

GLOSSARY

The field of astrobiology is by definition multidisciplinary, therefore, any glossary devoted to it is likely to be incomplete. Nevertheless, the editors hope that the following glossary, which contains approximately 1000 terms commonly used in astrobiology, will help specialists in one field to obtain pertinent information or clarifications about other disciplines.

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A

a (astronomy): Orbital parameter, semi-major axis of elliptical orbit.

Abiotic: In absence of life.

Ablation (astronomy): Loss of matter by fusion or vaporization during the entrance of an object into the atmosphere.

Absolute magnitude: Magnitude of a stellar object when seen from a distance of 10 parsecs (32.6 light-years) from Earth.

Acasta: Region of Northern Territories (Canada) where the oldest relicts of continental crust were discovered. These gneisses were dated at 4.03 Ga.

Accretion (astronomy): Matter aggregation leading to the formation of larger objects (stars, planets, comets, asteroids). Traces of accretion of their parent body (asteroid) can be observed in some meteorites.

Accretion disk: Disk of matter around a star (or around a black hole) such that matter is attracted by the central object and contributes to its growth. Disks around protostars, new-born stars and T-Tauri stars are accretion disks.

Accretion rate (astronomy): Mass accreted per time unit (typically 10^{-5} to 10^{-8} solar mass per year).

Accuracy: The accuracy of a method is its capacity to measure the exact value of a given quantity.

Acetaldehyde: CH_3CHO , ethanal.

Acetic acid: CH_3COOH , ethanoic acid.

Acetonitrile: CH_3CN , cyanomethane, methyl cyanide.

Achiral: Not chiral.

Acidophile: Organism which « likes » acidic media, which needs an acidic medium.

Actinolite: Mineral. Inosilicate (double chain silicate). $[\text{Ca}_2(\text{Fe},\text{Mg})_5\text{Si}_8\text{O}_{22}(\text{OH},\text{F})_2]$. It belongs to the amphibole group.

Activation energy (E_a): Empirical parameter that permits to describe, via Arrhenius law, the temperature dependence of a reaction rate. In the case of a reaction $\text{A} + \text{B} \rightarrow \text{C}$, E_a can be described as the energy difference between the reactants $\text{A} + \text{B}$ and the activated complex (AB^*) on the reaction pathway to C. It corresponds to an energy barrier.

Active site (of an enzyme): Part of an enzyme where substrate is specifically fixed, in a covalent or non-covalent way, and where catalysis takes place.

Activity (solar or stellar): All physical phenomena which are time dependent and which are related to star life (like stellar wind, solar prominence,

sun-spots). Their origin is mainly magnetic, they correspond to emissions of electromagnetic waves at different frequencies (from radio-waves to X-rays) and also to emissions of charged particles (protons, alpha particles and heavier particles). In the case of the Sun, the solar activity is cyclic. The shorter cycle is an eleven year cycle.

Activity: In non-ideal solution, activity plays the same role as mole fraction for ideal solution.

Adakite: Volcanic felsic rock generated in subduction zone, by partial melting of the subducted basaltic oceanic crust.

Adaptive optics: The goal of adaptive optics is to correct the effects of atmospheric turbulence on the wavefronts coming from stars. The basic idea consists of measuring the wavefront form each 10 ms (to follow the atmospheric turbulence), and to deform the mirror(s) accordingly to correct and stabilize the wavefront.

Adenine: Purine derivative which plays an important role in the living world as component of nucleotides.

Adenosine: Nucleoside which results from condensation of adenine with ribose.

ADP: Adenosine diphosphate (see also ATP).

Aerobian: Organism whose life requires free oxygen in its environment.

Aerobic respiration: Ensemble of reactions providing energy to a cell, oxygen being the ultimate oxidant of organic or inorganic electrons donors.

Aerosols: Liquid or solid sub-millimetric particles in suspension in a gas. Aerosols play an important role in atmospheric physics and chemistry.

Affinity constant: The efficiency of recognition of a target by a ligand is characterised by an affinity constant (in M^{-1}) which is the ratio of ligand-target

concentration ($[ligand-target]_{eq}$) to the product of the free ligand and free target concentrations at equilibrium ($[ligand]_{eq} \times [target]_{eq}$): $K = \frac{[ligand-target]_{eq}}{[ligand]_{eq} \times [target]_{eq}}$.

AIB: See aminoisobutyric acid.

Akilia: Region of Greenland near Isua where are exposed sediments and volcanic rocks similar in both composition and age (3.865 Ga) to the Isua gneisses.

Alanine (Ala): Proteinic amino acid containing three carbon atoms.

Albedo: Fraction of the incident light which is reflected by a reflecting medium (i.e. atmosphere) or surface (i.e. ice cap). A total reflection corresponds to an albedo of 1.

Albite: Mineral. Tectosilicate (3D silicates). Sodic plagioclase feldspar $Na-AlSi_3O_8$.

Alcalophile: Organism, which « likes » alkaline (basic) media, or needs an alkaline medium

Alcohol: R-OH.

Aldehyde: R-CHO.

Aldose: Any monosaccharide that contains an aldehyde group (-CHO).

ALH84001: Martian meteorite found, in 1984, in the Alan Hills region (Antarctica). In 1996, the claim that it contains traces of metabolic activity and even, possibly, microfossils was the starting point of strong debates.

Aliphatic hydrocarbon: Hydrocarbon having an open chain of carbon atoms. This chain can be normal or forked.

Allende: Large carbonaceous chondrite (meteorite) of 2 tons, of the C3/CV type and found in Mexico in 1969.

Allocthonous sediment: Sediment that formed in a place different of its present day location (transported).

Alpha helix: A type of secondary helical structure frequently found in proteins. One helix step contains approximately 3.6 amino acid residues.

Alteration (*Weathering*): Modification of physical and chemical properties of rocks and minerals by atmospheric agents.

Amide: $R-CO-NH_2$, $R-CO-NH-R'$, $R-CO-NR'R''$ depending if the amide is primary, secondary or tertiary. The bond between the CO group and the N atom is generally called the amide bond but when it links two amino acid residues in a polypeptide or in a protein, it is called the peptide bond.

Amine: Derivatives of ammonia NH_3 in which one, two or three H atoms are substituted by an R group (a group containing only C and H atoms) to give primary, secondary or tertiary amines.

Amino acid (AA): Organic molecule containing a carboxylic acid function (COOH) and an amino function (generally but not always a NH_2 group). If the two functions are linked to the same carbon atom, the AA is an alpha amino acid. All proteinic AA are alpha amino acids.

Amino acids (*biological*): AA directly extracted from organisms, fossils, sedimentary rocks or obtained, after hydrolysis, from polypeptides or proteins found in the same sources.

Amino acids (*proteinic*): AA found as building blocks of proteins. All proteinic AA are homochiral and characterized by an L absolute configuration.

Amino isobutyric acid (AIB): Non proteinic alpha amino, alpha methyl AA. Detected in chondrites.

Amino nitrile: Molecule containing a CN group and an amine function. It could have played a role in the prebiotic synthesis of amino acids.

Amitsôq: Region of Greenland where are exposed the oldest huge outcrops ($\sim 3000 \text{ km}^2$) of continental crust, dated at 3.822 Ga (gneiss)

Amorphous: Solid state characterized by a lack of order at large distances

Amphibole: Mineral family. Inosilicate (water-bearing double chain silicate), including actinolite, hornblende, glaucophane, etc.

Amphibolite: Rock generated by metamorphism of basalt. It mainly consists in amphibole and plagioclase feldspar crystals, sometimes associated with garnet.

Amphiphile: Molecule with a hydrophilic part and a lipophilic part.

Amplification (*of DNA*): Production, in relatively large quantity, of fragments of DNA by in vitro replication, starting from a very small initial sample (see: PCR).

Amu (atomic mass unit): Atomic mass unit such that the atomic mass of the ^{12}C (carbon isotope) has exactly a mass equal to 12.0000.

Anabolism: General term to designate a group of biochemical reactions involved in the biosynthesis of different components of living organisms.

Anaerobian: Organism, which does not need free oxygen for his metabolism. In some cases, free oxygen is a poison for anaerobian organisms.

Anaerobic respiration: Ensemble of reactions providing energy to a cell, the ultimate oxidant being an inorganic molecule other than oxygen.

Anatexis: High degree metamorphism where rock begins to undergo partial melting.

Andesite: Effusive mafic magmatic rock (volcanic); it mainly consists in sodic plagioclase feldspar + amphibole \pm pyroxene crystals. These magmas are abundant in subduction zones. Diorite is its plutonic equivalent.

Angular momentum: The angular momentum, L of a rigid body with a moment of inertia I rotating with an angular velocity ω is $L = I\omega$. In the absence of external torque, the angular

momentum of a rotating rigid body is conserved. This constancy of angular momentum allows to fix constraints on star and planetary system genesis from huge interstellar gas clouds.

Anorthite: Mineral. Tectosilicate (3D silicates). Calcic plagioclase feldspar $\text{CaAl}_2\text{Si}_2\text{O}_8$.

Anorthosite: Plutonic magmatic rock only made up of plagioclase feldspar. Generally, it consists in an accumulation (by flotation) of plagioclase crystals. Relatively rare on Earth, anorthosites are widespread on the Moon where they form the “primitive” crust.

Anoxic: Environment (water, sediment, etc.) where oxygen is highly deficient or absent. Synonym: anaerobic.

Anthophyllite: Mineral. Inosilicate (double chain silicate). $[(\text{Mg})_7 \text{Si}_8 \text{O}_{22} (\text{OH}, \text{F})_2]$. It belongs to the amphibole group.

Antibody (immunoglobulin): Glycoprotein produced because of the introduction of an antigen into the body, and that possesses the remarkable ability to combine with the very antigen that triggered its production. Polyclonal antibodies are produced by different types of cells (clones), whereas monoclonal antibodies are exclusively produced by one type of cell by fusion between this cell and a cancerous cell.

Anticodon: Triplet of nucleotides of tRNA able to selectively recognize a triplet of nucleotides of the mRNA (codon).

Antigen: Foreign substance that in an organism, is able to induce the production of an antibody.

Antisense: Strand of DNA that is transcribed into a mRNA (messenger RNA).

Aphelia: In the case of an object in elliptical motion around a star, the point which corresponds to the largest distance with respect to the star.

Apollo: Ensemble of asteroids whose orbits intersect Earth orbit.

Aptamer: Synthetic polynucleotide molecule that binds to specific molecular targets, such as a protein oligonucleotide. Contrarily to nucleic acids, aptamers are able to fold back into a 3D structure, thus leading to the formation of binding cavities specific to the target.

Archaea: One of the three main domains of the living world. All the organisms of this domain are prokaryotes. Initially, these organisms were considered as the most primitive form of life but this is no longer accepted by most biologists. Most extremophiles such as hyperthermophiles and hyperacidophiles belong to archaea domain.

Archaean (*Aeon*): Period of time (Aeon) ranging from 4.0 to 2.5 Ga. Archaean aeon belongs to Precambrian. Unicellular life existed and possibly was already aerobic

Archebacteria: See Archaea.

Arginine: Proteinic alpha amino acid containing six carbon atoms and a guanido group in the side chain.

Aromatic hydrocarbon: Hydrocarbon that contains one or several benzene ring(s).

Aspartic acid (*Asp*): Proteinic AA with an acidic side chain.

Assimilative metabolism: In a cell, reduction process by which an inorganic compound (C, S, N, etc) is reduced for use as a nutriment source. The reduction reaction necessitates an energetic supply (endothermic).

Asteroid belt: Ring-shaped belt between Mars and Jupiter where the majority of the asteroids of the Solar System are located

Asteroid: Small object of the Solar system with a diameter less than 1000 km. Many of them are orbiting around the Sun, between Mars and Jupiter (asteroid belt).

Asthenosphere: Layer of the Earth mantle, located under the lithosphere and having a ductile behaviour. It is affected by convective movements. Depending on geothermal gradient, its upper limit varies between 0 km under mid oceanic ridges and 250 km under continents.

Astrometry: Part of astrophysics that studies and measures the position and motion of objects in the sky. By extension, astrometry refers to all astrophysics phenomena that can be documented or studied by observation and measurement of the motion of celestial object.

Asymmetric atom: Synonym for chirotopic carbon. See asymmetric.

Asymmetric: An atom is called asymmetric when it is surrounded by four ligands which are oriented in 3D space in such a way that they define an irregular tetrahedron. Such an atomic arrangement is chiral and can exist as two enantiomeric forms. These two enantiomers are called D or L depending on their absolute configuration. The D/L nomenclature is now replaced by the R/S nomenclature of Cahn, Ingold and Prelog but the D/L system is still accepted for amino acids and oses. The asymmetric carbon atom is a particular (but very important) example of asymmetric atom.

Atmosphere: Gaseous envelope around a star, a planet or a satellite. In absence of rigid crust or ocean, the atmosphere is defined as the most external part of the object. *The primary atmosphere* of a young planet corresponds to the first gaseous envelope directly generated from protostellar nebula. *The primitive atmosphere* of the Earth corresponds to the atmosphere in which prebiotic chemistry occurred, when free oxygen was in very low concentrations. In the

second part of the past century, this primitive atmosphere was considered as being highly reductive. Today, it is considered as mainly consisting in carbon dioxide, nitrogen and water vapour.

ATP synthetase: Enzyme involved in ATP synthesis.

ATP: Adenosine triphosphate. Molecule which plays an important role in the living world for the energy transfers. Its hydrolysis in ADP and in inorganic phosphate is an exergonic reaction.

AU (astronomical unit): Average Earth-Sun distance corresponding to 149.6×10^6 km (or approximately 8 minute light and 100 Sun diameters).

Authigenic minerals: In a sedimentary environment, minerals generated by direct local precipitation of dissolved ions.

Autocatalysis: Chemical reaction such that a reaction product acts as a catalyst for its own synthesis.

Autochthonous sediment: Sediment that formed in the place where it is now.

Automaton (chemical automaton): As defined by A. Brack, chemical system able to promote its own synthesis.

Autotroph: Organism which is able to synthesize its own constituents from simple molecules like water and carbon dioxide.

B

Bacteria: One of the three domains of the living world. Organisms of this domain are all prokaryotes. They are the more abundant micro-organisms on Earth. One of their characteristics consists in the presence of a cell-wall containing muramic acid. Some of these organisms are extremophiles like *Aquifex* and *Thermoga*.

Bacteriochlorophylls: Pigment found in micro-organisms and containing a tetrapyrrole acting as a ligand for an Mg cation (similarly to chlorophylls of green plants).

Barophile: Micro-organism that lives optimally (or can only grow) in high pressure environments such as deep sea environments.

Basalt: Effusive mafic magmatic rock (volcanic); it mainly consists in plagioclase feldspar + pyroxenes \pm olivine crystals. It results of 20 to 25% melting of the mantle. Gabbro is its plutonic equivalent.

Bases in nucleotides: See nucleic base, purine bases and pyrimidine bases.

Benioff plane: In a subduction zone, interface between the subducted slab and the overlying mantle wedge.

Beta sheet: A secondary pleated structure frequently observed in proteins.

BIF (*Banded Iron Formation*): Sedimentary rocks widespread in Archaean terrains and no more generated today. They consist in alternation of black iron-rich (magnetite) and white amorphous silica-rich layers.

Bifurcation (thermodynamics): This term describes the behaviour of a system; which submitted to a very small variation in exchange conditions with its surroundings, jumps suddenly from one stationary state to another one. The characteristics of new stationary state cannot be predicted on the basis of a complete knowledge of the initial stationary state.

Binding energy (nuclear): In an atom the nuclear binding energy is the energy necessary to break the atomic nucleus into its elementary components. This is also the amount of energy released during the formation of an atomic nucleus.

Biocenosis: Group of interacting organisms living in a particular habitat

and forming an ecological community (ecosystem).

Biochemical sediment: Sediment formed from chemical elements extracted from water by living organisms (for instance, limestone formed by an accumulation of shells).

Biofilm: Tiny film (few μm thick) consisting in colonies of micro-organisms fixed on an inorganic or organic surface.

Biogenic sediment: Sediment formed by precipitation of ions dissolved in water by the mean of living beings (e.g. calcium ion in shells).

BIOPAN: Experimental module made by ESA to be fixed on a Russian satellite of the Photon type, the aim of the system is to expose samples or dosimeters to space conditions as vacuum, microgravity or radiation.

Bioprecipitation: Precipitation of solid mineral phases linked to the metabolism of living organism. Through selective evolution, this process was used by organisms to reduce the toxic excess of some soluble compounds or elements (for example Ca), then to constitute new functionalities (exo- or endoskeleton, protective tests, teethes ...). In some extent, the organisms can favour bioprecipitation while the surrounding physico-chemical conditions are unfavourable. This is for example the case of diatoms that precipitate an SiO_2 test under seawater conditions, which would normally dissolve SiO_2 .

Biosensor: Device containing biological compounds on/in a membrane, which translates biological parameters such as electric potential, movement, chemical concentration, etc. into electrical signals.

Biosignature: observable considered as an evidence of the presence of life.

Biosphere: Ensemble of species living on Earth.

Biosynthesis: production of a chemical compound by a living organism, equivalent to anabolism.

Bio-tectonic: Environmental concept proposed to account for the situation in Lake Vostok (Antarctica), where crustal tectonics (faults) controls and activates hydrothermal circulation. The latter provides chemical elements allowing life to survive. In the ocean, as well as in the oceanic crust, life linked to magmatic activity should rather be called bio-magmatic.

Biotite: Mineral. Phyllosilicate (water-bearing sheet silicate). $[K(Fe,Mg)_3Si_3AlO_{10}(OH)_2]$. It belongs to the mica group and is also called black mica.

Biotope: Smallest unit of habitat where all environment conditions and all type of organisms found within are the same throughout.

