolved problem. How have microbes adapted to colonize every available environmental niche, including other organisms? How did they evolve to colonize mammals and our human ancestors? Answers to these questions will allow us to understand the emergence and evolution of life on our planet, inform the search for life elsewhere and, in the making, reveal important insight that will help us fight infections.

A microbial world

There is little doubt today that prokaryotes were the earliest forms of life on our planet. Life as we know it is currently based on energy-conserving reactions that allow the exploitation of naturally occurring redox gradients to perform chemical, mechanical and transport work. Over 30 years of research on the origin of life has led to recognition

overlooked. Only in the last decade have we begun to appreciate how the geosphere and biosphere have co-evolved, ultimately resulting in the complex network of metabolic reactions we see today.

Besides controlling biogeochemical cycles, microbes also affect human and animal health. Microorganisms that comprise both beneficial strains and potential pathogens colonize the exposed areas of our bodies and our gastrointestinal tract. Recent studies have


?
Nautilia
Lebetimonas
Caminibacter / Cetia
Nitratiruptor
Thioreductor
Hydrogenimonas
Nitratifractor
Sulfurovum
Sulfurimonas
?
Sulfurospirillum
?
Wolinella
Campylobacter
Helicobacter
Arcobacter

RESEARCH ARTICLE

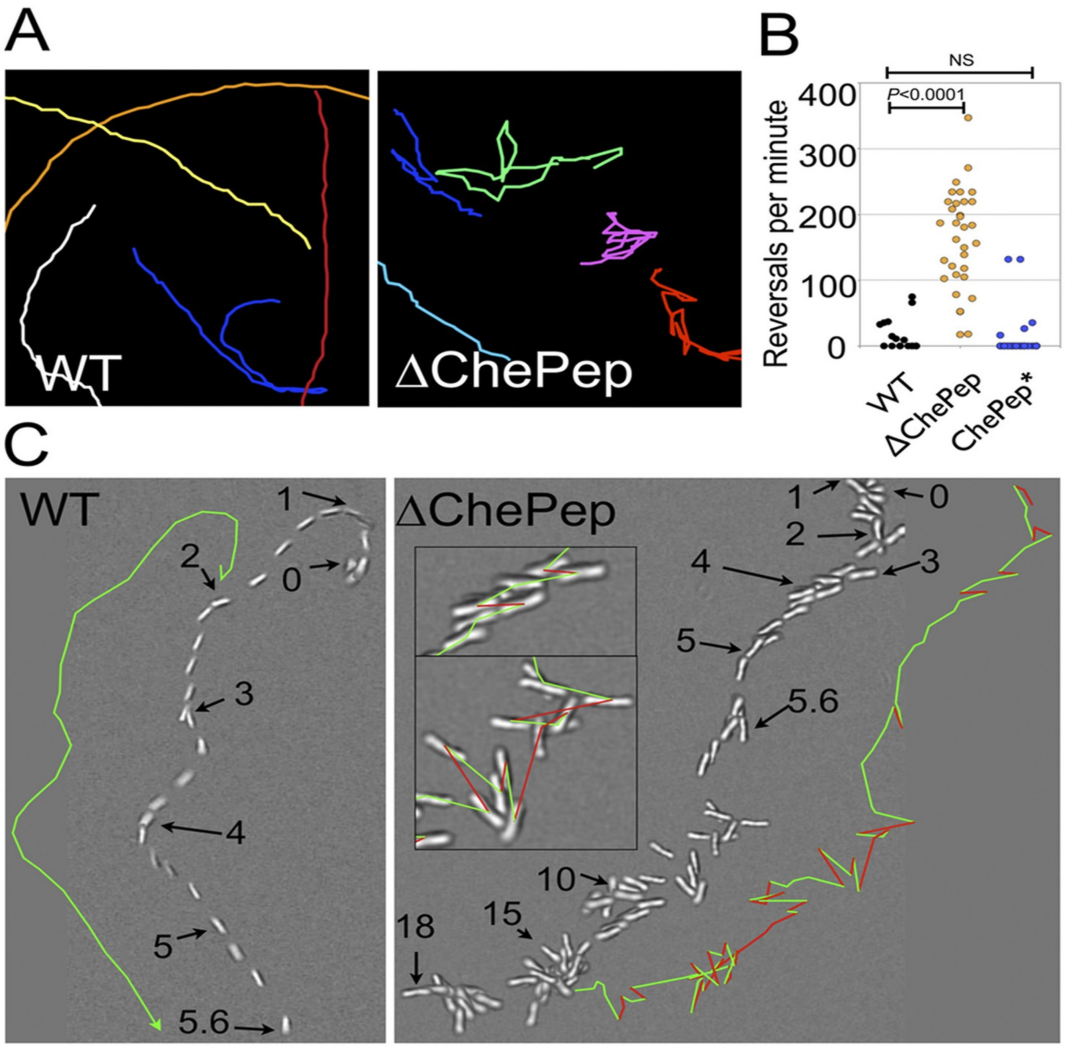
ChePep Controls *Helicobacter pylori* Infection of the Gastric Glands and Chemotaxis in the *Epsilonproteobacteria*

