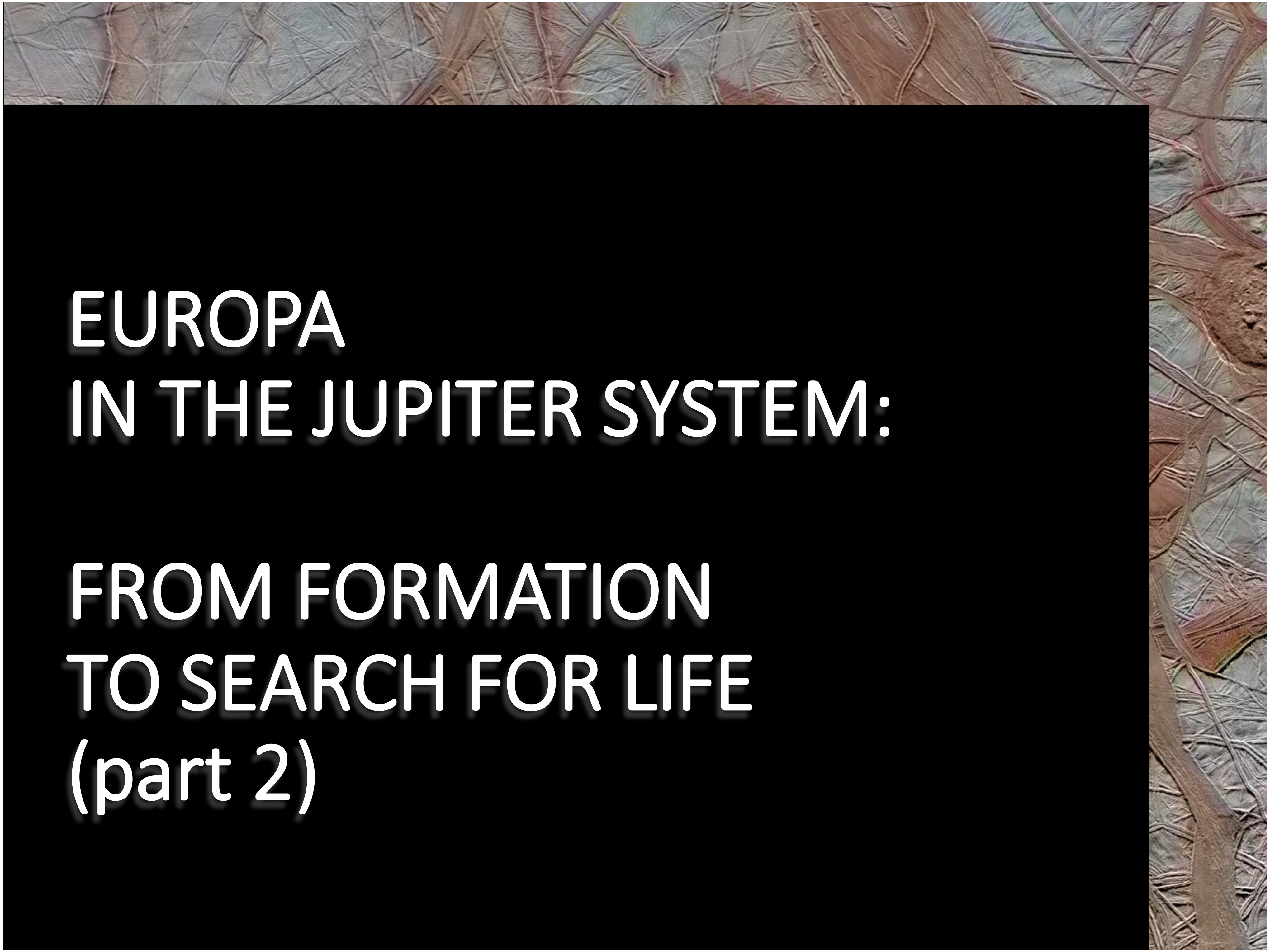


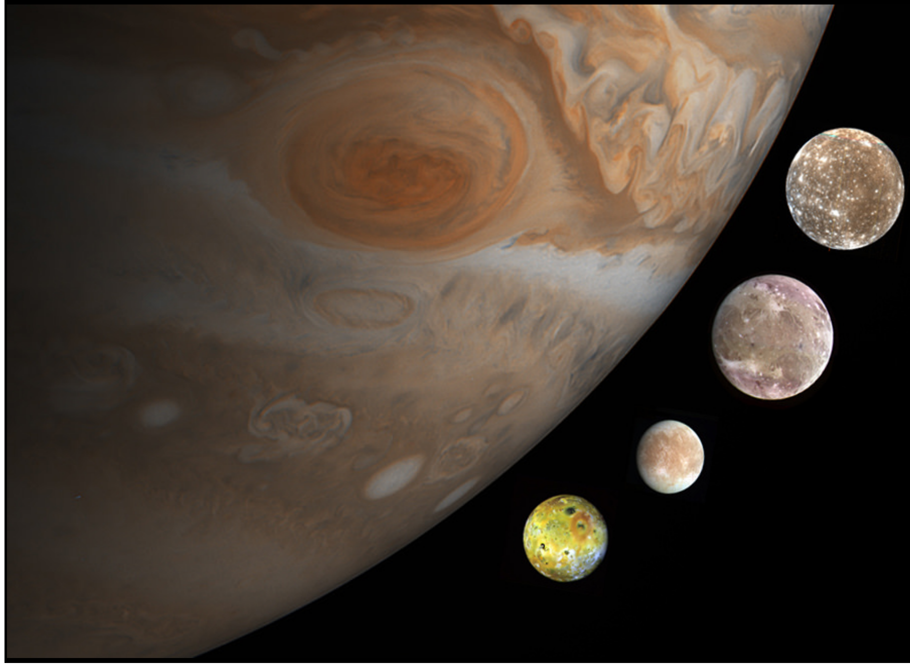
EUROPA
IN THE JUPITER SYSTEM:

FROM FORMATION
TO SEARCH FOR LIFE
(part 2)