Bipolar flow (astronomy): Flow of matter in two opposite directions, perpendicularly to the circumstellar disk associated to a new-born star. The components of the bipolar flow are molecules, atoms, ions and dust particles.

Birthline: Locus, in the Hertzsprung-Russell diagram where young stars become optically visible.

Black body (radiation): Radiation emitted by a body at a temperature T and such that the coupling between matter and radiation is perfect. Such a body is black. The total power emitted by unit area and the power emitted at a well defined frequency depends only on the temperature (the T^4 dependence is given by the empirical Stefan law and by the theoretical Planck law). As a first approximation and on the basis of their emission properties, stars and planets can be described as black bodies.

Black smoker: Also called hydrothermal vent. Structure observed on the oceans floor generally associated with

mid ocean ridges. There, hot hydrothermal fluid, rich in base metal sulphides, enters in contact with cold oceanic water. Polymetallic sulphides and calcium sulphate precipitate progressively building a columnar chimney around the vent.

Blast: Blast (Basic Local Alignment Search Tool) represents a powerful and rapid way to compare new sequences to an already existing database, which may either contain nucleotides (Blastn) or proteins (Blastp). Since the BLAST algorithm establishes local as well as global alignments, regions of similarity embedded in otherwise unrelated proteins could be detected. The Blast program gives a value for each of the high scoring results, together with the probability to find an identical score in a database of the same size by chance.

Blue algae: See cyanobacteria. Old name for some prokaryotic unicellular which are not algae.

Bolometric light (or bolometric magnitude): Total radiation output by time unit of a stellar object.

Bootstrap: Statistical method with re-sampling, commonly used to measure the robustness and the reliability of phylogenetic trees.

Braking radiation: Electromagnetic radiation emitted by high speed particle (electron, proton) when deviated by a magnetic or electric field. (Also see Bremsstrahlung).

Branching ratio: In the case of a chemical or of a nuclear reaction, such that different reaction paths exist, the branching ratio is the relative rate constants or probabilities of occurrence per unit of time for each different path.

Breccias (geology): Sedimentary or magmatic rocks consisting in an accumulation of angular fragments in a sedimentary or magmatic matrix.

Bremsstrahlung: German word also used in French and English to describe the electromagnetic radiation emitted by high speed particle (electron, proton) when deviated by a magnetic field.

Brown Dwarf: Space body born as a star, but whose mass is too small (< 80 Jupiter mass) to allow nuclear reaction: both core temperature and core pressure are insufficient to initiate hydrogen fusion.

C

C (*alpha*): Carbon atom linked to a chemical function we are interested in. More specifically, the carbon atom directly linked to the carboxylic function in amino acids. In alpha amino acids, the amino group is linked to the alpha carbon. The Greek letters alpha, beta, gamma ... are used to describe carbon atoms separated from the function by one, two, three... other carbon atoms.

CAI (*Ca-Al Inclusions*): Ca-and Al-rich inclusions abundant in some chondrite meteorites.

Caldera: Circular km-sized structure due to the collapse of superficial formation induced by the emptying of an underlying magma chamber.

Carbonaceous chondrite: Chondrite with high carbon content. The famous Murchison meteorite is a carbonaceous chondrite.

Carbonate compensation depth (CCD): Depth below which sedimentary carbonates are systematically dissolved in seawater. This depth depends on the physico-chemical conditions of the environment (amount of sinking particles due to surface biological production, deep-water circulation, etc.). These conditions can change from one

ocean to another and may also change through time. The present Atlantic ocean CCD is at about 3500 m.

Carbonate: $(\text{CO}_3)^{2-}$ -bearing mineral e.g. Calcite = CaCO_3 ; Dolomite = $\text{MgCa}(\text{CO}_3)_2$.

Carbonation: In Ca-, Mg-, K-, Na- and Fe- bearing minerals, chemical reaction of alteration resulting in the formation of carbonates.

Carbonic anhydride: CO_2 . Synonym for carbon dioxide. **Carbonyl:** $-(\text{CO})-$, this chemical function is found in carboxylic acids, ketones, aldehydes, amides and many other organic molecules.

Carboxylic acid: Organic molecule containing a COOH group.

C-asteroid: Asteroid containing carbon. C-asteroids are the parent-bodies of carbonaceous chondrites.

Catabolism: Part of metabolism involving all degradation chemical reactions in the living cell resulting in energy production. Large polymeric molecules such as polysaccharides, nucleic acids, and proteins are split into their smallest size constituents, such as amino acids, after which the monomers themselves can be broken down into simple cellular metabolites. The small size constituents can be subsequently used to construct new polymeric molecules. These reactions involve a process of oxidation that releases chemical free energy, part of which is stored through synthesis of adenosine triphosphate (ATP). All these reactions require enzymatic catalysis.

Catalysis: Chemical process such that a substance (catalyst) increases reaction rate by changing reaction pathway but without being chemically modified during reaction. Enzymes are very efficient catalysts able to increase reaction rates by several orders of magnitude

and also able to limit the number of secondary products and therefore to increase reaction selectivity.

CCD (*Charge-Coupled Device*): Silicon photo electronic imaging device containing numerous photo-sensors (often at least 1000 X 1000). The most used astronomic detector in the visible wavelength domain.

Cell: Complex system surrounded by a semi-permeable membrane which can be considered as the basis unit of all living organisms.

Cenancestor: Last ancestor shared by all living beings. Synonym of LUCA.

Cenozoic (*Era*): Period of time (*Era*) ranging from 65 Ma to today, it is also called Tertiary Era but in addition also it includes Quaternary area.

Chalcophile: Chemical element frequently associated with sulphur (i.e. Cu, Zn, Cd, Hg...).

Chandrasekhar mass: Also called Chandrasekhar limit. In astrophysics, the maximum possible mass of a white dwarf star. This maximum mass is about 1.44 times the mass of the Sun. After having burned all its nuclear fuel the star atmosphere collapses back on the core. If the star has a mass below Chandrasekhar limit, its collapse is limited by electron degeneracy pressure; if the mass is above the Chandrasekhar limit it collapses and becomes a neutron star and possibly a black hole.

Chemical derivatization: Typically, derivatization consists in the chemical modification of a compound in order to produce a new compound easier to detect due to its new physico-chemical properties (volatility, absorption in ultraviolet, fluorescence...). The derivatization of a molecule involves altering part of it slightly or adding a new part to the original compound.

Chemical sediment: Sediment formed by direct precipitation of ions dissolved in water.

Chemolithoautotroph: Chemotroph that uses CO₂ as only source of carbon.

Chemolithotroph: Chemotroph that takes its energy from the oxidation of inorganic molecules such as NH₃, H₂S, Fe⁺⁺. On Earth, the first living organisms could have been chemolithotrophs.

Chemolitotroph: Chemotroph that takes its energy from the oxidation of inorganic molecules. On Earth, the first living organisms could have been chemolitotrophs.

Chemoorganotroph: Chemotroph that takes its energy from oxidation of organic molecules.

Chemotroph: Organism that takes its free energy from the oxidation of chemicals.

Chert: Microcrystalline to cryptocrystalline sedimentary rock consisting of quartz crystals whose size in < 30 μm, or of amorphous silica. Synonym: flint.

Chicxulub: Large (180 km in diameter) impact crater, located in Mexico Gulf. It is assumed to result of the collision of a big (10 km in diameter) meteorite, 65 Ma ago. This impact is considered as the cause of the important biological crisis at the Cretaceous-Tertiary boundary that led to mass extinction of thousands of living species, such as ammonites, dinosaurs, etc.

Chirality: Property of an object (and therefore of a molecule) to be different from its mirror image in a plane mirror. A hand is an example of a chiral object (in Greek: *cheir* means hand). Any object is chiral or achiral and if it is chiral, it can exist as two enantiomorphous forms (called enantiomers for molecules).

Chlorophylls: Pigments of major importance in the oxygenic photosynthesis. The chemical structure of all chlorophylls is based on a porphyrin ring system chelating an Mg^{2+} cation. Chlorophylls are found in higher plants, algae and some micro-organisms.

Chloroplast: sub-Cellular structure that plays a fundamental role for photosynthesis in all photosynthetic eukaryotes. Chloroplasts have more probably an endosymbiotic origin.

Chondre: Small spherical aggregate of radiated silicate minerals (typically 1 mm in diameter) which is frequent in stony meteorites and especially in chondrites. Olivine is the main component of chondres.

Chondrite: Undifferentiated stony meteorite unmelted and frequently considered as a very primitive object. Chondrites have the same composition as the Sun except for volatile elements.

Chromatographic co-elution: Refers to organics compounds that cannot be separated by a given chromatographic method and that migrate at the same speed leading to a single detectable signal.

Chromatography: Preparative or analytical chromatography: experimental method based on the properties of all molecules to be absorbed more or less selectively by a solid phase (the stationary phase) and therefore to migrate at different rates when they are « pushed away » by a mobile phase which can be a gas (gas chromatography or GC) or a liquid (LC or HPLC for High Performance LC).

Chromophore: Chemical group that absorbs UV and visible wavelengths, thus colouring the molecules or objects that contain them.

Chromosome: Sub-cellular structure containing most of the genetic material of the cell. Prokaryotic cells generally

contain only one chromosome made of a circular DNA molecule while eukaryotic cells generally have several chromosomes, each of them containing a linear DNA molecule.

CIP (for Cahn-Ingold-Prelog): General nomenclature used in chemistry to describe chiral molecules and more generally stereoisomers. Following the International Union of Pure and Applied Chemistry (IUPAC), CIP nomenclature must replace all other nomenclatures including D, L Fisher nomenclature except for amino acids and sugars for which the D/L nomenclature is still accepted.

Circular dichroism: The absorption coefficient of right and left circularly polarized light are different if the absorbing medium is chiral. By plotting the difference between the absorption coefficients as a function of the light wavelength, the curve which is obtained corresponds to the circular dichroism curve of the medium.

Circumstellar disk: Disk of gas and dust particles around a star.

Class [0,I,II,III] (astronomy): Classification of young stellar objects based on their electro-magnetic emission in the micro-wave and infra-red domains. It consists in an evolution sequence from the protostars (0 and I) to the T-Tauri stars (III).

Clast: Fragment of mineral or rock included in another rock.

Clay: Mineral family. Phyllosilicate (water-bearing sheet silicate), e.g. kaolinite, illite, smectite, montmorillonite.

CM matter: Pristine material of the solar system, analogue to constitutive matter of CM carbonaceous meteorites (M = Mighei) and very abundant in micrometeorites.

CNO cycle: Series of hydrogen burning reactions producing helium by using C,

N, O as catalysers. These reactions provide the energy of the main sequence stars with a mass $> 1.1 M_{\text{Sun}}$.

Coacervat (droplet): Protein and polysaccharides containing emulsion. According to Oparin, model of proto-cells.

Codon: Triplet of nucleotides in a mRNA molecule which corresponds to a specific amino acid of a protein synthesized in a ribosome or which corresponds to a punctuation signal in protein synthesis.

Coenzyme: Small molecule that binds with an enzyme and that is necessary to its activity. ATP, CoA, NADH, biotine are examples of coenzymes. Coenzymes are often derived from vitamins.

Collapse (astronomy): Process that describes the formation of stars from dense cores. The process seems to be fast: less than 10^5 years.

Coma: Broadly spherical cloud of dust particles and gaseous molecules, atoms and ions surrounding cometary nucleus. It appears when nucleus becomes active, generally when approaching the Sun.

Combustion: Used to describe any exothermal chemical reaction involving dioxygen and organic reactants. Sometimes used in astrophysics to describe the thermonuclear fusion reactions taking place in the stars and which, obviously, are also exothermal.

Comet: Small body of the Solar system with an average size of 1 to 100 km, travelling generally on a strongly elliptic orbit around the Sun. Comets are constituted of ice and dust and are considered as the most primitive objects of the Solar system.

Cometary nucleus: Solid part of a comet (1-100 km diameter), made of ice (H_2O , CH_3OH , CO ...) and of dust.

Cometary tail: Part of an active comet; three different cometary tails are

known depending from their composition (dust particles and molecules, neutral sodium atoms, ions).

Complex molecule (Astronomy): Molecule containing more than 3 atoms.

Complexation: Chemical term used to describe the non-covalent interaction of a molecule or, more frequently, an inorganic ion with other molecules (called ligands) to give a supramolecular system described as a complex.

Condensation: Chemical reaction involving two molecules and leading to the formation of a new chemical bond between the two subunits but also to the elimination of a small molecule (generally a water molecule). The formation of bonds between the subunits of many biochemical polymers are condensation reactions (examples: polynucleotides, polypeptides, polysaccharides).

Configuration: Term used in stereochemistry. Stereoisomers (except if they are conformers) have different configurations. As an example, butene can be cis or trans and it corresponds to two different configurations. In the case of chiral the D- and L-valine, the stereoisomers are enantiomers and they have « opposite » configurations. It is important to make a clear distinction between the relative configurations of two enantiomers and the absolute configuration of each of them.

Conglomerate (chemistry): In the restricted case of crystallized chiral molecules, a crystalline state such that all molecules of the same chirality (homochiral) crystallize together giving a mixture of crystal which, themselves, are of opposite chirality.

Conglomerate (geology): Detrital sedimentary rock consisting in an accumulation of rounded fragments in a sedimentary matrix.

Continental margin: Submarine part of a continent making the boundary with oceanic crust.

Continents: Emerged and associated shallow depth (<300 m) parts of the Earth surface. Their average composition is that of a granitoids.

Continuum (astronomy): in emission (or absorption) spectroscopy, emission (or absorption) background of a spectrum extending on a large frequency domain. Frequently, lines are superimposed on the continuous spectrum. Black body radiation corresponds to a continuous spectrum.

Cool Early Earth: Period of time between Earth accretion (4.55 Ga) and the late heavy bombardment (4.0–3.8 Ga). This model considers that period of early Earth as quiescent with respect to meteoritic impacts, thus being potentially favourable for life development.

Core (geology): Central shell of a planet. On Earth core mainly consists in iron with minor amounts of nickel and some traces of sulphur; it represents 16% volume but 33% mass of the planet. It is subdivided in a solid inner core from 5155 to 6378 km depth and a liquid outer core from 2891 to 5155 km depth.

Coronagraphy: Technique used in astronomy and that consists of masking one part of the observed field (for instance a bright star) to allow the observation of a lower luminosity object located in the immediate vicinity. This technique was first developed by Bernard Lyot, who masked the sun disk to observe its corona, thus leading to the given name of coronagraphy.

COROT: French project for the search of extrasolar planets based on a 25 cm telescope and able to detect planets having a diameter equal to two times

the Earth diameter and located at 0.5 AU from its star.

Cosmic rays: Highly accelerated ions coming from the Sun (solar wind, essentially protons) or coming from other and extrasolar sources (galactic cosmic rays).

Covalent bonds: Interatomic bonds such that two atoms share one, two or three electrons pairs leading to the formation of a single, a double or a triple bond. A covalent bond is described as a polarized bond if the two bonded atoms have different electronegativities.

CPT (theorem): general theorem of physics which assumes that physical laws are unchanged if, simultaneously, space is reversed (parity operation), time is reversed (the sense of motion is reversed) and matter is replaced by anti-matter. In many cases but not all, the CP theorem alone is valid.

Craton: Huge block of old (often Precambrian in age) and very stable continental crust (see also shield)

Crust (geology): The more superficial shell of the solid Earth. Its lower limit with the mantle is called Mohorovicic (Moho) discontinuity. Together with the rigid part of the upper mantle it forms the lithosphere. Two main crusts exist 1) oceanic crust, basaltic in composition and about 7 km thick, it constitutes the ocean floor; 2) continental crust is granitic in composition, with a thickness ranging between 30 and 80 km, it constitutes the continents.

Cryosphere: Part of the Earth surface made of ice.

Cumulate: Igneous rock generated by accumulation of crystals extracted from magma.

Cyanamid: $\text{NH}_2\text{-CO-CN}$.

Cyanhydric acid: HCN, hydrogen cyanide. Triatomic molecule that during prebiotic period could have played the

role of starting material for purine synthesis.

Cyanoacetylene or better cyanoethyne: H-CC-CN.

Cyanobacteria: Microorganism belonging to the Bacteria domain and able to perform oxygenic photosynthesis. In the past, these microorganisms were improperly called « blue algae ». The cyanobacteria could be the ancestors of chloroplasts.

Cyanogen: C₂N₂.

Cysteine (Cys): Proteinic amino acid containing three C atoms and a -SH group in its side chain. In a proteinic chain, two cysteine residues can be linked together by a -S-S- bond (disulfide bond) often used to stabilize protein conformation. Two cysteines linked together by a disulfide bond is a cystine molecule.

Cytidine: The ribonucleoside of cytosine. The corresponding deoxyribonucleoside is called deoxycytidine.

Cytochrome c: One particular example of the large cytochrome family. Cytochrome c is a protein involved in the electron transfers associated to aerobic respiration. In the eukaryotic cells, cytochrome c is localized in the mitochondrias.

Cytoplasm: Whole content of a cell (protoplasm) except the nucleus whose content is called nucleoplasm.

Cytoplasmic membrane: also called plasmatic membrane or cell membrane.

Cytosine (C): One of the nucleic bases of pyrimidine type.

D

D/H ratio: D = Deuterium; H = Hydrogen. Due to their mass difference, molecules containing either H or D are able to fractionate. For instance,

during vaporization, a molecule containing the light isotope (H) is more efficiently vaporized than its heavy equivalent (D). Chemical reactions, including biochemical ones are also able to fractionate these isotopes. Consequently the D/H ratio can provide information on the biotic or abiotic origin of some organic molecules. The D/H ratio can be very high in chondritic organic matter due to D-enrichment during reactions taking place in the interstellar clouds.

Dalton (Da): Molecular mass unit equal to the sum of the atomic masses given in amu (atomic mass unit).