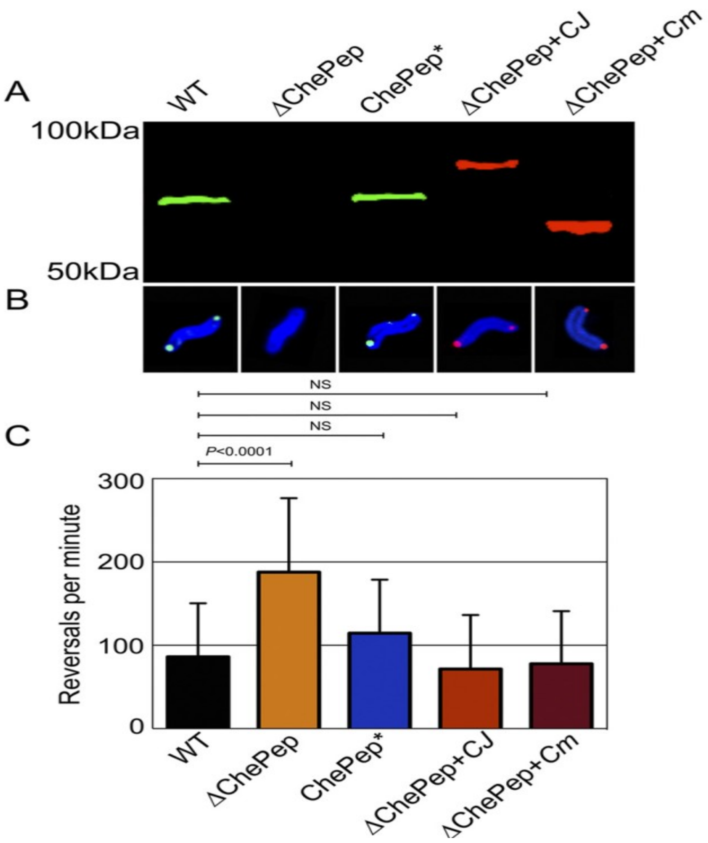
Michael R. Howitt,[a] Josephine Y. Lee,[a] Paphavee Lertsethtakarn,[b] Roger Vogelmann,[a]* Lydia-Marie Joubert,[c] Karen M. Ottemann,[b] and Manuel R. Amieva[a,d]

Department of Microbiology and Immunology, Stanford University School of Medicine, Stanford, California, USA[a]; Department of Microbiology and Environmental Toxicology, University of California, Santa Cruz, Santa Cruz, California, USA[b]; Cell Sciences Imaging Facility, Stanford University School of Medicine, Stanford, California, USA[c]; and Department of Pediatrics, Stanford University School of Medicine, Stanford, California, USA[d]

* Present address: II, Medizinische Klinik Universitätsmedizin Mannheim, Mannheim, Germany