FROM FORMATION TO SEARCH FOR LIFE

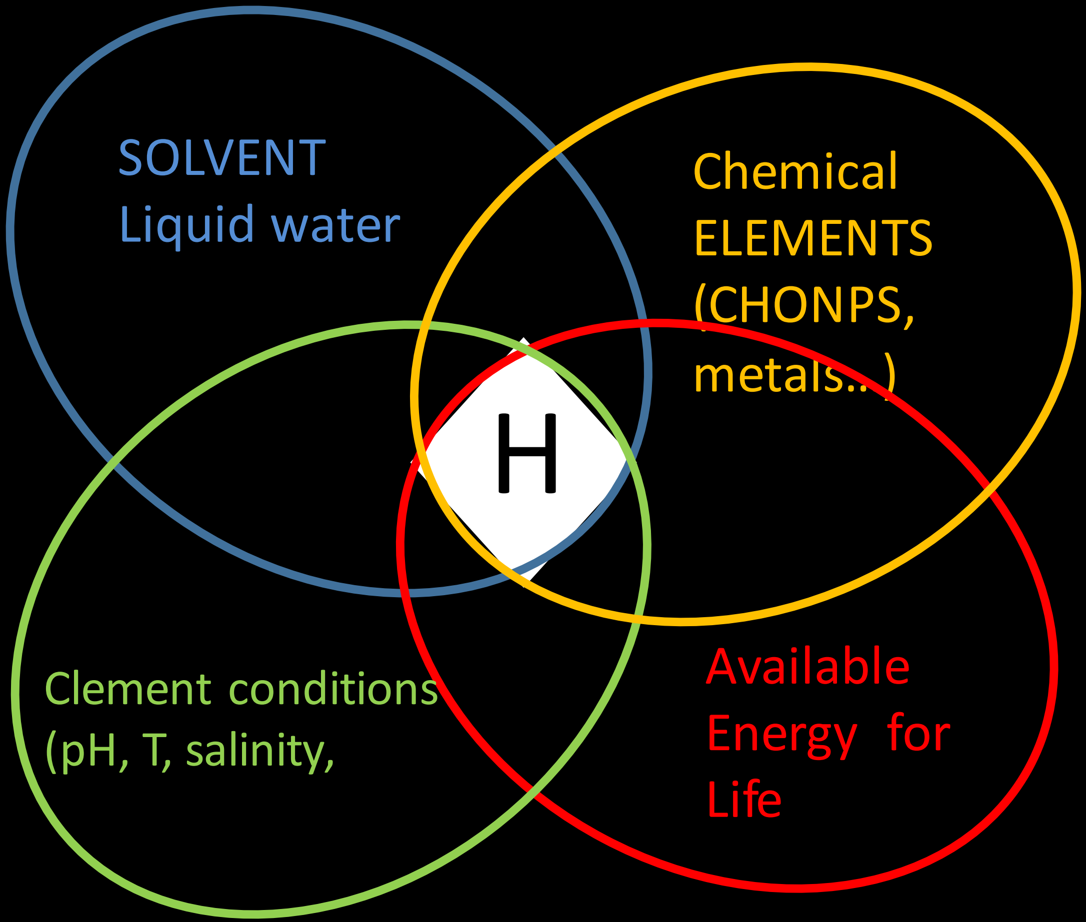
Europa habitable zone. Ocean worlds

Europa biosphere



HABITABILITY REQUIREMENTS

LIFE on Earth



SOLVENT
Liquid water

Chemical
ELEMENTS
(CHONPS,
metals…)

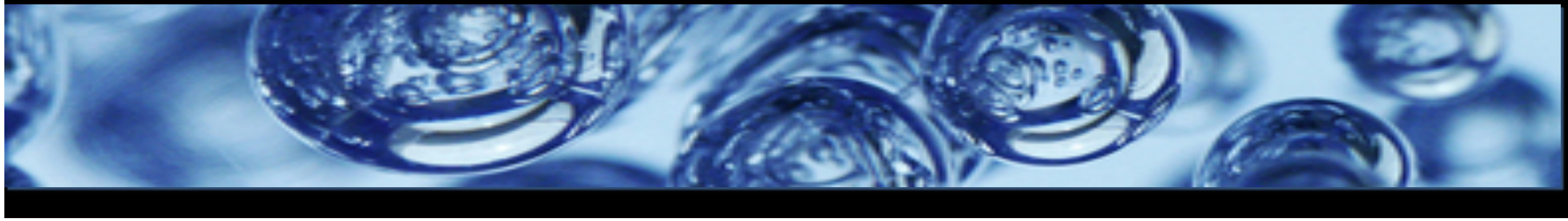
H

Clement conditions
(pH, T, salinity,

Available
Energy for
Life

HABITABILITY REQUIREMENTS

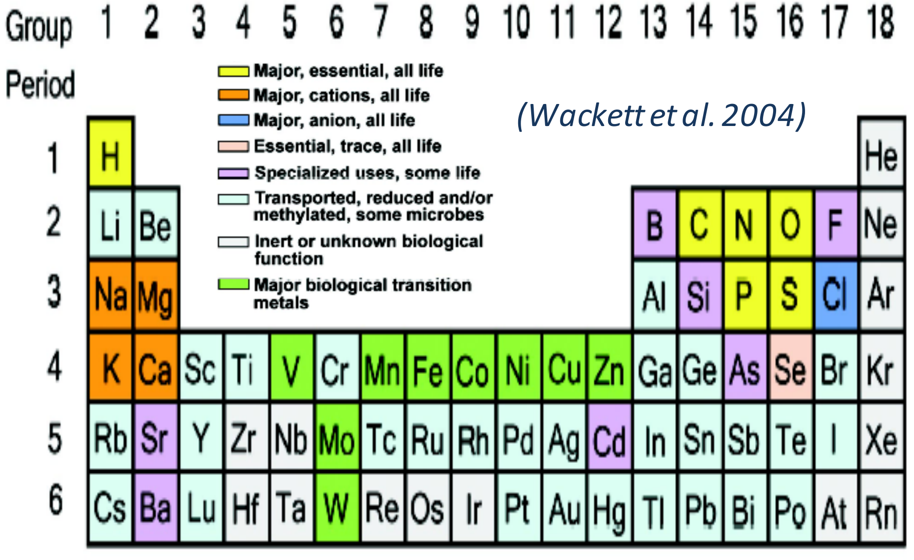
FUNCTION	DESCRIPTION
Uses as reactant	takes part in many metabolic reactions. •e.g. hydrolysis of sugar, raw material for photosynthesis.
Uses as solvent	good solvent for inorganic and many small organic substances.
Acts as medium for transportation	liquid nature, can flow from one area to others. •many chemicals can dissolve in it.
Acts as medium for chemical reaction	many chemicals can dissolve in it. •not easily subjected to large temperature fluctuation, thus reactions can take place in a constant rate.
Provides support	provides turgidity to support herbaceous plants and small organisms •provides buoyancy for aquatic organisms
Others	decreases body temperature by evaporation of water from body surface e.g. sweat •necessary for forming body secretion e.g. digestive juice •medium for fertilization of eggs and sperms in mammals