DAP: Abbreviation frequently used to design two different molecules, diamino propionic acid and diamino-pimelic acid.

Darwin: Research programme from the European Space Agency devoted to the search of extrasolar planets and the study of their atmosphere composition by spatial interferometry, in the infra-red spectral region. Five independent telescopes of 1,5 m each constitute the basis of this very sophisticated system.

Daughter molecule (in comet): In the cometary coma, any molecule produced by photo-dissociation of a parent molecule coming from the nucleus.

Deamination: Reaction associated to the elimination of an amine group (NH₂, NHR or NRR').

Decarboxylation: Reaction associated to the elimination of a CO₂ molecule.

Decay constant (λ): Probability that over a given time interval, one radionuclide will decay. This probability is unique for each isotope and its value is independent of its chemical and mineralogical environment. The constant (λ) unit is s⁻¹.

Deccan (Trapps): Voluminous stacking of basaltic flows emplaced in North-

west India at the end of Cretaceous period. It constitutes the evidence of an extremely important volcanic event contemporaneous with the extinction of dinosaurs.

Delta (*isotopic*) (δ): Difference between the isotopic ratio of a sample (R_e) and that of a standard (R_s). $\delta = 1000 \cdot (R_e - R_s) / R_s$, e.g. $\delta^{18}\text{O}$.

Denaturation: Change of the native conformation of a biopolymer. More specifically and in the case of proteins, denaturation can be induced by increasing temperature and/or pressure or by adding a chemical reagent (like urea). Denaturation can be reversible or irreversible. It is generally associated with a loss of enzymatic properties

Denitrification: Capability of some organisms to transform dissolved nitrate (NO_3^-) into molecular nitrogen (N_2) or nitrogen oxide (N_2O). This metabolism requires anoxic or dysoxic conditions.

Dense clouds: See interstellar clouds.

Dense core (*Astronomy*): Gravitationally bound substructure located inside a molecular cloud and surrounded by protoplanetary disks. Dense core collapsing leads to the formation of one or several stars.

Deoxyribose: Ose or monosaccharide having a structure identical to ribose except that the OH group in position 2' is replaced by an H atom. In living organisms, deoxyribose comes from ribose via a reduction reaction.

Depletion: Impoverishment of chemical element abundance when compared to a standard of reference composition.

D-Glucose: D enantiomer of glucose. It plays a primeval role in living cells where it produces energy through both anaerobic (fermentation) and aerobic

(associated with respiration) metabolism. D-glucose is also a precursor of several other molecules such as oses and nucleotides.

Diagenesis: Chemical and/or biochemical transformation of sediment after its deposition. This process, which generally consists in cementation and compaction, transforms a running sediment in a compact rock.

Diapirism: Gravity driven magma or rock ascent in the Earth. Generally low density materials rise up into greater density rocks.

Diastereoisomers (*or diastereomers*): Stereoisomers that are not enantiomers. Diastereoisomers are characterized by physical and chemical properties which can be as different as observed for isomers having different connectivity (constitutional isomers).

Diazotrophy: Capability of some organisms to assimilate nitrogen as N_2 . This assimilating process is also called nitrogen biofixation.

Differentiation (*Chemistry*): Separation of an initially homogeneous compound into several chemically and physically distinct phases.

Differentiation (*Earth*): Separation from a homogeneous body of several components whose physical and chemical properties are contrasted. In the case of Earth these components are core, mantle, crusts, hydrosphere and atmosphere.

Diffuse clouds: See interstellar clouds.

Dinitrogen: N_2 , also frequently called nitrogen.

Dioxygen: O_2 , also frequently called oxygen.

Disk (of second generation): Disk around a star resulting from the breaking off of solid bodies previously formed like planetesimals, asteroids or comets. The beta Pictoris disk is prob-

ably a secondary disk.

Dismutation: Reaction that from a single reactant gives two products one of them being more oxidized than the reactant and the other one more reduced. A typical example is the transformation of an aldehyde into an alcohol and an acid.

Dissimilative metabolism: In a cell, mechanism that uses a compound in energy metabolism. The reduction reaction releases energy (exothermic).

Dissolve inorganic carbon equilibrium: Concentration proportions of the main chemical forms of the dissolved inorganic carbon in aqueous solution: $\text{HCO}_3^-/\text{CO}_3^{2-}/\text{CO}_2$. These proportions depend on the physico-chemical conditions, especially the pH.

Disulfide bond: Covalent bond between two S atoms. When the $-\text{SH}$ groups of two cysteines react on each other in presence of an oxidant, it gives a cystine molecule, i.e. a cysteine dimer linked by a $-\text{S}-\text{S}-$ bond. Disulfide bridges stabilize the ternary and quaternary structures of proteins. Some irreversible denaturating of proteins can be associated to formation of disulfide bonds.

DNA: Desoxyribonucleic acid, long chain polymer of desoxynucleotides. Support of the genetic code in most living cells. Frequently observed as a double helix made by two complementary strands

Drake (Equation of): Empirical formula (containing several adjustable parameters) which, following his author, gives a rough estimation of the number of « intelligent civilizations » in the galaxy.

Dust (interstellar, cometary): Small solid particles (0.1 mm – 1 mm), generally made of silicates, metal ions and/or carbonaceous matter.

Dysoxic: Environment (water, sediment, etc.) where oxygen is in limited amount. Synonym: dysaerobic.

E

e (astronomy): Orbital parameter that measures the eccentricity of elliptical orbit.

Eccentricity: Parameter (e) characterizing the shape of an orbit. e is equal to 0 for a circle, equal to 1 for a parabola, higher than 1 for a hyperbola and between 0 and 1 for an ellipse.

Ecliptic: Geometric plane of the Earth orbit. More precisely, average planar of Earth-Moon barycentre orbit.

Eclogite: High degree metamorphosed basalt. It consists in an anhydrous rock made up of pyroxene and garnet.

Ecosystem: Community of organisms and their natural environment: Ecosystem = community + biotope.

Eddington: ESA project devoted to asteroseismology and search for extra-solar planets by the transits method. Kepler: similar project for exoplanetary science.

Electrophoresis: Analytical method used in chemistry and based on the difference between diffusion rates of ions when placed in an electric field. Initially the ions are adsorbed on a support or immersed into a viscous medium. Capillary electrophoresis is a technique adapted to the analysis of small samples.

Enantiomeric excess (i.e. in percents): In the case of a mixture of two enantiomers whose respective concentrations are D and L with D greater than L, i.e. = $(D - L / D + L)$. 100

Enantiomeric ratio: In the case of a mixture of two enantiomers, the enantiomeric ratio is the ratio of the two enantiomers.

Enantiomers: Two stereoisomers that differ only due to their opposite chirality (like an idealized left hand and an idealized right hand).

Enantiomorph: Two objects that differ only due to their opposite chirality (like an idealized left hand and an idealized right hand).

Enantioselectivity: A reaction leading to products which are chiral is said to be enantioselective if it gives an excess of one enantiomer. Enantioselectivity is generally induced by a chiral reactant or a chiral catalyst (like an enzyme). Enantioselectivity is also used to describe a reaction such that starting from a mixture of enantiomers; one of them reacts faster than the other. In this case, the reactant must be chiral.

Enantiotopic (Chemistry): A planar molecule like H-CO-CH_3 can be seen as a scalene triangle with summits of different colours. In the 2D space, such an object is chiral and the two faces are said to be enantiotopic. A chiral reagent is able to differentiate enantiotopic faces.

Endergonic: A chemical reaction or a physical change is endergonic if it requires a supply of free energy from its surroundings to succeed.

Endogenous (Biochemistry): That takes place inside. For instance an endogenous organic synthesis is a synthesis that occurs in a planetary atmosphere or at the bottom of an ocean. Antonym = exogenous.

Endogenous (Geology): Word that refers to petrogenetic mechanisms taking place inside the Earth, as well as to the rocks generated by such mechanisms. A magmatic or a metamorphic rock is an endogenous rock. Antonym = exogenous.

Endolithic (biology): Micro-organisms living in rocks.

Endosymbiosis: Process by which an eukaryotic cell lives in symbiosis with an other cell (generally a prokaryotic cell) located in its cytoplasm. Chloroplasts and mitochondria are considered as vestiges of endosymbiotic prokaryotes.

Endothermic: A chemical reaction or a physical change is endothermic if it needs a supply of energy from its surroundings to succeed.

Enstatite: Mineral. Inosilicate (simple chain silicate). Mg-rich Pyroxene [MgSiO_3].

Envelope (circumstellar): In astronomy, cloud of dust particles and gas surrounding a new-born star (protostar).

Enzyme: In biochemistry, a molecule which catalyses a reaction. Most enzymes are proteins but some are polynucleotides (ribozymes).

Epitope: Region on a macromolecule that is recognized by an antibody. It is generally about 5 to 12 amino acids long, which is the size of the antigen binding site on the antibody.

Equator (celestial): Plane perpendicular to the rotation axis of the Earth and corresponding to an extension in space of the terrestrial equator.

Escape velocity: Velocity required for a body to escape the planetary gravity field. On Earth, the escape velocity is 11 km/s.

Escherichia Coli: Bacteria found in the intestine and commonly used in experimental bacteriology. Its size is of the order of one micron. Its genome codes, approximately, for 3000 proteins.

Ester: Molecule that can be described as the result of condensation of an acid and an alcohol associated with elimination of a water molecule. ($-\text{O-CO}-$) is the ester bond.

Eubacteria: Sometimes used instead of bacteria, in order to point out the dif-

ference between Bacteria and Archaea. Archaeas themselves are sometimes called Archebacterias.

Eukaria: One of the three domains of life (together with bacteria and archaea). Eukaryotic cells are members of the Eukaria domain.

Eukaryote: Any organism from Eukarya domain and characterized by a nucleus (containing the genetic material) separated from the cytoplasm by a membrane. Eukaryotes can be unicellular or pluricellular.

Europe: Satellite of Jupiter with a diameter of about 3100 km (same size as the Moon). An ocean could exist beyond its icy surface.

Evaporite: Sedimentary rock generated by evaporation of huge volumes of water; chemical elements dissolved in water precipitate leading to the deposition of minerals such as halite (NaCl) or gypsum = (CaSO₄, 2H₂O).

Exergonic: Chemical reaction or a physical change is exergonic when it provides free energy to its surroundings.

EXOCAM: Special reactor used to experimentally simulate exobiological processes.

Exogenous (Biochemistry): That takes place outside. For instance exogenous molecules are molecules synthesised in an extraterrestrial environment and imported on Earth by (micro) meteorites or interplanetary dust particles. Antonym = endogenous.

Exogenous (Geology): Word that refers to petrogenetic mechanisms taking place at the surface of the Earth (in atmosphere or hydrosphere), as well as to the rocks generated by such mechanisms. A sedimentary rock (sandstone, limestone, etc...) is an exogenous rock. Antonym = endogenous.

Exon: Sequence of transcribed nucleotides that is present in natural RNA and which corresponds to a DNA sequence. In DNA, exons are separated by introns (intervening sequences). Exons and introns are respectively coding and non-coding sequences for proteins.

Exoplanet: Planet orbiting around a star other than the Sun. The number of already discovered exoplanets is greater than 100. (More information on this fast developing field is available on www.obspm.fr/planets)

Exoplanetology: Part of astrophysics devoted to extrasolar planets.

Exosphere: The outermost region of a planet's atmosphere. This is the place where most of the photodissociation reactions of molecules take place. From the exosphere, the molecules with sufficient velocity can escape the Earth's gravitation.

Exothermic: A chemical reaction or a physical change is exothermic if it provides energy to its surroundings.

Explosive nucleosynthesis: Nucleosynthetic reactions taking place during star explosion. The characteristic time of these reactions is by far shorter than that of the same reaction occurring in a star at rest.

Extinction (interstellar, atmospheric): Decrease of the light intensity of a star due to light diffusion or absorption by a medium (planetary atmosphere, interstellar cloud). In an interstellar cloud, visible magnitude can be reduced by a factor of 1 while the reduction can be as large as 100 in a protostar dense nucleus.

Extremophile: Micro-organism that optimally lives (or optimally grows) in "extreme" physico-chemical environments (P, T, Ph...).

F

Fatty acid: Carboxylic acid R-COOH where R is a long chain containing only C and H atoms.

Fayalite: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). $[(\text{Fe})_2\text{SiO}_4]$. This mineral is the ferrous end-member of olivine series (peridot family).

Feldspar: Mineral family. Tectosilicate (3D silicate). Feldspars are subdivided into two main chemical groups: 1) Alkali feldspars ($\text{NaAlSi}_3\text{O}_8$ = Albite and KAlSi_3O_8 = Orthoclase); 2) Plagioclase feldspars ($\text{NaAlSi}_3\text{O}_8$ = Albite and $\text{CaAl}_2\text{Si}_2\text{O}_8$ = Anorthite). These minerals constitute 52% of the continental and oceanic crusts.

Fermentation: Biochemical process such that complex organic molecules (i.e. glucose) are transformed into low molecular mass molecules (i.e. ethanol) by cells, in anaerobic conditions. Fermentation corresponds to an oxidation process but the final electron acceptor is an organic molecule instead of oxygen. During fermentation as during respiration, ATP is produced but less efficiently.

Ferrihydrite: Iron hydroxide, $5\text{Fe}_2\text{O}_3 \cdot 9\text{H}_2\text{O}$.

Fisher: German chemist who was the first to introduce the D/L nomenclature to differentiate enantiomers and to characterize their absolute configurations.

Fisher-Tropsch (reaction of): Reaction which gives hydrocarbons from a mixture of H_2 and CO. The FT reaction had and still has a great industrial importance but it could also have been important in prebiotic chemistry. The FT reaction requires metallic catalysts.

Flint (or flintstone): see chert.

Flint: Rock mainly made of amorphous silica and having a biogenic origin. It

frequently appears as nodules in chalk or limestone.

Fluid inclusion: 1 to 100 μm -sized cavities in minerals that contain fluids trapped during mineral crystallization.

Fluorophore: Fluorescent molecule. This molecule absorbs light and its electrons are excited to higher energy states; their return to lower energy states is accompanied by light emission (fluorescence).

Formaldehyde or methanal: The simplest aldehyde (H-CO-H).

Formation (geology): Group of terrains or rocks having the same characteristics.

Formic acid: HCOOH, methanoic acid.

Formose (reaction): Starting from formaldehyde in water solution at high pH, this reaction leads to the formation of a large variety of sugars. Its importance in prebiotic chemistry remains an open question. It is also called Butlerow reaction.

Forsterite: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). $[(\text{Mg})_2\text{SiO}_4]$. This mineral is the magnesium end-member of olivine series (peridot family).

Fossil (geology): All kind of trace of passed life (bone, shell, cast, bio-molecule, track, footprint, etc...).

Fractionation (Chemistry): Separation of chemical elements or isotopes by physical or chemical mechanisms.

Frasil: Ice disks with a diameter of few mm that are observed in water as soon as surfusion occurs. Frasil is common in Arctic and Antarctic rivers but also below the huge ice platforms moving forward in the Antarctic Ocean.

Free-fall time: Time required for an object of mass m, initially at rest, to reach an object of mass M ($M > m$) under effect of gravitation alone. It gives a good approximation of the time required for an accretion disk to col-

lapse during the protostar stage (typically 10^5 years).

FRET: (*Fluorescence Resonance Energy Transfer*). The energy of an excited electron in one molecule (the donor) can be passed on to an electron of another molecule in close proximity (the acceptor) through resonance, then released as a photon. If the donor is on a target and the acceptor on a ligand, a molecular recognition event can be detected by the photon emission resulting from the ligand-target complex formation.

Furanose: A "furanose ring" is a cyclic ose formed of 4 carbons and an oxygen atom.

G

Ga: Giga annum = one billion years (= Gy)

Gabbro: Plutonic magmatic rock. It has a granular texture and mainly consists in pyroxenes and plagioclase (\pm olivine). Basalt is its effusive equivalent.

Gaia: Ambitious project of ESA to measure the position of one billion of stars with a precision of one micro arc second. Gaia is essentially devoted to the search for extraterrestrial planets.

Galactic "Open" cluster (*Astronomy*): Cluster that can contain from a dozen to a few thousand of stars ("I" population) and are younger than globular clusters.

Garnet: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). Its general composition is $\text{Y}_2^{+++} \text{X}_3^{++} (\text{SiO}_4)_3$ (Y = Al, Fe^{+++} , Cr and X = Ca, Mg, Fe^{++} , Mn). Garnet is stable at high pressure (> 70 km depth). In the mantle, at depth, garnet is the only aluminium-bearing phase.

GC (*gas chromatography*): Chromatographic method using gas as moving

phase. It can be used in analytical and preparative chemistry.

Gene: Segment of DNA, containing hundreds to thousands nucleotides, found in a chromosome. A gene codes for a specific protein.

Genome: Ensemble of genes of an organism.

Genomic: Science that studies genomes. Genomic includes studying and sequencing of genomes as well as method for the analyses of mRNA (transcriptome) and proteins (proteome). Genomic also tries to index the genes of an organism, to localize them on chromosomes, to determine their sequence and to study their functionality.

Genotype: Ensemble of the genetic characters of an organism.

Geocruiser: Asteroid with an orbit that intersects that of Earth. Objects on such an orbit may eventually collide with Earth.

Geographic pole: Point where the rotation axis (instantaneous) of a planet intersects the globe surface.

Geomorphology: Branch of the geosciences that studies the characteristics, the configuration and the evolution of land forms. The methods developed on Earth to interpret the geomorphologic mechanisms (magmatism, erosion, sedimentation, etc..) are especially well adapted to the interpretation of images from other planets, where remote sensing is the only available source of information.

Geothermal gradient: Thermal gradient corresponding to the temperature increase with depth. In the Earth crust geothermal gradient is $\sim 30^\circ\text{C.km}^{-1}$.