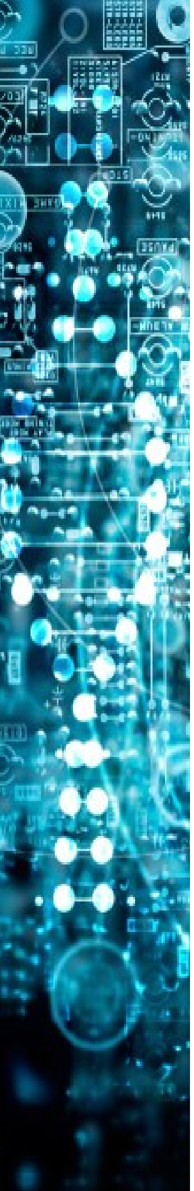
ABSTRACT **Microbes use directed motility to colonize harsh and dynamic environments. We discovered that *Helicobacter pylori* strains establish bacterial colonies deep in the gastric glands and identified a novel protein, ChePep, necessary to colonize this niche. ChePep is preferentially localized to the flagellar pole. Although mutants lacking ChePep have normal flagellar ultrastructure and are motile, they have a slight defect in swarming ability. By tracking the movement of single bacteria, we found that ΔChePep mutants cannot control the rotation of their flagella and swim with abnormally frequent reversals. These mutants even sustain bursts of movement backwards with the flagella pulling the bacteria. Genetic analysis of the chemotaxis signaling pathway shows that ChePep regulates flagellar rotation through the chemotaxis system. By examining *H. pylori* within a microscopic pH gradient, we determined that ChePep is critical for regulating chemotactic behavior. The *chePep* gene is unique to the *Epsilonproteobacteria* but is found throughout this diverse group. We expressed ChePep from other members of the *Epsilonproteobacteria*, including the zoonotic pathogen *Campylobacter jejuni* and the deep sea hydrothermal vent inhabitant *Caminibacter mediatlanticus*, in *H. pylori* and found that ChePep is functionally conserved across this class. ChePep represents a new family of chemotaxis regulators unique to the *Epsilonproteobacteria* and illustrates the different strategies that microbes have evolved to**



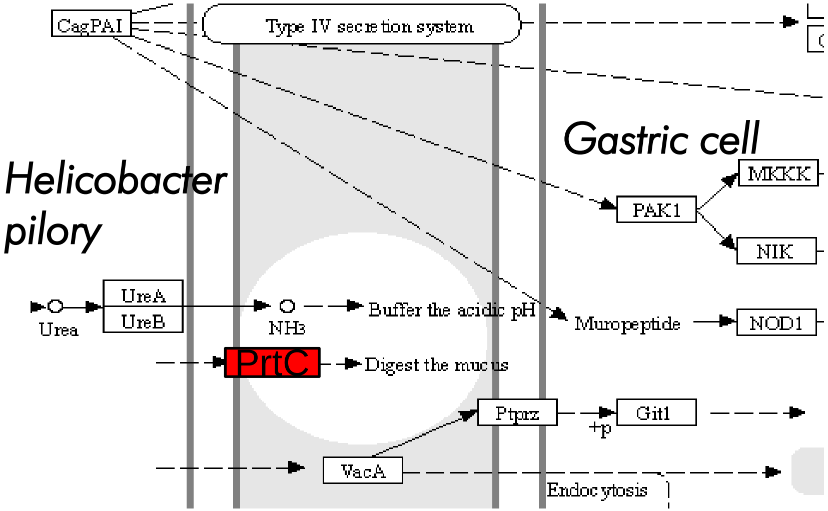


$ChePep_{Hp}$:$ChePep_{Cm}$ 35% aa sim

Howitt et al 2016 mBio



Conserved function of PrtC in environmental and pathogenic Epsilonproteobacteria

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                 ** **.**: :* :: .*: : ::  *  :* . :  :   :  * .  .    *:. *