HABITABILITY REQUIREMENTS

The elements used by living organisms either in:

- structural macromolecules (proteins, lipids)
- energy transformation
- electron transfer chains
- energy sources, and as oxidants or reductants



(Wackett et al. 2004)

Mineral Surface	Elemental composition	Properties
Basalt minerals	Si, O, Fe	Major mineral surface on early Earth
Apatite	Ca, PO_4^{2-}	Primary phosphate mineral
Clays	Si, Al, O	Can organize organics into films and catalyze polymerization reactions
Pyrite	FeS_2	Source of reducing power
Calcite	$CaCO_3$	Chiral surfaces; concentrate organics such nucleotides from models
Quartz	SiO_2	Chiral surfaces
Ultramafic minerals	Fe, Mg	Generate hydrogen and organic compounds from CO_2
Borate minerals	B	Catalyze the synthesis of ribose

(Modified from Deamer, 2007)

HABITABILITY REQUIREMENTS

Light source

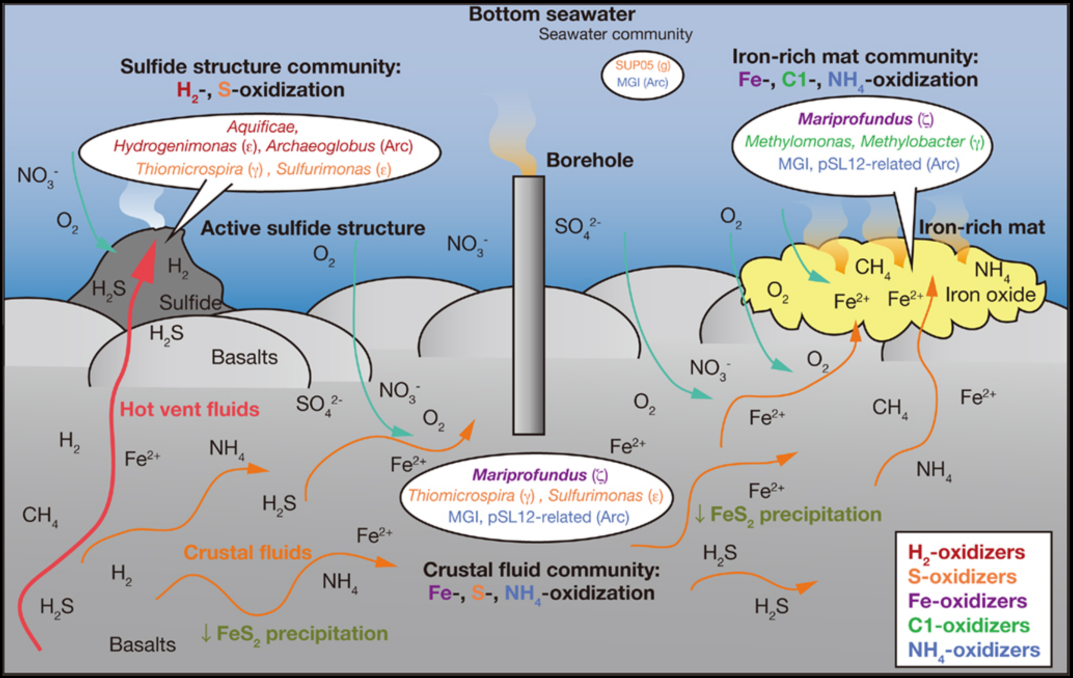
Photosynthesis, Radiolysis, generation of oxidants