Giant planets: Large size planets of low density, such as Jupiter, Saturn, Uranus and Neptune. One can distinguish two groups: gaseous giants, Jupiter and

Saturn, mainly made up of gas (H_2 , He) coming from the protosolar nebula and icy giants, Uranus and Neptune, rich in ice (H_2O , NH_3 , and CH_4). They all have a core made of heavy elements and were formed in the outer part of the solar nebula, beyond the ice line.

Glacial-interglacial alternation: Oscillatory change of ice volume, mainly due to the extension of ice caps located in high latitudes. The episodes of large ice cap extension are called glacial, while those of minimum extension are called interglacial. These oscillations are not a permanent feature of the Earth's climate; they require specific conditions, in term of plate tectonic configuration (position of the continents), and orbital parameters. The present-day climate is interglacial.

Glaciation: Cold period in the Earth history characterized by the presence of a large cryosphere (ice). Frozen water accumulates and forms ice caps on the continents; consequently, it becomes unable to return to ocean whose level decreases. The main glaciations occurred during Precambrian, Early Cambrian, End of the Ordovician, Carboniferous, and from the Oligocene to the Quaternary.

Glass inclusion: 1 to 100 μm -sized cavities in minerals that contain magma trapped during mineral crystallization.

Glass: Amorphous material. In volcanic rocks, it can result of the rapid cooling of the magma.

Global ecosystem: (= planetary ecosystem). The whole set of interactions between the living and non-living compartments of a life-bearing planet, which contribute to regulate its state far from the thermodynamic equilibrium (where no life is possible).

Globular cluster (Astronomy): Large spherical cluster containing from a few

thousands to several millions of old stars ("II" population)

Glucide: Name for sugar molecule, also called carbon hydrate, saccharide or ose. In living cells, they can be energy providers and components of nucleic acids or of wall proteins (glycoproteins).

Glucose: $CH_2OH(CHOH)_4COH$. D-glucose is the wider spread ose. Glucose is an aldohexose : the carbonyl group belongs to the aldehyde function (aldose); it contains 6 atoms of carbon (hexose). L-Glucose is also called levulose and D-Glucose is called dextrose.

Glutamic acid (Glu): Alpha AA with a side chain containing an acidic $COOH$ function. Described as a hydrophilic AA.

Glutamine (Glu): Amino acid containing 5 C atoms with a NH_2 group in the side chain, it is considered as hydrophilic.

Glycan: Synonymous of polysaccharides.

Glyceraldehyde: $(HO-CH_2-CHOH-CHO)$; the simplest aldose, containing only one chirotopic carbon atom. The two enantiomers play an historical role in stereochemistry because they are at the origin of the D, L nomenclature which describes absolute configuration (Fisher). Glyceraldehyde is the biochemical precursor of other oses.

Glycerol: $(HO-CH_2-CHOH-CH_2OH)$; 1,2,3-propanetriol also called glycerine, component of many membrane phospholipids (which are esters of glycerol).

Glycine (Gly): The simplest amino acid and the only one which is achiral.

Glycolic acid: $HO-CH_2-COOH$.

Gneiss: Metamorphic rock made up of quartz, feldspars and micas. All mica crystals show the same orientation thus defining a surface of preferential cutting up called « foliation plane ».

Gondwana (*Gondwanaland*): Palaeozoic super-continent formed by convergence and agglomeration of continents (Peninsular India, Madagascar, Africa, Australia, South America and Antarctica) due to plate tectonic activity. It was mainly located in the South hemisphere.

Gram +: Bacteria previously coloured during a Gram test and which does not lose the colour after a treatment with ethanol (« positive » response).

Granite: Plutonic magmatic rock. It has a granular texture and mainly consists of quartz, alkali feldspar and plagioclase feldspar; mica can be present whereas amphibole is rare. Rhyolite is its effusive equivalent.

Granitoid: Family of quartz-bearing plutonic magmatic rocks including granites, granodiorites, tonalites and trondhjemites.

Granodiorite: Plutonic magmatic rock. It is similar to granite but contains no more than 10% alkali feldspar.

Green bacteria: Micro-organisms of the Bacteria domain able to perform anoxygenic photosynthesis.

Greenhouse effect: Warming of a planet surface due to the trapping by planet atmosphere of the electro-magnetic waves received and radiated by the planet.

Greenstone belts: Volcanic (basalts and komatiites) and volcano-sedimentary formation widespread in Archaean terrains. It generally presents an elongated shape (~100 km long and few tens km wide). Its green colour is due to metamorphism of basalts and komatiites.

Guanine (*G*): Nucleic base with purine structure.

Gy: Giga year = one billion years (= Ga).

H

Habitable zone (HZ): Zone around a star where the physical conditions (temperature, presence of liquid water, etc.) on the orbiting planets are considered favourable for the birth and the development of an “Earth-like” life.

Hadean (*Aeon*): Period of time (Aeon) ranging from 4.55 Ga (Earth formation) to 4.0 Ga (oldest known rock: Acasta gneisses). Hadean aeon belongs to Precambrian.

Hadley cell: On Earth tropospheric convection cell; the air masses rise at the level of the equator and descend at about 30° latitude. At intermediate latitude, this cell is relayed by Ferrel cell and by Polar cell at high latitudes. Sometimes, the term Hadley circulation is used to describe the whole system. This global tropospheric circulation results in a redistribution of heat from the equator towards the poles. The concept remains true on Mars as on many other planets. In the case of Mars and Earth, the planet rotation strongly affects the circulation. For instance, the air moving toward the equator in the lower atmosphere is deflected by the Coriolis effect to create the easterlies trade winds in the tropics.

Half-life (T): Synonym of period. For a single radioactive decay process the half-life is the time needed for the number of radioactive atoms to decrease to half its original value. Half-life (T) is linked to the decay constant (λ) by the relation $T = \ln(2)/\lambda$. T unit is s.

Halogen (*Chemistry*): Fluorine (F), Chlorine (Cl), Bromine (Br), Iodine (I), Astatine (At). Chemical element belonging to the (VIIA) period in the Mendeleïv periodic table.

Halophile: Micro-organism that lives optimally (or can only grow) in environments with high salt concentration (1M NaCl).

Hamiltonian (operator): Mathematical entity describing the motion of a classic or quantic particle. In quantum mechanics, this mathematical entity allows one to write the wave equation for a stationary state whose solutions give the probability density of one or several electrons in any point in space.

Hapten: Can be considered as an isolated epitope. By definition a hapten is a small molecule (few 100's Da), not antigenic by itself: alone hapten cannot induce immune response; it stimulates production of antibodies only in combination with a specific protein called carrier or schlepper.

Harzburgite: Peridotite made up of olivine and orthopyroxene. It generally corresponds to residual mantle after lherzolite melting and extraction of basaltic magma.

HD 209458b: First exoplanet, whose previous detection by radial velocimetry method has been confirmed by the observation of a transit in front of its parent star (HD 209458).

Heavy element (astronomy): Any element other than hydrogen and helium.

Helium: Rare gas whose ^3He isotope is used in geology as marker of a recent degassing process from the deep mantle.

Hertzsprung-Russel diagram (HR diagram): In astronomy, a two-dimensional diagram with star temperature (or spectral type) as abscissa and star luminosity (or absolute magnitude) as coordinate. Temperatures decrease from left to right and the spectral types sequence is OBAFGKM.

Heterocycle: Cyclic organic molecule containing heteroatoms (i.e. atoms

other than C.) as constituents of the cyclic structure.

Heterosphere: Part of an atmosphere located above the homopause and where each gas density distribution decreases according to its own scale height.

Heterotrophous: Organism which uses reduced organic molecules as principal carbon source for its biosynthesis. Nowadays, these reduced organic molecules are generally produced by other organisms. At the beginning of life, these reduced molecules were probably found in the environment.

Histidine (His): Proteinic amino acid containing an imidazole group in its side chain. Histidine residues (hystidyl) are frequently found in active site of enzymes.

HMT: ($\text{C}_6\text{H}_{12}\text{N}_4$); hexamethylenetetramine, could be a minor component of comet nucleus.

Homeostasis (Biology): In living organisms homeostasis is the regulation of a physical or of a chemical factor, which attempts to actively keep these factors at equilibrium, even in case of external environmental change (i.e. thermal regulation). This involves a feedback mechanism.

Homeostasis: Property of a living organism to maintain unchanged some of its physico-chemical characteristics even in presence of a change in the environment. Homeostasis requires autoregulation.

Homoacetogens: Microorganisms of the Bacteria domain producing acetate from H_2 and CO_2 .

Homochirality: Of the same chirality. All proteinic amino acids are L while ribose in RNA or ATP is always D. The origin of homochirality for the large majority of the chiral constituents of organisms

remains an active research subject.

Homogenization temperature: Temperature at which a fluid inclusion transforms from a multi-phase (heterogeneous, for instance gas + seawater) to a one-phase (homogeneous) state. This temperature is considered as the minimal temperature of formation of the fluid inclusion.

Homology (biology): Two structures in two different species are homologous (and therefore comparable) irrespective of their forms, if they are connected in the same way to identical structures.

Homolysis: Homolytic cleavage or homolytic fission. Breaking of a bond such that each molecule fragment retains the same amount of binding electrons; consequently, no electric charge is created due to the cleavage.

Homolytic (rupture): Rupture of a chemical bond in which the bonding electrons are equally partitioned between the two fragments; no charge appears during this process.

Homopause: Atmospheric boundary between the homosphere and the heterosphere.

Homosphere: Part of an atmosphere where the gases are uniformly mixed. Their densities decrease as the altitude increases following a single mean scale height, defined by the mean molecular weight and the temperature.

Hornblende: Mineral. Inosilicate (double chain silicate). $[\text{Na}_{0-1}\text{Ca}_2(\text{Fe}^{++}, \text{Mg})_{3-5}(\text{Al}, \text{Fe}^{+++})_{0-2}\text{Si}_{8-6}\text{Al}_{0-2}\text{O}_{22}(\text{OH}, \text{F})_2]$. It belongs to the amphibole group.

Hot Jupiter: Jupiter massive-like exoplanet, orbiting close to a star. Most of the extrasolar planets so far discovered belong to this type.

Hot spot: see mantle plume.

HPLC (High Performance Liquid Chromatography): Very efficient liquid

phase chromatography performed under high pressure up to 100-400 bars.

Hydrocarbons: Molecules containing only C and H atoms. If the hydrocarbon contains an aromatic system, it is said aromatic. If the hydrocarbon contains only tetra-coordinated C atoms, the hydrocarbon is called aliphatic. Some hydrocarbons result from the polymerization of isoprene (2-methylbutene); they are called isoprenoid hydrocarbons. Latex contains isoprenoid hydrocarbons.

Hydrogen bond: Intermolecular but sometimes intramolecular low energy bond (about 20 kJ/mol) involving generally an H atom linked to an electronegative atom like O, N, S and an atom bearing non-bonding electron pairs such as O or N. The H-bond implies an H-donor and an H-acceptor.

Hydrogen cyanide: H-CN.

Hydrogen sulphide: (H₂S)

Hydrogenoid (function): Exact electronic wave function describing the motion of the electron in an atom with a single electron.

Hydrolysis: Cleavage of a molecule due to reaction with H₂O.

Hydrosphere: The whole water available on Earth surface; it includes, oceans, seas, lakes rivers, underground waters and atmospheric water vapour.

Hydrothermal vent: see black smoker.

Hydroxy acid: Carboxylic acid containing also an alcohol function. Glycolic acid is the simplest hydroxy acid.

Hydroxyl (group): -OH or alcohol group

Hyperthermophile: Micro-organism that lives optimally (or can only grow) in high temperature environments (> 80°C).

Hypoxanthine (6-hydroxypurine): Purine base and biological precursor of adenine and guanine.

I

Ice shelves: Ice platforms generated by glaciers whose ice progresses from Antarctica land over ocean. Ross shelf is about 1000km wide and extends over 600km in ocean. They are the source of very large tabular icebergs.

Ices (*astronomy*): Solid form (crystalline or amorphous) of volatile molecules like water, carbon dioxide or ammonia.

IDP: Interplanetary Dust particle.

Igneous rocks: Magmatic rocks = due to magma crystallization.

Immunoaffinity chromatography: (IAC) All chromatographic methods based on a stationary phase that contains antibodies or fragments of antibodies.

Immunogenic: Substance able to induce an immune response.

Impact melt rock: Rock associated with impact craters (= impactite). It resembles a lava and consists of a mixture of solid or molten fragments from the local lithologies floating in a glassy microcrystalline or recrystallized matrix. It is generated by cooling of the magma produced by the melting of the target lithologies under the high temperatures and pressures induced by the collision.

Impactite: Heterogeneous breccia generated at depth by the impact of a large-size stellar body (> 10,000 tons). It is made up of fragments of the rock substrate included in a vitreous matrix.

Impactite: Lithologies generated during meteorite impact. Melt-rock, suevites and breccias found inside or at close proximity of an impact crater are called impactites.

Inclination (1) (*astronomy*): Angle between the orbital plane of a solar object and the ecliptic plane in degrees (always lower than 90°).

Inclination (2) (*astronomy*): Angle between the orbital plane of an interstellar object and the “sky plane” (plane perpendicular to the “line of sight” i.e. the straight line joining the observer and the stellar object).

Indels: Acronym for insertions / deletions. Phylogenetic analysis on several DNA or protein sequences requires sequences with same length. During the process of alignment, alignment gaps (indels) must be introduced in sequences that have undergone deletions or insertions.

Interferometry: Observation and astrophysical measurement technique based on the use of several disconnected telescopes spread over an area, and allowing reaching the angular resolution a single-dish telescope with the same area would give. This technique can be implemented different ways: visibility measurement, direct imaging by aperture synthesis, differential phase measurement, nulling interferometry. . .

Interplanetary dust: Small grains left behind by asteroids and comets, and dispersed in a cloud including the whole Solar system.

Interstellar cloud: Cloud of gas (98 %) and dust (2 %). The gas is mainly H (diffuse cloud) or H₂ (molecular cloud). Molecular clouds are called dense clouds ($n(\text{H}_2) > 10^3$ molecules.cm⁻³) or dark clouds if dense and cold (10-20 K).

Intertidal environment: Environment between high and low tide. Also called tide range.

Intron: Non-coding sequence of nucleotides that separates exons. Introns are removed during the maturation processes of the three types of RNA by splicing.

Ion-molecule (*reaction*): Kind of reaction between two gaseous reactants and initiated by ionizing cosmic rays,

X-rays or UV radiation. They are important in interstellar clouds and in planetary ionospheres.

IR: Infrared. Wavelength ranging between 1 and 300 μm .

Iridium (*Ir*): Element belonging to platinum element family. Its concentration in Earth crust is extremely low. A local Ir enrichment as at the Cretaceous-Tertiary (K/T) boundary is interpreted as a strong argument in favour of meteoritic impact.

ISM: Interstellar medium.

Isochron (geology): Rectangular diagram plotting isotopic ratio of a disintegration system (abscissa = parental isotope; ordinate = daughter isotope) (e.g. $^{87}\text{Sr}/^{86}\text{Sr}$ versus $^{87}\text{Rb}/^{86}\text{Sr}$). In this diagram, cogenetic rocks of the same age plot along a straight line whose slope is proportional to age. This method of age determination is widely used in geology.

Isocyanhydric acid: $\text{H}-\text{N}=\text{C}$.

Isocyanic acid: $\text{HN}=\text{C}=\text{O}$.

Isoleucine (*Ile*): Proteinic amino acid containing six carbon atoms and described as hydrophobic. Ile is considered as one of the prebiotic AA.

Isoprenoid hydrocarbon: Hydrocarbon formed by polymerization of isoprene $\text{eCH}_2=\text{C}(\text{CH}_3)-\text{CH}=\text{CH}_2$.

Isostasy (Geology): Hydrostatic equilibrium in the Earth's crust such that the forces tending to elevate landmasses balance the forces tending to depress them. When this equilibrium is broken, the return to equilibrium takes place by vertical movements of the crust. For instance, in Scandinavia during the last ice age the weight of the ice caps pushed the continental crust into the mantle. As the ice melted, the load decreased and the lithosphere bounced back towards equilibrium level, (this

process is still going on at a rate of about 1m per century).

Isotopic ratio: Concentration ratio of two isotopes or concentration ratio of two isotopomers of a molecule (like H_2O and D_2O). Isotopic ratio can provide information on the age of a sample (when used in isochron calculation) as well as on its origin and source.

Isovaline (*Iva*): Hydrophobic non-proteinic amino acid, isomer of valine and containing five carbon atoms.

Isovaline: Hydrophobic non proteinaceous amino acid. This constitutional isomer of valine contains five C atoms.

Isua: Region of Greenland where are exposed the oldest sediments so far recognized 3.865 Ga (gneiss). They contain carbon whose origin could be biogenic. (See also Akilia)

J

Jeans escape: Process leading to the escape of atomic or molecular species from a planet atmosphere. It happens when the thermal agitation rate is greater than escape rate. The lighter elements or molecules (like H, H_2 or He) escape faster than the heavier ones.

Jovian planets: Other name for giant planets.

Jupiter: The fifth and largest planet (1400 times the Earth volume, 320 times the Earth mass) of the Solar system. Jupiter is 5.2 AU away from the Sun. Its gaseous envelope mainly made of H_2 and He, surrounds a core of ice and rocks (10–20 Earth mass).

Juvenile gases: Gases produced by or trapped inside the Earth and which reach the surface of Earth for the first time. ^3He is an example of juvenile gas detected in sub-marines geothermal fluids.

K

K/T (Strata): Few centimetre-thick sedimentary layer located at the Cretaceous-Cainozoic boundary. Its Iridium-enrichment is interpreted as due to a giant meteoritic impact.