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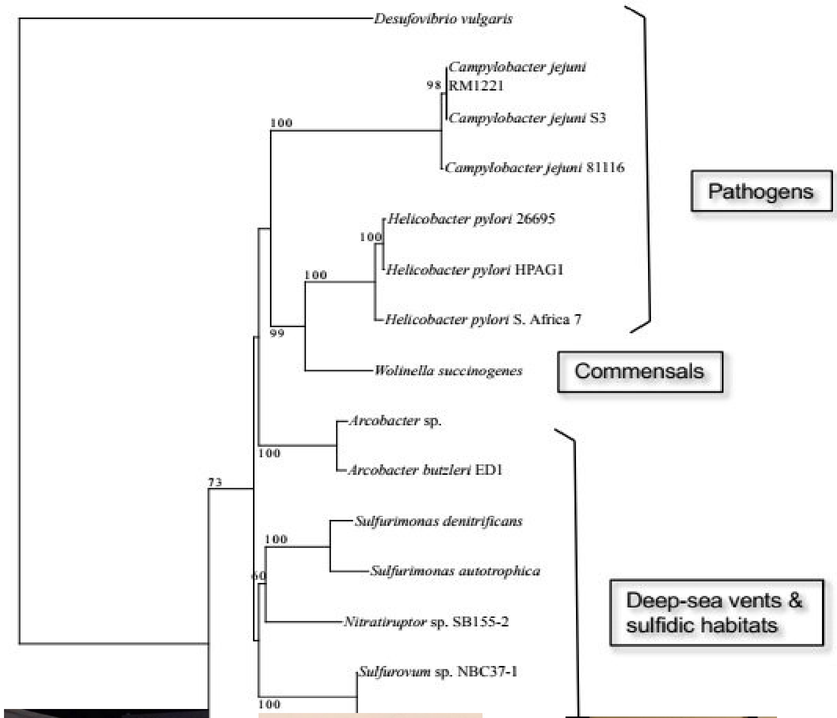
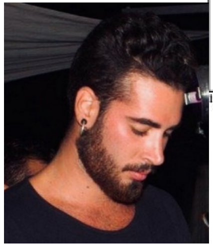
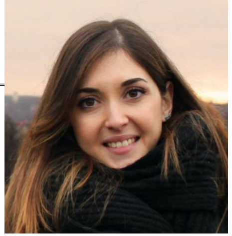


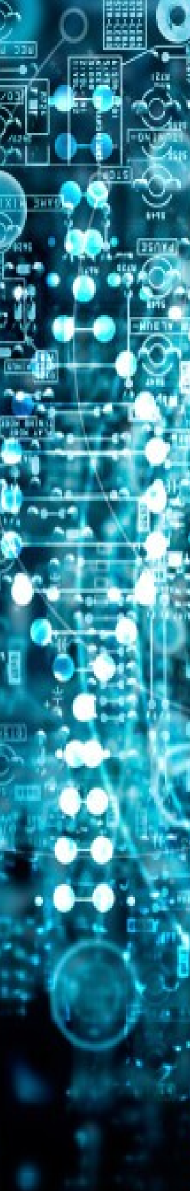


Alessandro Coppola

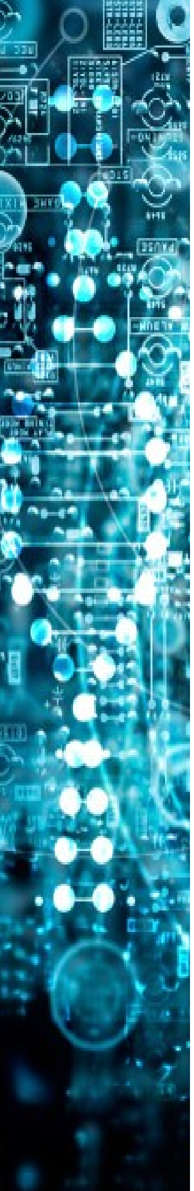


Angelica Severino

Alessandro Masi



WHERE THEM ARCHAEA AT?



Bacteria: medical and environmental relevance

About >16,000 bacterial species are known today (>150,000 if we include uncultured)

538 *are known pathogens or facultative pathogens (~0.36%)*

Archaea: any medical relevance?