Chemical source

Redox process

Other gradients

thermal, osmotic …



The “Unity of Metabolism” predicts that organisms *(even with different biochemistries than Earth organisms) on any active planet (water) will use the same chemical energy sources and electron acceptors and donors as Earth organisms*

A variation of “follow the energy”, Hoehler, Amend and Shock, (2007); Shock and Holland, (2007)

Why Europa stands out as a potential habitat?

Explain

- Aqueous reservoirs in the subsurface
- Bio-essential elements
- Available energy for life

Distribution of water at depth
  ocean
  shallow chambers/subglacial lakes
  water-rock interactions

Reservoirs potentially connected with the surface
Endogenic materials can provide clues about aqueous reservoirs

Energy/geological activity.
  Interactions with the objects in the Jupiter system
  Hydrothermal systems and chemical disequilibria
  Maintain the liquid water and rock-water interaction

Building blocks and geochemical cycling

Why Europa is the best place to search for extant life?

Dark biosphere under the ice active today.

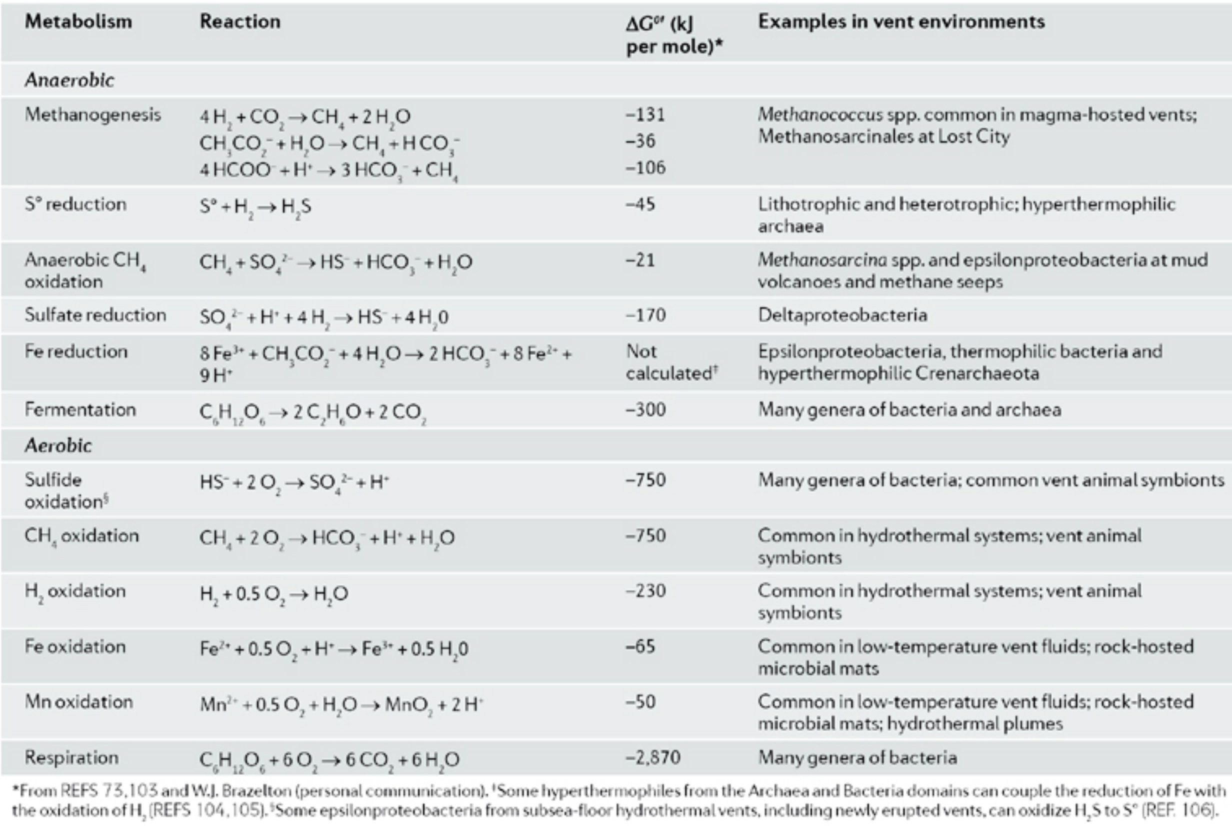
Abiogenesis in hydrothermal systems

A second origin of life. Convergent evolution as a consequence of abiogenesis

Evidences of life. Searching strategy

THE POTENTIAL BIOSPHERE

- MICROBIAL ECOSYSTEMS: CHEMOTROPHIC
  - Distribution controlled by hydrothermal activity, which provide primary nutrients (H2, CH4, ketones)
  - Surface bounded, not free-living
  - No carbonate mats as do chemotrophic colonies around terrestrial smokers because they need sulfate (oxigenated environment), and P above the lysocline