Kepler: Spacecraft NASA mission devoted to detection of Earth-type exoplanets (equipped with a 1m telescope).

Keplerian rotation: Orbital motion that follows Kepler's laws.

Kerogen: Insoluble organic matter found in terrestrial sediments and in some types of meteorites like carbonaceous chondrites.

Kilo base or kilo base pair (kb): Unit used to measure the number of nucleotides in a gene or a genome: 1000 base pairs of DNA or 1000 bases of RNA.

Komatiite: Ultramafic high-Mg lava. It contains olivine and pyroxene; minerals which sometimes can have needle or dendritic shapes (spinifex texture). Komatiites were abundant before 2.5 Ga and extremely rare after.

Kuiper Belt or Edgeworth-Kuiper: A large ring-shaped reservoir of comets beyond Neptune at about 30 astronomical units (AU) from the Sun.

L

L/D (Ratio): For a chiral molecule, the ratio between the L and the D enantiomer concentrations.

Lactic acid: HO-CH(CH₃)-COOH.

Lagrange points: The five points determining the equilibrium position of a body of negligible mass in the plane of revolution of two bodies (ex: star-planet couple) in orbit around their common gravity centre.

Late Heavy Bombardment: Heavy bombardment of the Moon (and certainly also of the Earth and others telluric planets) which happened between 4 and 3.8 Ga ago. It could correspond to either the end of a long period of bombardment by asteroids, meteorites and comets or to a short time cataclysmic phenomenon.

Laurasia: Palaeozoic super-continent formed by convergence and agglomeration of continents (Europe, North America and Asia) due to plate tectonic activity. It was mainly located in the North hemisphere. Continent resulting of Pangaea broke in two parts at the end of Palaeozoic.

Lava: Magma emplaced as a flow at the surface of the Earth or any other planet.

Leaching: Dragging of soluble elements or particles of a soil by infiltrated water.

Leucine (Leu): Proteinic amino acid containing six C atoms and considered as one of the prebiotic AA.

Lherzolite: Peridotite made up of olivine and pyroxenes (ortho- and clinopyroxenes) as well as of an Al-bearing mineral. Its melting generates basaltic magmas leaving a harzburgite residue.

Ligand: Any atom or group of atoms bonded to the atom we are interested in. As an example, the four ligands of a chirotopic (asymmetric) carbon atom are necessarily different.

Ligase: Class of enzymes that catalyses the binding between two molecules (or two DNA fragments).

Light-year: Measure of distance used in astronomy, it corresponds to the distance that light runs in one year (0.946 10¹⁶ m).

Liquidus: Line which, in composition vs. temperature or pressure vs. temperature diagrams, separates the

domain where crystals and liquid coexist from the field where only liquid exists.

Lithophile (Geochemistry): Chemical element frequently associated with oxygen. A lithophile element has a greater free energy of oxidation per gram of oxygen than iron; it occurs as an oxide generally in silicate minerals (i.e. Si, Al, Na, K, Ca, etc. . . (Synonym = oxyphile).

Lithosphere: External rigid shell of the Earth. Its definition is based on rheological behaviour of rocks. It includes crusts (continental and oceanic) as well as the upper rigid part of the mantle its thickness varies between 0 and 250 km and more or less corresponds to the 800°C isotherm.

Lithotroph: See chemolithotroph. Living organism that takes its energy from the oxidation of inorganic molecules such as NH_3 , H_2S , Fe^{++} .

Low mass star: Star with mass $< 2 M_{\text{sun}}$.

L_{sun} (Astronomy): Sun luminosity ($3.826 \cdot 10^{24} \text{ W}$).

LUCA: Last Universal Common Ancestor. Hypothetical microorganism that stood at the root of all lines leading to the present day living beings. Appeared after a long evolution, it cannot be considered as a primitive form of life.

Lysine (Lys): Proteinic amino acid containing six C atoms with an amino group in its side chain and which, therefore, is basic and hydrophilic. Lysyl residues are frequently found in the active site of enzymes.

M

Ma: Mega annum = Mega year = one million years (= My)

Macronutrient: Chemical element necessary in large amounts for the proper growth and metabolism of a living organism (i.e. C, O, H, N, P, K, S, Ca, Mg. . .). In seawater, the main macronutrients are water, CO_2 nitrates and phosphates (sources for H, O, C, N and P respectively). See also micronutrient.

Mag: Magnitude.

Magma: Molten rock which can be completely liquid or consist in a mixture of liquid and crystals. It is produced by high temperature ($> 650^\circ\text{C}$ for granite; $> 1200^\circ\text{C}$ for basalt) melting of pre-existing rocks. Mantle melting generates basalts whereas oceanic crust fusion rather generates adakites or TTG and continental crust gives rise to granites.

Magnesiowurstitute: Mineral, Oxide. $[(\text{Mg},\text{Fe})\text{O}]$. Magnesiowurstitute together with perovskite is probably the main component of the lower terrestrial mantle (depth $> 660 \text{ km}$).

Magnetic anomaly: Difference between the measured and the theoretical value of the magnetic field intensity of Earth.

Magnetic pole: Point where the magnetic dipole axis of a planet intersects the globe surface.

Magnetite: Mineral: Iron oxide $[\text{Fe}^{++}\text{Fe}^{+++}_2\text{O}_4]$. Its ferromagnetic properties make it able to record past Earth magnetic field characteristics. It can also exist in some bacteria called "magneto-tactic".

Magnitude (Mag) (Astronomy): Measure of brightness of a stellar object on a logarithmic scale. The difference between two successive magnitudes is a factor 2.512. $\text{Mag} = -2.5 \log_{10} (I/I_0)$; Less bright is a star, more is its magnitude. The magnitude is calculated on a chosen spectral interval (visible, IR) or on the total spectrum (bolometric magnitude).

Major half-axis: For an elliptic orbit, half of the distance aphelia-perihelia.

Mantle plume: Ascending column of hot mantle assumed to be generated near the mantle-core boundary or at the upper-lower mantle boundary, (= hot spot). Near surface, this column can melt giving rise to oceanic island magmatism (i.e. Hawaii; La Réunion, etc.)

Mars Express: ESA space mission towards Mars.

Mantle: In a planet, mantle is the shell comprised between crust and core. On Earth it represents 82% of the volume and 2/3 of the mass, it is divided into upper mantle (until 700-km depth) and lower mantle (until 2900 km depth).

Mass loss rate (astronomy): Mass ejected per time unit by a star during its formation. Ejection takes place through stellar winds and bipolar jets (typically 10^{-5} to 10^{-8} solar mass per year).

Massive star: Star with mass $> 2 M_{\text{sun}}$.

Matrix (Chemistry): Parent molecule that allows the pre-positioning of isolated elements thus making possible their polymerisation.

Maturation (Genetics): Transformation step of mRNAs leading to their functional form. It occurs by splicing “Introns sequences”.

Megaton: Unit of energy equivalent to the energy released by 10^9 kg of TNT (trinitrotoluene). Corresponds to $4.2 \cdot 10^{15}$ J.

Mercaptans: Other name of thiols: sulphur analogues of alcohols.

Mesopause: Atmospheric boundary between mesosphere and thermosphere.

Mesophase: Matter state exhibiting characteristics of two phases. Liquid crystals have the fluidity of liquids but are characterized by an order at short range similar to what is observed in crystals.

Mesosphere: Atmospheric layer located above the stratosphere and below the thermosphere, between 45–50 km and 80km (in the case of the Earth) or, if the stratosphere is absent, directly above the tropopause (as in the case of Mars and Venus).

Mesotartaric acid: $\text{HOOC-CHOH-CHOH-COOH}$, alpha-beta-dihydroxysuccinic acid, molecule containing two asymmetric carbon of opposite chirality. This molecule is achiral by internal compensation.

Mesozoic (Era): Period of time (Era) ranging from 250 Ma to 65 Ma, it is also called Secondary Era.

Metabolism: All the reactions taking place in a cell or in an organism. Metabolism is divided into two subclasses: anabolism and catabolism. The very large majority of metabolic reactions are catalyzed by proteinic enzymes.

Metallicity: In a star, a galaxy or a gas cloud, the metallicity is the proportion of heavy elements (heavier than helium).

Metamorphism: Solid state transformation of a rock due to change in pressure and/or temperature conditions. New mineral assemblage, stable in new P-T conditions will appear. New minerals crystallise perpendicular to oriented pressure thus defining a new planar structure called foliation. Most often metamorphism corresponds to dehydration of the rock.

Metasediments: Sediments transformed by metamorphism.

Metasomatism: Change in rock composition due to fluid circulation. For instance, in a subduction zone, the fluids (mainly water) released by dehydration of the subducted slab, up-rise through the mantle wedge. These fluids which also contain dissolved elements,

not only rehydrate the mantle peridotite, but also modify its composition.

Meteor Crater: Impact crater in Arizona. It is about 1.2 km in diameter and 170m deep. The impact which took place 50 000 years ago was due to an iron meteorite of about 25 m in diameter. Impacts of this kind generally occur every 25,000 year.

Meteorite: Extraterrestrial object, fragment of an asteroid, of a planet (like Mars) or of the Moon that falls on the Earth surface.

Methanogen: Archeobacteria producing methane CH_4 from CO_2 and H_2 . Some methanogens are hyperthermophilic.

Methanogen: Methane-producing microorganism of the Archaea domain.

Methionine (*Met*): Proteinic amino acid containing five carbon atoms with a $-\text{SCH}_3$ group in its side chain.

Methylalanine: Synonymous of alpha aminoisobutyric acid (alpha-AIB).

MGS (*Mars Global Surveyor*): American probe that have carried out a complete cartography of Mars (from September 1997).

MHD: Magnetohydrodynamic.

Mica: Mineral family. Phyllosilicate (water-bearing sheet silicate): biotite = black mica $[\text{K}(\text{Fe},\text{Mg})_3\text{Si}_3\text{AlO}_{10}(\text{OH})_2]$; muscovite = white mica $[\text{KAl}_2\text{Si}_3\text{AlO}_{10}(\text{OH})_2]$

Microarray: Microarrays are small, solid supports on which thousands of different substances (antibodies- proteins- DNA) can be implanted in specific locations. The supports are usually glass microscope slides, but can also be silicon chips or nylon membranes. The substance is printed, spotted, or actually synthesized directly onto the support. Microarrays are used to test large

number of targets quickly or when the only small quantities of the sample to be studied are available.

Micrometeorite: Very small meteorite (< 1 mm). The 50-400 μm fraction is the most abundant found on Earth. Micrometeorites constitute more than 99% of the extraterrestrial material able to reach the Earth surface (major impacts excepted)

Micronutrient: Chemical element required in small amounts for the proper growth and metabolism of a living organism (i.e. B, Cu, Co, Fe, Mn, Mo, Zn...). See also macronutrient.

Microorganism: Organism invisible without a microscope. Includes prokaryotes and unicellular eukaryotes (i.e. yeasts).

Microspheres: Spherical clusters of organic molecules found in Precambrian rocks or produced in laboratory from amino acids polymers (proteinoids). Today, the Fox proteinoids microspheres are not still considered as plausible models of primitive cells.

Microsporidia: Parasitic unicellular eukaryotes that have been shown to be highly derived fungi from the fungi. Microsporidia were thought for some time to be primitive.

Migmatite: High-temperature metamorphic rock affected by partial melting.

Milankovitch (*theory of*): Theory connecting the Earth climate variations to astronomic variations such as changes of Earth's orbit or obliquity with time.

Miller-Urey (*experiment of*): One of the first experimental simulations of what was considered as atmospheric prebiotic chemistry (1953). Synthesis of a large variety of organic molecules including few amino acids from a very

simple mixture containing reduced small molecules (H_2 , CH_4 , NH_3 and H_2O) submitted to an electric discharge.

Mineral: Solid material defined by both its chemical composition and crystal-line structure.

Minimal protosolar nebula: Minimal mass of gas, necessary for the formation of the solar system planets (= mass of all planets + H + He \approx 0.04 solar mass).

Minor planet: Asteroid or planetoid.

Mitochondria: Organelles in the cytoplasm of all eukaryotic cells where ATP synthesis takes place during aerobic respiration. Mitochondria have their own DNA and could have an endosymbiotic origin.

Mitosis: Nucleus division, cell division step including cytokinesis.

MM: Micrometeorites.

Moho (Mohorovicic): Discontinuity in seismic waves that marks the crust-mantle boundary.

Mole: SI unit for amount of substance; it is defined as the number of atoms in exactly 0.012 kg of carbon-12 (1mole of atoms = 6.02×10^{23} atoms; 1 mole of molecules = 6.02×10^{23} molecules).

Molecular beacon: Molecular beacons are single-stranded oligonucleotide hybridization probes that form a stem-and-loop structure. The loop contains a probe sequence that is complementary to a target sequence, and the stem is formed by the annealing of complementary arm sequences that are located on either side of the probe sequence. A fluorophore is covalently linked to the end of one arm and a quencher is covalently linked to the end of the other arm. Molecular beacons do not fluoresce when they are free in solution. However, when they hybridize to a nucleic acid strand containing a target

sequence they undergo a conformational change that enables them to fluoresce brightly.

Molecular clouds: See interstellar clouds.

Molecular flow: see bipolar flow.

Molecular recognition: Chemical term referring to processes in which a specific molecule (ligand) adhere in a highly specific way to another molecule (target), forming a large structure.

Monophyly: Term that describes a taxonomic group sharing a single ancestor and all its descendants (i.e. the mammals).

Monosaccharides: See oses.

Montmorillonite: Mineral. Phyllosilicate (water-bearing sheet silicate). Clay mineral belonging to the smectite group.

MORB (Mid Ocean Ridge Basalt): Basalt generated in mid oceanic ridge systems where oceanic crust is created. Most of ocean floor has a MORB composition.

m-RNA: Messenger RNA. Obtained by transcription of a DNA segment and able to orient the synthesis of a specific protein in the ribosome.

MS (Mass Spectrometry): Analytical method involving a preliminary ionization of atoms or ionization and fragmentation of molecules followed by measures of atomic or molecular masses. These measures can be carried out from precise study of ions trajectories or time of flight in an electric and/or magnetic field.

MSR (Mars Sample Return): NASA-CNES space mission project for the return of Martian soil samples (~1 kg) extracted by automatic probes. Launch expected between 2009 and 2014, and samples return three to five years later.

Murchison: Carbonaceous chondrite (CM) felt in Australia in 1969. Frag-

ments recovered immediately after the fall were (and still are) subjected to many analyses, mainly chemical. More than 500 organic compounds were identified, including amino acids and nucleic bases.

Muscovite: Mineral. Phyllosilicate (water-bearing sheet silicate). $[KAl_2Si_3AlO_{10}(OH)_2]$. It belongs to the mica group and is also called white mica.

Mutation: Any change of the genetic material, transmitted to the descendants.

My: Mega year = one million years (= Ma)

Mycoplasma: The simplest and the smallest known microorganisms, they live as parasites in animal or vegetal cells. They long be considered as possible analogues of the first cells; now considered as Gram+ bacteria which lack their rigid cell wall and evolved by reduction.

N

Nanobacteria: Hypothetical bacteria, whose size could be around few nanometres, smaller than any known bacteria. Their existence is very much debated.

N-carbamoyl-amino acids: A molecule showing many similarities with amino-acids except that one of the H atoms of the amino group is substituted by the carbamoyl polyatomic group ($-CO-NH_2$). N-carbamoyl-amino acids could have been prebiotic precursors of some amino acids.

Neutral (mutations) (*Genetic*): Term coming from the neutral theory of molecular evolution proposed by Kimura. A neutral mutation is a mutation leading to sequences selectively and functionally equivalent. They

are said neutral in regards of evolution.

Neutron star: Remnant of a dead star with an initial mass greater than $\sim 8M_{Sun}$. When electron degenerated pressure becomes too low; electrons penetrate into nucleus and are transformed into neutron by reacting with protons (neutralisation). Then they develop a neutron degenerated pressure.

NGST (*Next Generation Space Telescope*): NASA project of space telescope (4m), it must succeed to the HST (Hubble Space Telescope).

Nitrification: Microbial oxidation, autotrophic or heterotrophic, of ammonium to nitrate

Nitrile: R-CN where the CN group is the cyano group (cyano as prefix but nitrile as suffix).

Non reducing atmosphere: Atmosphere of CO_2 , N_2 , H_2O where hydrogen is absent or in low quantity, either in the form of free H_2 or hydrogen-containing compounds, such as methane or ammonia. Also named oxidized or neutral atmosphere according to its composition.

Non-sense (*codon*): When a codon (triplet of nucleotides) does not specify an amino acid but corresponds to a termination codon (Term.). In the « universal code », these codons are UAA, UAG and UGA.

Normative (*rock composition*): Rock mineralogical composition recalculated from its chemical composition.

Nuclear pores: Complex structures, highly specialized, embedded in the nuclear membrane. They allow the transfer of macromolecule between nucleoplasm and cytoplasm.

Nucleation (*Astronomy*): Mechanism of formation of solid bodies by accretion of planetesimals.

Nucleic acid: Long chain polymeric molecule obtained by condensation of

nucleotides. DNA and RNAs are nucleic acids.

Nucleic base: Linked to ribose or deoxyribose by a hemiacetal bond, it gives nucleosides. Nucleic bases are purine bases or pyrimidine bases. Nucleosides together with a phosphate group are the sub-units of nucleotides. By condensation, nucleotides give the polynucleotides (including DNA and all RNAs).

Nucleides: Constituents of atom nucleus, i.e. protons and neutrons.

Nucleon: Common name for proton or neutron.

Nucleoplasm: Protoplasm within the nucleus of eukaryotes.

Nucleotide: Molecule made by condensation of a base (purine or pyrimidine), an ose and a phosphate group linked to the ose. Nucleotides are ribonucleotides when the ose is ribose or deoxyribonucleotide when the ose is deoxyribose. DNA is a polydeoxyribonucleotide while RNAs are polyribonucleotides. The symbol of a nucleotide is determined by the base (A for adenine, C for cytosine, G for guanine, T for thymine, U for uracil).