If we play the number game we should have identified 16-20 Archaeal pathogens

And yet there are no known Archaea pathogens, and the etiologic agents of all major disease are known

PLOS | PATHOGENS

PEARLS

Archaea in and on the Human Body: Health Implications and Future Directions

Mor N. Lurie-Weinberger, Uri Gophna*

SPECIAL VIEWPOINTS

The Search for Unrecognized Pathogens

David A. Relman

+ See all authors and affiliations

Science 21 May 1999:
Vol. 284, Issue 5418, pp. 1308-1310
DOI: 10.1126/science.284.5418.1308

AMERICAN SOCIETY FOR MICROBIOLOGY | Infection and Immunity

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Minireview

Archaea and Their Potential Role in Human Disease

Paul B. Eckburg, Paul W. Lepp, David A. Relman

DOI: 10.1128/IAI.71.2.591-596.2003

BioEssays

Problems and paradigms

Pathogenic archaea: do they exist?

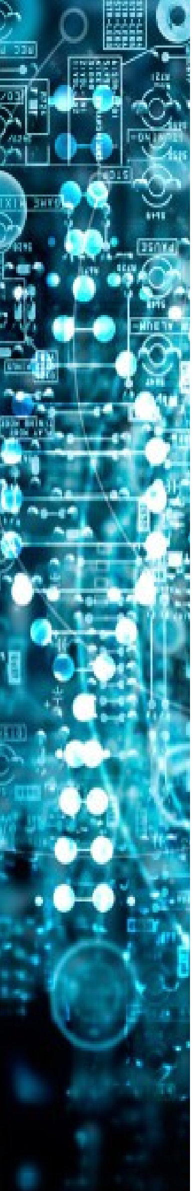
Ricardo Cavicchioli, Paul M.G. Curmi, Neil Saunders, Torsten Thom

First published:17 October 2003 | https://doi.org/10.1002/bies.10354 | Citations: 50

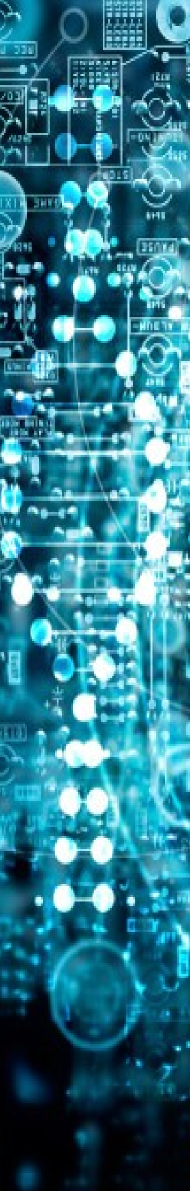
Hypotheses

The proportional lack of archaeal pathogens: Do viruses/phages hold the key?

*Erin E. Gill and Fiona S. L. Brinkman**



THE ROLE OF OPEN SCIENCE



Open Science: what is it?

Open science is the movement to make scientific research (including publications, data, physical samples, and software) and its dissemination accessible to all levels of an inquiring society, amateur or professional.

Open science is transparent and accessible knowledge that is shared and developed through collaborative networks.

OPEN SCIENCE

Open Science: Why?

OpenScience is part of a large movement, started with Open Source Software many years ago.

open science

open source

open source hardware

Open Access

OPEN DATA

see https://www.gnu.org/philosophy/free-sw.html for more info


Reproducible
Raphael Ritson-Williams


FAST


IMMORTAL

The power of sharing

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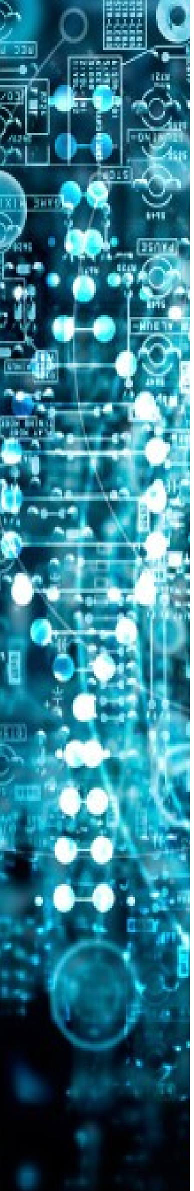

Great power comes from comparison!