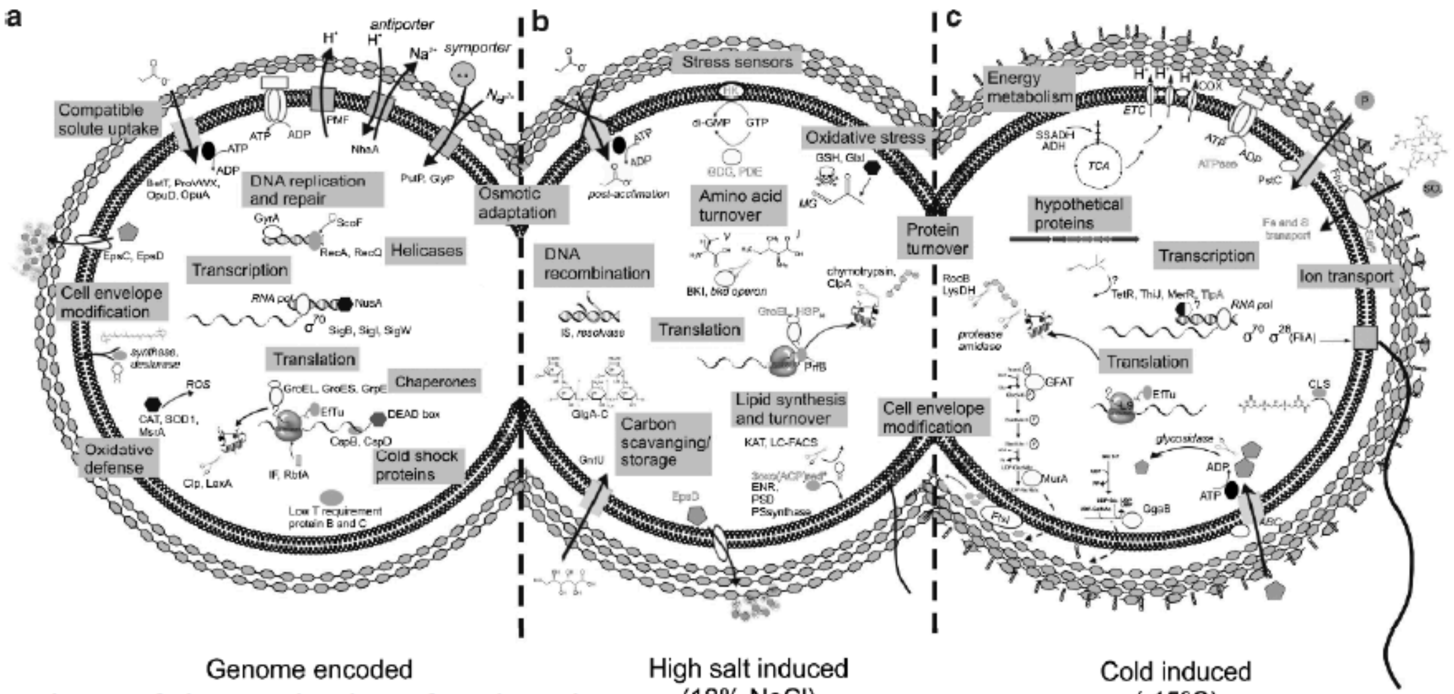


Metabolism	Reaction	$\Delta G^{0\prime}$ (kJ per mole)[*]	Examples in vent environments
Anaerobic			
Methanogenesis	$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$ $CH_3CO_2^- + H_2O \rightarrow CH_4 + HCO_3^-$ $4HCOO^- + H^+ \rightarrow 3HCO_3^- + CH_4$	−131 −36 −106	*Methanococcus* spp. common in magma-hosted vents; Methanosarcinales at Lost City
S° reduction	$S^\circ + H_2 \rightarrow H_2S$	−45	Lithotrophic and heterotrophic; hyperthermophilic archaea
Anaerobic CH_4 oxidation	$CH_4 + SO_4^{2-} \rightarrow HS^- + HCO_3^- + H_2O$	−21	*Methanosarcina* spp. and epsilonproteobacteria at mud volcanoes and methane seeps
Sulfate reduction	$SO_4^{2-} + H^+ + 4H_2 \rightarrow HS^- + 4H_20$	−170	Deltaproteobacteria
Fe reduction	$8Fe^{3+} + CH_3CO_2^- + 4H_2O \rightarrow 2HCO_3^- + 8Fe^{2+} + 9H^+$	Not calculated[†]	Epsilonproteobacteria, thermophilic bacteria and hyperthermophilic Crenarchaeota
Fermentation	$C_6H_{12}O_6 \rightarrow 2C_2H_6O + 2CO_2$	−300	Many genera of bacteria and archaea
Aerobic			
Sulfide oxidation[§]	$HS^- + 2O_2 \rightarrow SO_4^{2-} + H^+$	−750	Many genera of bacteria; common vent animal symbionts