Nucleus (*Biology*): Eukaryote cell substructure that contains the chromosomes.

O

Obduction: Mechanism leading to the thrusting of oceanic lithosphere onto continental crust.

Obliquity: Angle between the ecliptic and the celestial equator, actually, 23.3 degrees for the Earth. This angle is $> 90^\circ$ if the planet has a retrograde rotation.

Ocean resurgence: See upwelling.

Oceanic rift: Central depression in a mid ocean ridge, this is the place where oceanic plates are created.

Oligomer: Small polymer, generally containing less than 25 monomeric units

Oligomerization: Polymerization involving a small number of monomers.

Oligopeptides: Small polypeptide (less than 25 AA residues even if the definition is not so strict).

Olivine: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). $[(\text{Fe}, \text{Mg})_2\text{SiO}_4]$. This mineral which belongs to the peridot family, is silica-poor is one of the main components of the terrestrial upper mantle. It is also common in meteorites.

OMZ: See Oxygen Minimum Zone.

Oort cloud: Huge spherical collection of comets, orbiting the Sun between 10 000 and 100000 AU.

Ophiolite: Part of oceanic lithosphere tectonically emplaced (obducted) on a continental margin.

Optical activity: Orientation change of the linearly polarized plane of light after its passage through a chiral medium.

Optical rotatory dispersion: Change of the optical power of a chiral medium with the wavelength of the linearly polarized light.

Orbital Migration: Change, in course of time, of a planet-star distance; this hypothesis is proposed in order to explain the presence of massive planets close to their star.

Organic molecule: Until the beginning of the 19th century, organic molecules were molecules extracted from plants or animals. Today, any molecule containing carbon atoms is called organic. Carbonates, CO and CO_2 are borderline cases. Organic molecules generally contain C atoms with an oxidation number lower than 4.

Organometallic molecule: Molecule containing one or more metal atoms.

Organometallic: Organic molecule containing one or more metallic atoms bonded by covalent bonds or by coordination to the organic moiety of the molecules. Metallic salts of organic acids are not considered as organometallic compounds.

Orgueil: Large CI carbonaceous chondrite (very primitive), without chondres, which fell in France in 1864, near Montauban.

Ornithine: $\text{NH}_2\text{-CH-COOH-(CH}_2\text{)}_3\text{-NH}_2$. Non proteinic amino acid, precursor of arginine.

Orogenesis: Mountain chain genesis.

Orographic: Related to relief. In weather science, the presence of a relief can induce changes in atmospheric circulation resulting in weather changes (i.e. orographic rainfalls).

Orthose: Mineral. Tectosilicate (3D silicates). Alkali feldspar KAlSi_3O_8 .

Oses (or saccharides): Large group of molecules of primeval importance in the living world. Some of them are monomers like glucose ($\text{C}_6\text{(H}_2\text{O)}_6$) or ribose ($\text{C}_5\text{(H}_2\text{O)}_5$). Some of them are dimers like lactose or saccharose; some of them are polymers (polysaccharides) like starch or cellulose.

Outer membrane: membrane surrounding the plasma membrane in Gram negative bacteria (i.e. *Escherichia coli*).

Oxidative phosphorylation: In living cells, biochemical process that results in ATP synthesis; energy is provided by protons transfer across the cell membrane.

Oxygen minimum zone (OMZ): Part of the water column where the oxygen consumption due to respiration exceeds its supply by lateral circulation, giving rise to dysoxic or anaerobic conditions. The OMZ areas occur generally where the intermediate or deep circulation is

weak, and/or when biological productivity at the surface is high.

Oxyphile: See lithophile.

P

P4: Certification for laboratories accredited to analyze high-risk infectious agents. Such laboratories must be protected against any risk of contamination by viruses and microorganisms, from inside to outside and from outside to inside. These two conditions must absolutely be realised for extraterrestrial sample analyses.

PAH (Polycyclic Aromatic Hydrocarbons): Organic molecules like naphthalene or anthracene containing several fused aromatic rings.

Paleomagnetic scale: Relative stratigraphic scale based on the successive inversions of the Earth magnetic field through time

Paleo-soil: Fossil soil. These formations are able to have recorded O_2 and CO_2 concentration of the primitive terrestrial atmosphere.

Paleozoic (Era): Period of time (Era) ranging from 540 Ma to 250 Ma, it is also called Primary Era.

Pangaea: Super-continent that existed at the end of Palaeozoic era (– 225 Ma) and which later broke in two parts: Laurasia (N) and Gondwana (S).

Paralogous: Paralogous genes originate in gene duplication events, in contrast to the standard orthologous genes, which originate via speciation events.

Parent body: Asteroid or planet from which an object has been extracted, such as for example a meteorite.

Parent molecule (in comet): Molecule present in the comet nucleus.

Parity (violation of): Characterizes any physical property that changes when space is inverted or, in other words, which is not the same in the mirror world. Parity violation is observed in several phenomena related to the weak intranuclear interactions like the beta radioactivity. Parity violation is at the origin of the very small energy difference between enantiomers (PEVD for Parity Violation Energy Difference).

Parsec (secpa): Unit of astronomical length of 3×10^{18} cm (about 200,000 AU or 3.26 light-years); it is based on the distance from Earth at which stellar parallax is 1 second of arc. Average distance between stars in the Sun vicinity is around 1 parsec.

Pathfinder: American probe that landed on Mars on July 4th, 1997, formally named the Mars Environmental Survey (MESUR). It contained a rover "Sojourner" that explored Ares Vallis during several months. For instance, an "Alpha Proton X-ray Spectrometer" was used to analyse soil and rock samples in order to determine their mineralogy.

PCR (Polymerase Chain Reaction): Experimental method which, by successive molecular duplications, leads to a dramatic increase of a small initial amount of DNA. This result is obtained with an enzyme called DNA-polymerase isolated from thermophile bacteria.

Peptide: Polymer obtained by condensation of amino acids. In a peptide (or polypeptide), the number of AA residues is generally lower than 60. With a higher number of residues, the polymer generally adopts a well defined conformation and is called a protein.

Peridot: Mineral family, olivine is a peridot.

Peridotite: Rock made up of olivine and pyroxenes (ortho- and clino-pyroxenes) as well as of an Al-bearing mineral (spinel at low pressure and garnet at high pressure). Earth mantle is made up of peridotite.

Perihelia: In the case of an object in elliptical motion around a star, the point which corresponds to the shortest distance with respect to the star.

Permafrost: In arctic regions, permanently frozen soil or subsoil.

Perovskite: Mineral. $[(Mg,Fe)SiO_3]$. Perovskite together with magnesio-wursterite is probably the main component of the lower terrestrial mantle (depth > 660 km).

Petrogenesis: Mechanism(s) of formation of rocks.

PGE or platinum group elements: Transition metal belonging to the Platinum group: Ruthenium (Ru), Rhodium (Rh), Palladium (Pd), Osmium (Os), Iridium (Ir) and Platinum (Pt). They possess similar chemical properties (siderophile). In Earth's crust their abundance is very low, whereas it can be high in undifferentiated meteorites. On Earth, their high concentration in sediments is used as an indication of a meteorite impact, for example at the KT boundary. The elemental ratio between the PGE can provide information on the nature of the impacted meteorite.

pH: Measure of the acidity of an aqueous solution. $pH = -\log_{10} (H^+)$ where (H^+) is the molar concentration of hydroxonium ion in solution. $pH = 7$ corresponds to the neutrality while a solution with $pH > 7$ is basic and a solution with $pH < 7$ is acidic.

Phanerozoic (Aeon): Period of time (Aeon) ranging from 0.54 Ga to today; it followed Precambrian and was characterized by metazoa development.

Phenetic: Taxonomic system for living beings based on overall or observable similarities (phenotype) rather than on their phylogenetic or evolutionary relationships (genotype).

Phenotype: The observable characteristics of an organism, i.e. the outward, physical manifestation of an organism.

Phenylalanine (*Phe*): Amino acid containing an aromatic phenyl group in its side chain. Phenylalanine contains nine amino acid residues.

Phosphoric acid: H_3PO_4 , dihydrogen phosphate. Molecule which plays an important role in the living world: nucleotides are esters of phosphoric acid.

Photochemistry: Chemistry involving energy supply coming from « light » (from IR to UV). When electromagnetic frequency is greater (X-rays, beta-rays or gamma rays), the term radiochemistry is generally used. Specific processes like photo-activation, photo-ionisation, photo-dissociation (including the production of free radicals), and photolysis are various aspects of photochemistry

Photodissociation: Dissociation of molecules due to the energy provided by electromagnetic radiation.

Photolysis: See photodissociation.

Photosynthesis: Synthesis using photons as energy supply. Photosynthesis can be performed at laboratory or industrial level as a sub-domain of photochemistry. In biochemistry, the term « photosynthesis » describes the different biosynthetic pathways leading to the synthesis of molecules under the influence of light. The photons are absorbed by cell pigments and their energy is converted into chemical energy stored in chemical bonds of complex molecules, the starting material for the synthesis of these complex molecules being small molecules like

CO_2 and H_2O . It is important to make a clear distinction between the aerobic photosynthesis (also called oxygenic photosynthesis) and the anaerobic photosynthesis. In the first case, water is the reductive chemical species and O_2 is a by-product of the reaction. It must be kept in mind that atmospheric dioxygen as well as oxygen atoms of many oxidized molecules on Earth surface have a biosynthetic origin. Green plants, algae and cyanobacteria are able to perform aerobic photosynthesis; their pigments are chlorophylls. The anoxygenic photosynthesis is not based on H_2O but on reductive species like H_2S . Finally, some halophile archaeas contain a pigment called bacteriorhodopsin and are able to use light energy supply for ATP synthesis. So, light energy is converted into chemical energy or better, in chemical free energy.

Phototroph: Organism whose energy source is light (photosynthesis).

Phylogenesis: History of the evolution of a group of organisms.

Phylogenetic tree: Schematic representation describing the evolutive relationships between organisms. It gives an image of the evolution pattern.

Phylotype: Environmental sequence, representing an organism. Sequence of a clone obtained from environment and representing an organism.

Phylum (*pl. phyla*): Group of organism evolutionary connected at high taxonomic rank.

Pillow lava: Lava extruded under water (ocean, lake) which produces its typical rounded pillow shape. Pillow lava forms the upper part of oceanic crust.

PIXE (*Proton-Induced X-ray Emission*): Device that allows the detection and identification of many elements (metals) in proteins.

Plagioclase: Mineral. Tectosilicate (3D silicates). Calco-sodic feldspar whose composition ranges between a sodic ($\text{NaAlSi}_3\text{O}_8 = \text{Albite}$) and a calcic ($\text{CaAl}_2\text{Si}_2\text{O}_8 = \text{Anorthite}$) poles. They represent about 40% of the Earth crust minerals.

Planet: Body formed in circumstellar disks by accretion of planetesimals and may be of gas.

Planetary nebula: This expression is not related to planets or to nebula. A planetary nebula is the low density and expanding gaseous envelope of a white dwarf. The last phase of evolution of a star whose mass is $< \sim 8M_{\text{Sun}}$ consists in an explosion (nova) and in the ejection of a gaseous envelope; the star relicts giving rise to the white dwarf itself.

Planetesimals: Small solid bodies ($\sim 1\text{--}100$ km) formed in the protosolar nebula, probably similar to asteroids and comets. Their collision and accretion built the planets.

Plankton (*plankton*): The whole organisms living in water and drifting along ocean and lake currents. It includes zooplankton (small animals) and phytoplankton (plants). Fishes and sea mammals, able to swim independently of current flow, constitute the nekton. Neston refers to organisms drifting at the air-water interface whereas benthos designates organisms living in or on the aquatic ground.

Plasma membrane (*or cell membrane*): Semi-permeable membrane that surrounds contemporary cells. It consists of a double layer of amphiphilic molecules (hydrophobic tail with hydrophilic head), mainly phospholipids, with proteins embedded in it. It may also contain some molecules, such as cholesterol or triterpenes, able to rigidify the whole.

Plasmid: Extrachromosomal DNA found in bacteria and yeasts, able to replicate independently.

Plasmon: Electronic cloud of a metal.

Plasts: Organites found in phototrophic Eukaryotes and containing photosynthetic pigments such as chlorophylls.

Plate (*lithospheric*): Piece of the rigid lithosphere that moves over the ductile asthenosphere affected by convection.

Plate tectonic: Theory that describes and explains the rigid lithospheric plate motion.

Plutonic: Magmatic rock, resulting of the slow cooling and crystallisation of magma at depth. Its texture is granular (big crystals), e.g. granite.

PMS Star: New-born star such that the internal temperature is yet too low ($< 10^7$ K) to initiate nuclear fusion of hydrogen into helium (i.e. T-Tauri stars) and characterized by a low mass.

PNA (*Peptide Nucleic Acids*): Synthetic analogues of nucleic acids such that the phosphate strand is replaced by a polypeptide backbone to which the bases are linked.

Polarized light: It is important to differentiate two limit cases. A linearly polarized light (or plane polarized light) is an electromagnetic radiation, whatever is its frequency, such that the electric vector and thus also the magnetic vector oscillate in a plane. If this radiation travels through a chiral medium, the plane of polarization is deviated (optical rotation). A circularly polarized light is an electromagnetic radiation such that its electric vector and thus also its magnetic vector describe, in space, an helix around the propagation direction. This helix can be right or left corresponding to the two possible circularly polarized lights

of a definite frequency. The linearly polarized light corresponds to the superposition of two circularly polarized lights of the same frequency.

Pole motion: Geographic pole motion at the Earth surface. This motion has low amplitude, since the pole only moves of few metres.

Polymerization: Chemical reaction such that molecules called monomers are covalently linked together and form long chain molecules, with or without branching. The polymerization can be the result of an addition of polymers like in polyethylene or polystyrene (industrial polymers) but the polymerization can also be the result of condensation reactions involving at each step, the elimination of a small molecule (generally water). Nylon is an industrial condensation polymer and most of biological macromolecules such as polypeptides, polynucleotides and polysaccharides are condensation polymers.

Polynucleotide: Polymer resulting from condensation of nucleotides.

Polypeptide: Polymer resulting from condensation of amino acids.

Polysaccharide: Polymer resulting from condensation of oses (in the past, oses were also called monosaccharides).

POM (*polyoxymethylene*): Polymer of formaldehyde.

Population I stars: Stars enriched in heavy elements (O, C, N...). They have been formed from the interstellar gas enriched by the previous generation(s) of stars formed over the billions of years of lifetime of the Galaxy. They are predominantly born inside the galactic disk. The Sun belongs to population I stars. Massive, hot stars are necessarily young and are therefore always population I stars.

Population II stars: Stars poor in heavy elements (O, C, N...). They have been

formed from low metallicity gas that has not been enriched by successive generations of stars. They are believed to be born in the early ages of the Galaxy. They are actually distributed predominantly in the halo of the Galaxy thus confirming that they are probable remnants of the infancy of our Galaxy.

Poynting-Robertson (effect): Effect of stellar light on a small orbiting particle. This causes the particle to fall slowly towards the star. Small particles (below 1cm) are more affected because the effect varies as the reciprocal of particle size.

p-p chain: Series of hydrogen burning reactions that produce helium. These reactions provide the energy of the main sequence stars whose mass is $< 1.1 M_{\text{Sun}}$.

ppb (*part per billion*): Relative concentration in mass = nanogram/gram.

ppbv (*part per billion in volume*): Relative concentration in volume = nanolitre/litre).

ppm (*part per million*): Relative concentration in mass = microgram/gram.

ppmv (*part per million in volume*): Relative concentration in volume = microlitre/litre)

Prebiotic chemistry: All chemical reactions which have contributed to the emergence of life.

Precambrian: Group of aeons ranging from Earth genesis (4.55 Ga) until the beginning of Palaeozoic era (0.54 Ga). It includes: Hadean, Achaean and Proterozoic aeons.

Precession (*of equinoxes*): Motion of Earth's rotation axis with respect to the celestial sphere due to the other bodies of the Solar system and more particularly to the Moon. The terrestrial pole describes a circle on the celestial sphere in 26000 years.

Primary structure (of a protein): Sequence of the amino acid residues in the proteinic chain.

Primitive atmosphere: The Earth primitive atmosphere refers to the atmosphere present when prebiotic chemistry occurred, free oxygen concentration was very low. This atmosphere was considered as highly reductive; today it is rather assumed to have been made up of carbon dioxide, nitrogen and water vapour (greenhouse).

Primitive Earth: The young Earth from its formation until 2.5 Ga.

Primitive nebula: See protosolar nebula.

Prion: Protein able to induce a pathological state because its conformation is modified.

p-RNA: Synthetic RNA molecule in which the sugar is a pyranose instead of a furanose.

Prokaryote: Microorganism in which chromosomes are not separated from the cytoplasm by a membrane. Bacteria and Archaea are prokaryotes.

Proline (Pro): Amino acid containing six C atoms with a unique characteristic. Its side chain links together the alpha atom and the N atom to give a five membered ring containing one N atom and four C atoms; the amino group is no longer a -NH_2 group but a -NH- group. Proline is frequently observed in protein secondary structures called beta turns

Proper motion (Astronomy): Apparent angular movement of a star on the celestial sphere during a year (perpendicular to the line of sight). Proper motion analysis can lead to detection of planets in orbit around this star.

Proper motion: Apparent angular movement of a star on the celestial sphere. The detailed observation and study of such motion can lead to the detection of planets orbiting the star.

Propionaldehyde: $\text{CH}_3\text{-CH}_2\text{-CHO}$ or propanal.

Protein Scaffold: Protein whose main function is to bring other proteins together in order for them to interact. These proteins usually have many protein binding domains (like WD40 repeats).