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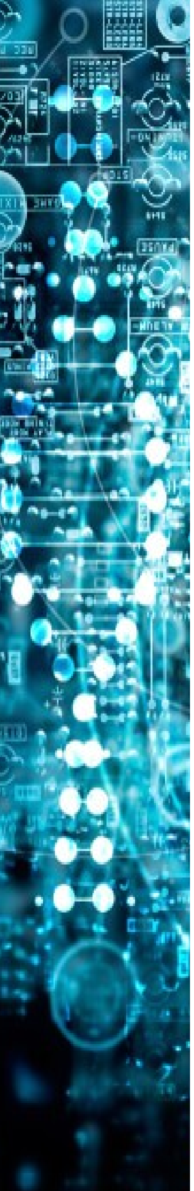
CGACCTCTCCTA

Biologist as Early Innovators in Big Data Resources

'70s-'80s	RCSB PDB PROTEIN DATA BANK	SIB swissprot EBI	
'90s	NCBI National Center for Biotechnology Information	EMBL	DDBJ DNA Data Bank of Japan
2000s	JGI JOINT GENOME INSTITUTE	MG-RAST metagenomics analysis server	camera



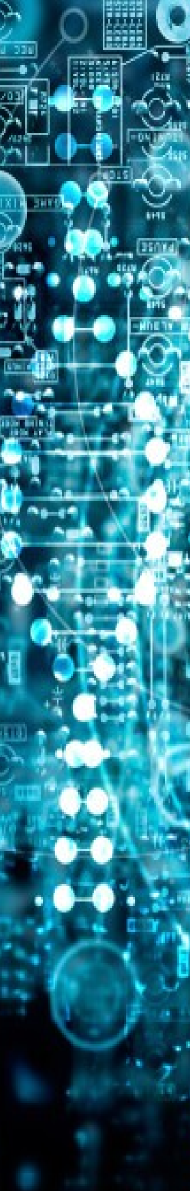
AddGene

Addgene is a global, nonprofit repository that was created to help scientists share plasmids. Plasmids are DNA-based research reagents commonly used in the life sciences. When scientists publish research papers, they deposit their associated plasmids at Addgene.

It played an important role in the spread of CRISPR-cas technology allowing quick access to reagents.

addgene

The nonprofit plasmid repository



Sharing Speeds Science

If it takes **5** hours to make a plasmid...
Addgene has saved researchers
5,000,000 hours.

This is the same as **570** years saved!

Deposits and Requests

We've now shipped
1,000,000+
plasmids.

Our repository contains **67,000+** plasmids available from **4,000+** depositing labs.

Fun Addgene Facts

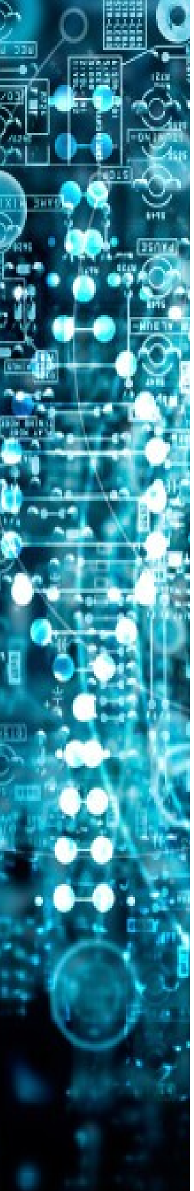
Since we were founded in 2004, Addgenies have formed Boston Triathlon teams for **9** years.

We've also gone on **317** outreach trips to reach scientists around the world.

OpenSourceMalaria

The Open Source Malaria project is an open science initiative designed to accelerate the pre-phase one testing of anti-malaria compounds by leveraging the open science principle in 2011.

All the experiments go on the web (including the ones that did not turn out well). All the data are available. Anyone can do anything they wish with the compounds (CC-BY licence). Anyone can take part in the research.



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