CH_4 oxidation	$CH_4 + 2O_2 \rightarrow HCO_3^- + H^+ + H_2O$	−750	Common in hydrothermal systems; vent animal symbionts
H_2 oxidation	$H_2 + 0.5O_2 \rightarrow H_2O$	−230	Common in hydrothermal systems; vent animal symbionts
Fe oxidation	$Fe^{2+} + 0.5O_2 + H^+ \rightarrow Fe^{3+} + 0.5H_20$	−65	Common in low-temperature vent fluids; rock-hosted microbial mats
Mn oxidation	$Mn^{2+} + 0.5O_2 + H_2O \rightarrow MnO_2 + 2H^+$	−50	Common in low-temperature vent fluids; rock-hosted microbial mats; hydrothermal plumes
Respiration	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	−2,870	Many genera of bacteria

[*] From REFS 73,103 and W.J. Brazelton (personal communication). [†] Some hyperthermophiles from the Archaea and Bacteria domains can couple the reduction of Fe with the oxidation of H_2 (REFS 104,105). [§] Some epsilonproteobacteria from subsea-floor hydrothermal vents, including newly erupted vents, can oxidize H_2S to S° (REF. 106).

FROM FORMATION TO SEARCH FOR LIFE

Planococcus halocryophilus, a bacterial strain isolated form the Arctic permafrost, has an active metabolism at -15ºC in a liquid brine