Proteins: Long chain biological polymers obtained by condensation of amino acids. The degree of polymerization (number of residues) ranges between 60 and 4000. Some proteins form aggregates. For example, haemoglobin is a tetramer containing two proteinic chains of one type and two proteins chains of another type; in each chain, a heme molecule containing a ferrous cation is settled in without being covalently bonded. Structural proteins are components of muscles or flagella; most enzymes are proteins and proteins are also carriers of other molecules like dioxygen or carbon dioxide. The activity of proteins is extremely dependent on their molecular conformation.

Proteobacteria: Group of bacteria including *Escherichia coli* and purple bacteria (photosynthetic bacteria). Mitochondria are relics of proteobacteria.

Proteome: The complete collection of proteins encoded by the genome of an organism.

Proteomics: Part of science that studies proteome. Proteomics not only analyses the complete protein collections but also determines their precise location, modifications, interactions, activities and functions. Consequently, it implies the simultaneous analyse of a huge amount of proteins in a single sample.

Proterozoic (Aeon): Period of time (Aeon) ranging from 2.5 to 0.54 Ga.

This aeon belongs to Precambrian and follows Achaean. Apparition of oxygen in atmosphere and of metazoa.

Proton motive force: Free energy difference (measured in volts) associated with proton translocation across a membrane. It depends on the electrical membrane potential and on the pH difference between the two reservoirs separated by the membrane. The proton motive force provides energy required for ATP synthesis.

Protoplanetary disks: Disk around a new-born star where accretion of planets is supposed to take place.

Protosolar nebula: Rotating disk of gas, dust and ice, from which the solar system is originated.

Protostar: several similar definitions exist. 1) new-born star such that half of its luminosity is due to accretion. 2) Body involved in an accretion process which will bring it on the main sequence. 3) Collapsing interstellar cloud. 4) Young object which is not yet optically visible. Protostars are rare because their time life is short (10^4 to 10^5 years): « Protostars are the Holy Grail of IR and submillimetric astronomy ».

Psychrophilic organism: Organism that lives optimally at a temperature lower than 10°C . Some psychrophilic organisms live at temperatures lower than 0°C .

Pulsar : Small neutron star in very fast rotation (one rotation in less than 1s) emitting a highly focalized radiation, circularly polarized and detected as very regular pulses. Pulsars are remnants of supernovae.

Purine bases: Guanine and adenine are examples of purine bases because their molecular skeleton corresponds to purine. These bases are found in DNA as in RNA's.

Purple bacteria: Micro-organisms of the bacteria domain able to perform anoxygenic photosynthesis.

PVED (Parity Violation Energy Difference): Energy difference between enantiomers due to parity violation at the level of the weak forces.

Pyranose: A "pyranose ring" is a cyclic ose formed of 5 carbons and an oxygen atom. It is the more stable form of oses.

Pyrimidine bases: Thymine, cytosine and uracil are examples of pyrimidic bases because their molecular skeleton corresponds to pyrimidine. Cytosine is found in DNA as in the RNAs while thymine is specific of DNA and uracil is specific of RNA's.

Pyrite: Mineral. Sulphide [FeS_2].

Pyrolysis: Thermal degradation of a molecule.

Pyroxene: Mineral family. Inosilicate (simple chain silicate). Divided in two families: 1) Orthopyroxene [$(\text{Fe},\text{Mg})_2\text{Si}_2\text{O}_6$] (e.g. enstatite) and 2) Clinopyroxenes [$(\text{Ca},\text{Fe},\text{Mg})_2\text{Si}_2\text{O}_6$] (e.g. augite, diopside).

Q

Q: Orbital parameter of a planet orbiting a star; distance between planet aphelia and star.

q: Orbital parameter; distance between planet perihelia and star.

Quartz: Mineral. Tectosilicate (3D silicate). It crystallizes in hexagonal or rhombohedral systems. In magma it characterizes silica sur-saturation. The rhombohedral crystals are chiral: quartz can therefore exist as D- or L-quartz depending from the helicity of the $-\text{O}-\text{Si}-\text{O}-\text{Si}-$ chain. A chiral quartz crystal can induce an enantioselectivity during a chemical reaction between

achiral reactants via a catalytic effect.

Quaternary structure (of a protein): In the case of protein forming supramolecular aggregates like haemoglobins, the quaternary structure corresponds to the arrangements in space of the subunits.

Quencher: Molecular entity that deactivates (quenches) a fluorophore.

R

R: solar radius (0.69×10^6 km) or 1/200 AU; approximately 10 times the Jupiter radius and 100 times the Earth radius.

Racemate (crystal): Crystalline form of a chiral substance such that each unit cell of the crystal contains an equal number of molecules of opposite chirality.

Racemic (mixture): Mixture of enantiomers containing an equal number of the two enantiomers. Such a mixture is described as achiral by external compensation.

Racemisation: Diminution of the initial enantiomeric excess of a homochiral ensemble of molecules or of a non-racemic mixture of enantiomers. It corresponds to an equilibration reaction: the system evolves spontaneously towards a state characterized by higher entropy and therefore, lower free energy. The highest entropy and lower free energy corresponds to the racemic mixture. Racemisation can be a very slow process: this is why enantiomers of amino acids, sugars and many other components of living species can be separated in many cases.

Radial velocity measurement: The line-of-sight velocity of a star or other celestial object towards or away from an observer. This method allows to determine a star's movements through

space and consequently to infer the existence (or not) of an orbiting object.

Radial velocity measurement: The line-of-sight velocity of a star or other celestial object towards or away from an observer. This method allows to determine a star's movements through space and consequently to infer the existence (or not) of an orbiting object.

Radial velocity: Star velocity component parallel to the view line. It causes the frequency shift observed in spectral emission lines (Doppler Effect). Periodical change in radial velocity can be an indirect proof that a planet orbits around the star (reflex motion).

Radiation pressure: Pressure applied by electromagnetic waves on any atom, molecule or particle.

Radioactivity (long lived species): Radioactive elements with long period (10^9 to 10^{11} years); they are still present in the Solar system.

Radioactivity (short lived species): Radioactive elements with short period ($< 10^7$ years). Nowadays they have totally disappeared in the Solar system.

Raman (spectroscopy): Physical method used for molecular structural analysis. Raman spectroscopy is based on inelastic diffusion of visible or UV light and gives information about the vibration modes of diffusing molecules. Raman spectroscopy must be considered as a complementary method with respect to IR spectroscopy.

Rare Earth Elements (REE): Chemical elements with very similar chemical properties. This family (lanthanides) ranges from Lanthanum ($Z = 57$) to Lutetium ($Z = 71$). In geochemistry, they are commonly used as geological tracers of magmatic processes. Indeed they are poorly sensitive to weathering or metamorphism, but on the opposite

they are excellent markers of magmatic processes such as melting or crystallization.

Rare gases (*He, Ne, Kr, Ar, Xe, Rn*): Monatomic gases corresponding to the (VIII A) period of Mendeleev periodic table (see “Astrobiological data”). Their isotopes can be used to trace some geological events of Earth differentiation (e.g. atmosphere and ocean formation).

Recovery ratio (%): A sample prepared by adding a known mass of target analyte to a specified amount of matrix sample for which an independent estimate of target analyte concentration is available. Spiked samples are used, for example, to determine the effect of the matrix on a method’s recovery efficiency.

Red giant (*astronomy*): Old star (spectral type K or M) still performing fusion of hydrogen but having already a helium core.

Reducing atmosphere: Atmosphere with high hydrogen content. Carbon, oxygen and nitrogen mainly exist as CH₄, H₂O and NH₃.

Reduction potential: Measure of the tendency for a molecule or an ion to give an electron to an electron acceptor that, itself, can be a molecule, an ion or an electrode. A conventional reduction potential scale for molecules in water allows to determine, a priori, what chemical species will be the electron acceptor and what will be the electron donor when they are mixed together at a well defined concentration.

Refractory inclusion: Aggregate of refractory minerals incorporated into a meteorite. See CAI.

Refractory: A refractory compound is a compound that remains solid over the whole temperature range undergone by

the host object (i.e. dust in a comet). Antonym: volatile.

Refractory: Substance which remains solid in all temperature conditions available in a particular body of the solar system (ex. dust particles in a comet). If not refractory a substance is said volatile.

Region (*HII region*): interstellar cloud such that H exists essentially as H⁺. Ionization is due to intense UV radiation coming from OB stars. HII is the old name used by spectroscopists to describe lines coming from H⁺ recombination.

Replication: biochemical process by which a DNA strand or a RNA molecule is copied into the complementary molecule. Replication is different from transcription and from translation.

Reservoir: In biogeochemistry or geochemistry, a reservoir is the available quantity of one chemical element (or species) within one specific compartment of the global ecosystem (ocean, atmosphere, biosphere, sediments, etc...). Any reservoir may evolve through exchanges with the other ones (biogeochemical or geochemical fluxes).

Residence time: The average time a chemical element or species spends in a geochemical or a biogeochemical reservoir (ocean, atmosphere, biosphere, sediments, etc...). Assuming the reservoir is in steady state (input flux = output = dQ/dt) and contains an amount Q of one element, the residence time $\tau = Q/(dQ/dt)$.

Retrotransposons: DNA sequences able to move from one site to another along the chromosome. Retroposons belongs to a transposons family which requires RNA molecule as intermediate. The more frequent retrotransposons are the

Alu sequences; around one million of such sequences have been identified in the human genome.

Ribose: Aldopentose of major importance in the living world; part of RNA nucleotides

Ribosomes: Intracellular structures containing many rRNA (ribosomal RNA) molecules together with a complex of 60–80 proteins. Synthesis of proteins takes place in ribosomes by condensation of amino acids; information about the correct sequence is given by a mRNA (messenger RNA) while each amino acid is linked to a specific tRNA (transfer RNA).

Ribozyme: RNA molecule acting as an enzyme.

Ridge (geology): Submarine mountain chain located at divergent lithospheric plate margins. On the Earth the total length of ridges is 60000 km.

Rift: Rift valley limited by faults = graben.

Rigid rotator (hypothesis): Molecular system frozen at its equilibrium geometry. Interatomic distances and bond angles do not vary during rotation.

Ringwoodite: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). $[(\text{Mg,Fe})_2\text{SiO}_4]$. Also called olivine γ phase. In Earth mantle, ringwoodite is stable between 520 and 660 km.

RNA world: Often considered as an early hypothetical stage of life evolution, based on a life without protein and such that RNAs would have played a double role: catalysis and support of genetic information. This theory is mainly based on the discovery of catalytic RNAs (ribozymes) and on an increasing knowledge about the importance of RNAs in contemporary life. For other scientists, the RNA world is the stage of evolution that preceded the DNA emergence.

RNA: Ribonucleic acid, a class of nucleic acids containing ribose as a building block of its nucleotides. RNAs themselves are divided into sub-groups like messenger-RNA (m-RNA), transfer-RNA (t-RNA), ribosomal-RNA (r-RNA).

Rock: Solid material made up of mineral assemblage. It constitutes telluric planets, asteroids and probably the core of giant planets.

Rocky planets: Other name for telluric planets.

Rodinia: Super continent that formed at about 750 Ma ago.

Root (Genetics): for a particular genetic tree, the last common ancestor of all the organisms of the tree.

Rosetta: ESA mission launched at the beginning of 2004; it will reach the P/Cheryumov-Gerasimenko comet after a 10 years trip. An orbiter will follow the comet during one year, and a lander will perform « in situ » analyses on comet nucleus surface.

Rotatory power: Deviation of the polarization plane of a radiation of well-defined frequency by a chiral medium.

Rovibrational (level): Energy level of a molecule expressed as a rotational quantum number J associated to a given vibration level v .

r-process (rapid): Nucleosynthetic mechanism that takes place during explosion events (i.e. Supernova) and leads to the synthesis of neutron-rich nucleus with atomic number >26 (Iron). During this process, the atomic nucleus captures a huge amount of neutrons and is immediately dissociated through β^- decay.

RRKM: Method of molecular dynamics for the calculation of rate constants of chemical reactions due to Rice, Ramsperger, Kassel & Marcus.

r-RNA: Ribosomal RNA. r-RNAs are the major components of ribosomes. Some of them have catalytic properties.

Rubisco (or RuBisCo): Ribulose-1,5 biphosphate carboxylase-oxygenase; enzyme which catalyses CO₂ metabolism. It is the most abundant enzyme on Earth.

Runaway greenhouse effect: Amplification of a greenhouse effect due to vaporization of molecules able to absorb infrared radiation emitted or received by the planet and which, themselves, contribute to greenhouse effect (i.e. Venus).

Runaway growth (astronomy): Increasing rate of planetary accretion with planet growth, it leads to an increasing size difference between the small and large bodies.

R_{sun}: Sun radius (0.69×10⁶ km); 1/200 AU; ~10 times Jupiter radius, ~100 times Earth radius.

Runoff channels: Kind of channels observed on Mars and which seems to originate by large water flows over a long period of time.

S

Sagduction: Gravity driven rock deformation. When high density rocks (e.g. komatiites) emplace over low density rocks (e.g. TTG), they create an inverse density gradient that results in the vertical sinking of dense rocks in the lighter ones. Sagduction was widespread before 2.5 Ga.

Sarcosine: (CH₃)NH-CH₂-COOH, non-proteinic N-methyl amino acid.

Schist: Fine grain sedimentary rock characterized by a cleavage (slate). It results of fine sediment (i.e. mud) metamorphism.

Secondary structure (of a protein): Spatial arrangement of the main chain

of a protein. Alpha-helices, beta-sheets, beta-turns are examples of secondary structures

Sedimentary rock: Rock generated on Earth surface. It can consist in the accumulation of rock particles (detrital) or of organic matter (oil, petrol, coal). It can also be produced by physico-chemical or biogenic precipitation of dissolved ions. Detrital particles and ions derived of alteration and erosion of pre-existing rocks.

Selenocysteine: Frequently described as the 21st proteinic amino acid because sometimes coded by the genetic code. It has the structure of the cysteine with a Se atom replacing the S atom.

SELEX: (*Systematic Evolution of Ligands by Exponential Enrichment*) Method that generates high-affinity RNA or DNA ligands through successive *in-vitro* rounds of directed molecular evolution. This process allows to identify aptamers by iterative enrichment for molecules capable of binding a target.

Semi major axis: Orbital parameter. Half of the major axis of an elliptical orbit.

Semi minor axis: Orbital parameter. Half of the minor axis of an elliptical orbit.

Semi-minor axis: Orbital parameter. Small axis of orbital parameter.

Sense: DNA strand that is not copied into mRNA. Therefore, the sequence of the sense strand corresponds to the mRNA sequence which, itself, corresponds to the transcription of the antisense strand. Sense and antisense DNA sequences are strictly complementary.

Sequence (genetics): Series of directly linked nucleotides in a DNA or a RNA strand; series of directly linked amino acids residues in proteins.

Sequence (main sequence) (astronomy): Stage in star evolution when it performs hydrogen fusion in its core. In a HR diagram, main sequence stars draw a straight line.

Sequencing: Experimental determination of a DNA, RNA or protein sequence.

Serine (Ser): Proteinic amino acid with a $-\text{CH}_2\text{-OH}$ side chain. Being hydrophilic, serine is generally present in the external part of the skin and can be used as the proof for human contamination of meteoritic samples. Serine is produced in very small amounts during simulation experiments considered as experimental models of interstellar chemistry.

Serpentine: Mineral family. Phyllosilicate (water-bearing sheet silicate) (i.e. Antigorite $[\text{Si}_4\text{O}_{10}\text{Mg}_6(\text{OH})_8]$). They are generated by olivine (and sometimes pyroxene) alteration. They play an important role in internal water cycle.

SETH (Search for Extraterrestrial Homochirality): Search for proofs of enantiomeric excesses in extraterrestrial objects.

SETI (Search for Extraterrestrial Intelligence): Search for electromagnetic signals (essentially in the radio-wave domain) that should be intentionally emitted by some living organisms and coming from sources located outside the Solar system.

Shield (geology): Huge block of old (often Precambrian in age) and very stable continental crust, e.g. Baltic shield (includes Finland, Sweden, Norway, and Western part of Russia).

Shocked quartz: Quartz crystal whose structure contains defaults characteristic of the high pressures realised by meteorite impacts.

Shocked quartz: Quartz showing characteristic microscopic defects of its crystalline structure that were generated by the passage of a high pressure (> 5 Gpa) shock wave. The most common modification is the formation of planar deformation features (PDF) consisting of fine lamellae of amorphous SiO_2 oriented parallel to two (or more) specific crystallographic planes. Under even higher pressure the whole quartz crystal can be transformed to glass. Shocked quartz are a diagnostic criteria to recognize meteorite impacts as no other natural process is capable of producing the required high pressure dynamic shock wave.

Siderite: Mineral, iron carbonate $[\text{FeCO}_3]$.

Siderophile: Elements frequently associated to iron (like Au, Pt, Pd, Ni...).

SIDP (Stratospheric IDP): IDP collected in the stratosphere by captors placed on airplanes.

Silicate: Wide mineral family of silicium oxides. The structure is based on a tetrahedron $(\text{SiO}_4)^{4-}$

Simple sugar: Old name for monosaccharide.

Site (active site): For an enzyme, specific locus where the substrate is fixed, ready to react with the reactant.

SL (Astronomy): Solar luminosity (3.826×10^{24} W) or 3.826×10^{33} erg s^{-1}

SM: Solar mass (2×10^{30} kg).

Small bodies: Comets and asteroids.

SMOW (Standard Mean Ocean Water): Standard reference sample for H and O isotopic abundance measurements.

SNC: Family of about 30 meteorites which, based on several experimental observations, are considered as having a Martian origin. SNC is the abbreviation for Shergotty, Nakhla and Chassigny, three meteorites of this family.