Genome encoded

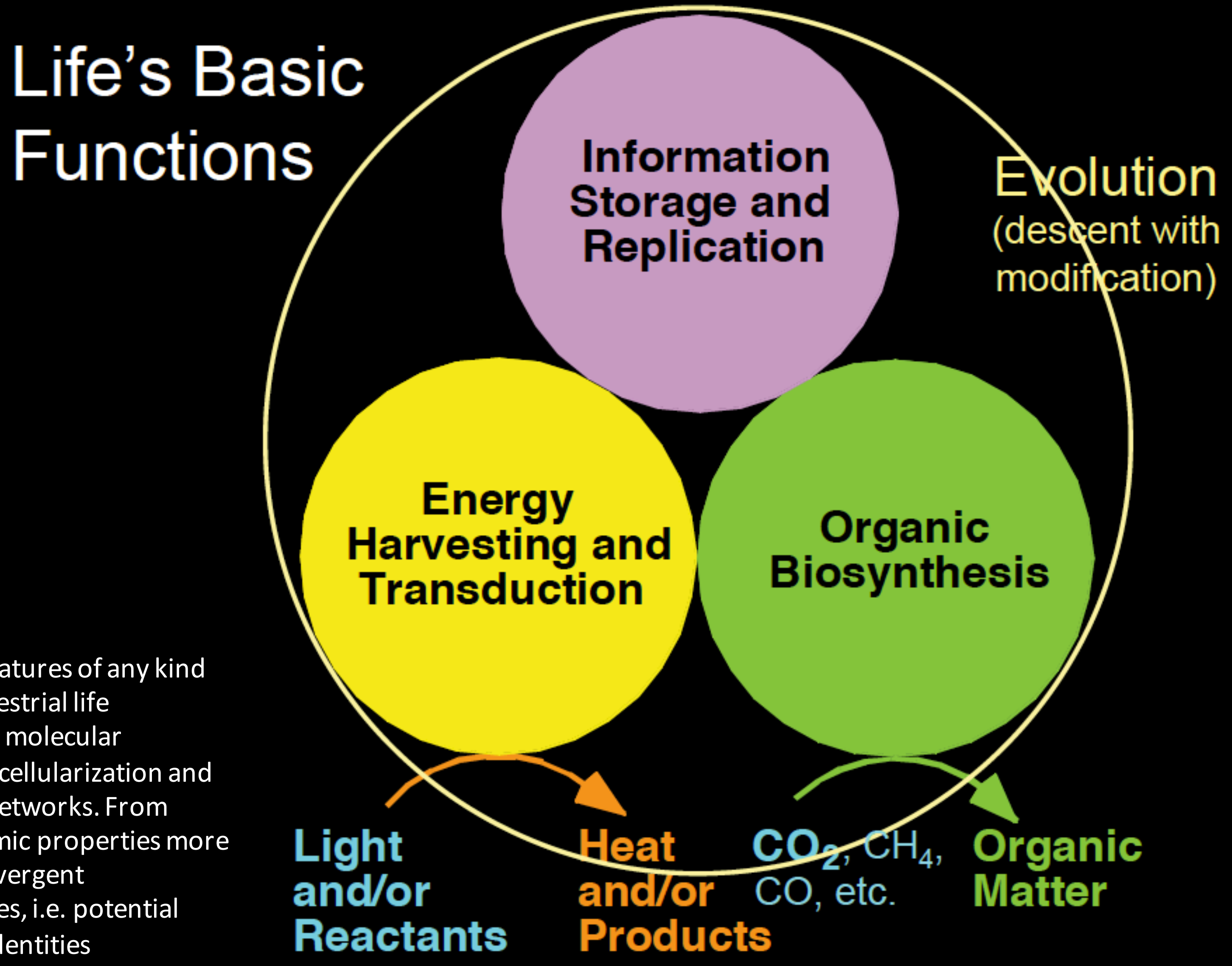
High salt induced (18% NaCl)

Cold induced (-15°C)

- Accumulation of glycogen has been found in salt-acclimated cyanobacteria (Page-Sharp et al. , 1998)
- Induction of different levels of osmolyte transporters

- Cell envelope precursors, modifications and synthesis.
- Energy metabolism.

POTENTIAL BIOSPHERE



Life's Basic Functions

Information Storage and Replication

Evolution (descent with modification)

Energy Harvesting and Transduction

Organic Biosynthesis

Light and/or Reactants

Heat and/or Products

CO_2, CH_4, CO, etc.

Organic Matter

Universal features of any kind of extraterrestrial life encompass: molecular replication, cellularization and metabolic networks. From these systemic properties more precise convergent biosignatures, i.e. potential molecular identities