Snow line: Limit between the regions where H_2O is gaseous and the region where it is solid. In a protoplanetary disks, the snow line marks the boundary between the region where telluric planets form from silicates, and the region where giant planets, made of an icy core surrounded by protoplanetary gases, are generated.

Snowball effect (Astronomy): During planetary accretion the larger objects grow more rapidly than the smaller ones, leading to an increasing difference in size between small and large bodies. This process accelerates (like a rolling snowball, the growing rate is proportional to its size), until the moment when the larger objects control the whole dynamic. See also Runaway growth.

Solar constant: Total energy delivered each second by the Sun and measured in $W.m^{-2}$, the surface being placed at 1AU of the Sun and perpendicularly to the light rays. The value of the solar constant is equal to $1360 W.m^{-2}$.

Solar type star: Star of G type, similar to the Sun.

Solidus: Line which, in composition vs. temperature or pressure vs. temperature diagrams, separates the domain where crystals and liquid coexist from the field where only crystals (solid) exists.

Spallation: Atomic nuclei breaking due to the collision between two atomic nuclei with energy greater than columbic barrier; it leads to the formation of new elements, stable or radioactive.

Speckle interferometry: Acquisition and statistical treatment of images technique that consists of the recovery of part of the information included in astrophysical images and lost because of the atmosphere imperfect transmission. This technique, developed during

the 80ies is not much used any longer and replaced by adaptive optics techniques that allow a real time partial correction of atmospheric turbulence effects.

Spectral type: Star classification procedure based on electromagnetic spectrum which, itself, depends on star surface temperature. The OBAFGKM classification ranges from surface temperature of about 50000 K (O type) until 3500 K (M type = Sun).

Spinel: Mineral. Oxide $[MgAl_2O_4]$. Stable at low pressure (depth < 70 km). In the mantle, at shallow depth, spinel is the only aluminium-bearing phase.

Spore (biology): a) Resistant, dormant, encapsulated body formed by certain bacteria in response to adverse environmental conditions. b) Small, usually single-cell body, highly resistant to desiccation and heat and able to develop into a new organism.

s-process (slow): Nucleosynthetic mechanism that takes place over long periods of time in environments with moderated neutron flux (i.e. Red giant). This mechanism leads to the synthesis of atoms with atomic number > 26 (Iron) that are located in the nuclear stability valley.

Star: Celestial object, generally spherical, where thermonuclear reactions take place (e.g. the Sun) or will take place in the future (e.g. the PMS stars) or has taken place in the past (neutron star)

Stellar cluster: Group of few hundreds to several millions of stars. The smallest groups are named associations. Most of the stars are formed in open clusters.

Stereoisomers (or stereoisomers): Isomers (molecules with identical atomic composition, i.e. the same number of the same atoms) such that the atoms are identically interconnected by covalent

bonds. If two stereoisomers are different in the same way that a left hand is different from a right hand, the stereoisomers are enantiomers. In all other cases, stereoisomers are called diastereoisomers (or diastereomers).

Stereoselectivity: When a chemical reaction leads to the formation of stereoisomers and when these latter are not exactly produced in the same amount, the reaction is called stereoselective. Similarly, when two stereoisomers react at a different rate with a reactant, the reaction is stereoselective. In the chemical literature, some authors have introduced subtle differences between stereoselectivity and stereospecificity.

Steric effect: One of the multiple « effects » introduced by organic chemists to explain the relative stability or the relative reactivity inside a group of molecules. The steric effect takes into account the size of each atom or groups of atoms. For instance, the steric effect of a $-\text{C}(\text{CH}_3)_3$ group is larger than the steric effect of a CH_3 group. The steric effect can be explained on the basis of repulsive term in the Van der Waals forces.

Stony meteorites: Mainly made up of silicates, they can contain from 0 to 30 % of metal grains and several percents of sulphides. They can be differentiated (achondrite) or undifferentiated (chondrite) even if CI undifferentiated chondrites do not contain chondrules.

Stop codon (*Genetic*): Codon that does not code for amino acids but that indicates the translation end. For the Universal code, these codons are UAA, UAG and UGA (synonym: termination codons).

Stratopause: Atmospheric boundary between stratosphere and mesosphere.

Stratosphere: Atmospheric layer located above the troposphere and below the mesosphere, between 9–17 km and 50 km. In stratosphere, temperature slightly increases with altitude which prevents it of convective movements.

Strecker (*synthesis*): Synthetic method producing amino acids from aldehyde, HCN, NH_3 and water. Frequently considered as important prebiotic reaction.

Stromatolite: Sedimentary structure consisting of laminated carbonate or silicate rocks and formed by the trapping, binding, or precipitating of sediment by colonies of microorganisms (bacteria and cyanobacteria).

Strong force: One of the four fundamental forces in physics which contribute to the stability of the atomic nucleus.

Subduction: Plate tectonic mechanism, where an oceanic plate sinks under an other lithospheric plate (generally a continental plate, but sometimes also an oceanic plate).

Sublimation: Direct phase change from solid to gas state.

Succinic acid: $\text{HOOC-CH}_2\text{-CH}_2\text{-COOH}$.

Suevite: Rock associated with impact craters (=impactite). Defined in the Ries crater (Bavaria), this brecciated rock containing melt material (glass) consists of fragments of local impacted lithologies and basement rocks, mixed in a fine-grained clastic matrix.

Sun: Star belonging to the main sequence (in H-R diagram); it is 4.56 Ga old. Sun-Earth distance corresponds to 8 light-minutes or 1 astronomic unit (1 AU).

Supernova: Exploding star which, before explosion, was either a binary

star (type I) or a massive star (type II). After explosion, the remnant becomes a neutron star.

Surface plasmon resonance (SPR): A biosensor system used for analyzing ligand binding and kinetics of specific molecules within complex mixtures without prior purification. Binding of a ligand to a biomolecule immobilized on a membrane (metallic film) results in changes in membrane surface plasmon resonance.

Symbiosis: Prolonged association between two (or more) organisms that may benefit each other. In the case of endosymbiosis, one organism lives into another one; their relationship is irreversible and implies a complete interdependence such as the two become a single functional organism. Mitochondria and chloroplasts are remnants of the endosymbiosis of photosynthetic bacteria.

Synchrotron radiation: Electromagnetic waves covering a large frequency domain and emitted under vacuum by high velocity electrons or ions, when their trajectory is altered, as by a magnetic field. Synchrotron radiation is naturally polarized.

Synonymous (codons): Different codons that specify the same amino acid; e.g. AAA and AAG specify lysine.

T

T Tauri star: New-born low mass star (lower than two solar masses) which starts to become optically observable. Classical T-Tauri are very young (less than 1 Ma old) and are not yet on the main sequence (PMS stars). They are surrounded by a disk, their luminosity is variable with an excess of IR with

respect to UV. T-Tauri stars we observe today are probably similar to the young Sun.

Talc: Mineral. Phyllosilicate (water-bearing sheet silicate) $[Mg_3(Si_4O_{10})(OH)_2]$. Talc frequently results of hydrous alteration of magnesian minerals (i.e. olivine).

Taxonomy: Science that classifies living species. Similar species belong to the same taxon.

Tectonic: Science of rock and crustal deformation.

Tektites: Natural glasses formed at very high temperature ($>2000^\circ\text{C}$) by meteoritic impacts.

Telluric planets: Small and dense rocky planets (density: 3 to 5.5 g cm^{-3}). These planets (namely Mercury, Venus, Earth and Mars) are silicate rich and were formed in the inner part of the proto-solar nebula, beyond the dust line.

Terraforming: Voluntary transformation of a planetary atmosphere in order to allow colonization by plants and animals (including man).

Tertiary structure (of a protein): Arrangement of the side chains of the residues in space, overall conformation of a protein.

Theia: Name given by some authors to Mars-sized object, which, after impacting the young Earth, led to the Moon formation. This cataclysmic event took place 4.5 to 4.45 years ago.

Thermolysis: Thermal degradation of a molecule into smaller fragments (atoms, radicals, molecules and, rarely, ions).

Thermonatrite: Mineral. Water bearing sodium carbonate $[Na_2CO_3 \cdot H_2O]$. This mineral is water-soluble and primarily forms in evaporite deposits and in desert soils where it may occur as a surface deposit, or in volcanic fumaroles

Thermonuclear reaction: Reaction leading to formation of heavier nuclei by fusion of lighter nuclei. Thermonuclear reactions require high T and high P conditions. In natural conditions, these reactions occur spontaneously in cores of main sequence stars or of heavier stars like giant stars. It occurs also during supernovae explosions.

Thermopause: Atmospheric boundary between thermosphere and exosphere.

Thermophile: Organism living optimally at high temperatures. They can be divided in “moderate thermophiles”, living optimally between 40 and 60°C, extreme thermophiles, between 60 and 80°C, and hyperthermophiles, living optimally at temperatures higher than 80°C (and up to ~120°C).

Thermosphere: Atmospheric layer located above the mesosphere and below the exosphere. At the top of the thermosphere, at an altitude of about 700 km (on Earth) the temperature can be > 1300 K.

Thin section (geology): Rock slice generally 30 μm -thick. At such a thickness most minerals are transparent and can be observed by transmitted light with a polarizing microscope.

Thiocyanate: R-S-CN.

Thioester: R-S-CO-R’.

Thioester: R-S-CO-R’.

Thiol: R-SH.

Tholeiite: Relatively silica-rich and alkali-poor basalt.

Tholins: Solid mixture of complex organic molecules obtained by irradiation of reduced gases like CH₄, NH₃. Could be present on Titan.

Threonine (Thr): Proteinic amino acid containing four C atoms and a –OH group in its side chain. Threonine is

described as a hydrophilic amino acid.

Thymine (T): Nucleic base belonging to purine and specific of DNA.

Titan: The biggest satellite of Saturn (~5000 km in diameter; which is approximately the same size as Mercury). In the solar system, this is the only satellite which possesses a dense atmosphere. Very probably, organic reactions could have taken place in its multi-components hydrocarbon-bearing atmosphere.

Titus-Bode law: Empirical law giving approximately the planet-Sun distance d as a function of the planet ranking n ($d = (4 + 3.2^{(n-2)})/10$). Mercury is an exception to this law ($d = 0.4$ AU).

Tonalite: Plutonic magmatic rock (granitoid), made up of quartz and calcic plagioclase feldspar; biotite and sometimes amphibole are minor mineral phases. Tonalite does not contain alkali feldspar. Dacite is its effusive equivalent.

TPF (Terrestrial Planet Finder): NASA project with a similar goal as the ESA Darwin project i.e. discovery of extrasolar terrestrial planets.

Transcription: Synthesis of an m-RNA as a copy of an anti-sense DNA single strand.

Transduction: Transfer of genetic material from one bacteria to another through viral infection.

Transfer of genes (horizontal transfer): Transfer of a gene from one organism to another which does not belong to the same species. Such transfer can occur through viral infection or by direct inclusion of genetic material present in the external medium. Horizontal transfer is different from vertical transfer from parents to children.

Transferase: Enzyme that catalyses transfer of a chemical group from one substrate to another.

Transform fault: Boundary between two lithospheric plates which slide without any crust creation or destruction.

Transit: Motion of a planet in front of the disk of its star.

Translation: Sequence enzymatic reactions such that the genetic information coded into a messenger RNA (m-RNA) leads to the synthesis of a specific protein.

Trans-neptunian object: (TNO) Solar-system body located beyond the orbit of Neptune, in the Kuiper belt or beyond.

Triangular diagram: Diagram classically used in geology to plot the chemical or mineralogical composition of a sample. Each apex of the triangle represents 100% of one component whereas the opposite side corresponds to 0% of the same component.

Triple point: In a P-T phase diagram of a pure compound, it corresponds to the unique P, T value where the three phases (gas, liquid, solid) coexist at equilibrium. For water, $P = 6.11$ mbar and $T = 273.16$ K.

t-RNA synthetase: Enzyme which catalyzes, in a very specific way, bond formation between an amino acid and its t-RNA.

t-RNA: Transfer RNA.

t-RNA: Transfer RNA. Polymer containing 70 to 80 ribonucleotides and specific of each amino acid to which it is linked. Able to recognize a triplet of nucleotides of m-RNA (codon) by a specific molecular recognition process involving a triplet of nucleotides of the t-RNA (anti-codon). The t-RNA's play a fundamental role for proteinic synthesis.

Trojans: Family of asteroids located at the Lagrange point on the Jupiter orbit. Their position together with the Sun and Jupiter positions determines an equilateral triangle.

Trondhjemite: Plutonic magmatic rock (granitoid), made up of quartz and sodic plagioclase feldspar; biotite is a minor mineral phase. Tonalite and trondhjemite are similar rocks except that in tonalite plagioclase is calcic whereas it is sodic in trondhjemite.

Tropopause: Atmospheric boundary between troposphere and stratosphere.

Troposphere: Lowest part of Earth atmosphere, as the temperature at its basis is greater than at its top, it is the place of active convection. On Earth, troposphere thickness ranges between 9 km (pole) and 17 km (equator). Most meteorological phenomena take place in troposphere.

Tryptophane (*Trp*): Proteinic amino acid containing eleven C atoms; tryptophane contains a heterocycle in its side chain. It is described as an aromatic amino acid.

TTG: Tonalite, Trondhjemite, Granodiorite. Rock association typical of the continental crust generated during the first half of Earth history.

Tunguska event: Explosion which took place in 1908 (June 30th) in Siberia and devastated 2000 km² of forest. It was probably due to the explosion in the atmosphere of small (< 50 m) asteroid or comet.

Tunnel effect: Description of tunnel effect requires the use of quantum mechanics because it is a direct consequence of the wave properties of particles. When a system A gives another system B while the internal energy of A is lower than the energy barrier (activation energy) required to cross the barrier from A to B, it can be said that

A gives B by passing « through the barrier » by a tunnel effect.

Turbidite: Sedimentary deposit deposited by a turbidity current according to a characteristic fining upward grain size sequence in deep water at the base of the slope and in the abyssal plain.

Turbidity current: Also called density current. Viscous mass of mixed water and sediment that propagate downward along the continental slope (of an ocean or a lake) due to its greater density. It may reach high speeds and has a high erosive power. Such currents are set in motion by earthquakes for example.

Turbulence (parameter) (*Astronomy*): In hydrodynamics, the « α model empirically describes the turbulent viscosity of a flow. It is based on a parameter α : $v_t = \frac{\alpha C_s^2}{\Omega}$ with C_s = local sound speed and Ω , the keplerian rotational frequency.

Tyrosine (*Tyr*): Proteinic amino acid containing nine C atoms. Its side chain contains a phenolic group.

U

Upwelling: Upward movement of cool and nutrient-rich sub-surface seawaters towards the surface. Upwelling is mainly controlled by local atmosphere dynamics (pressure, wind), frontal contact between water masses with different densities (oceanographic fronts) or by Eckman transport.

Uracil (*U*): Nucleic base belonging to pyrimidine family and specific of RNAs

Urea ($H_2N-CO-NH_2$): First organic molecule that has been synthesised from a mixture of inorganic molecules (Wohler).

UV radiation: Electromagnetic radiation characterized by wavelengths

ranging from 0.01 to 0.4 microns (energies from 124 to 3.1 eV).

V

Valine (*Val*): Hydrophobic proteinic amino acid containing five carbon atoms.

Van der Waals forces (*V.d.W.*): Interatomic forces acting between non-bonded atoms at the intramolecular level but also at the intermolecular levels. Repulsive V.d.W. forces are responsible for the no-infinite compressibility of matter and for the fact that atoms have sizes. Attractive V.d.W. forces are responsible for matter cohesion. V.d.W. forces play a major role in biochemistry: together with H-bonds and electrostatic interactions, they determine the preferred conformations of molecules and they contribute to molecular recognition phenomena.

Vernal point: Sun location on the celestial sphere at the vernal equinox (spring equinox). It is the origin of coordinates in the equatorial system.

Vertical tectonic: See sagduction

Vesicle (*geology*): Bubble-shaped cavities in volcanic rocks formed by expansion of gas dissolved in the magma.

Vesicle: Small sac, made of hydrophobic or amphiphile molecules, whose content is isolated from the surrounding environment.

Viking: NASA mission to Mars which started in 1976. The two landers (Chryse Planitia and Utopia Planitia) performed a series of very ambitious experiments to detect the presence of life on Mars. Unfortunately, many results were ambiguous.

Virus: System containing DNA or RNA surrounded by a proteinic enve-

lope (capside). When introduced in a living cell, a virus is able to replicate its genetic material by using the host cell machinery.

VLBI (*Very Long Baseline Interferometry*): Technique that allows a very accurate determination (50 microarc-sec) of the position of astronomical sources of radiowaves. This method is based on interferometry measurements using very distant radiotelescopes (large base) located on the same continent or on different continents or even on Earth and on a satellite.

VLT (*Very Large Telescope*): Group of four large telescopes (4 to 8 metres) and several smaller telescopes, able to work as interferometers and located in Chile. VLT is managed by ESO.

Volatile (volatile substance): Molecule or atom that sublimates at relatively low temperature (i.e. cometary ices).

Volatile: see refractory.

Volcanoclastic sediment: Sediment due to sedimentation in the sea or in a lake of volcanic products (i.e. ashes).

W

Wadsleyite: Mineral. Nesosilicate (isolated SiO_4 tetrahedrons). $[(\text{Mg},\text{Fe})_2\text{SiO}_4]$. Also called olivine β phase. In Earth mantle, wadsleyite is stable between 410 and 520 km.

Wall (of a cell): Extracellular membrane. In bacteria, cell wall structure is complex: the walls of gram-positive and gram-negative bacteria are different.

Water triple point: See triple point.

Watson-Crick: Canonical model of DNA (double helix) involving the pairing of two polynucleotide strands via H-bonds between A and T or G and C.

RNA is generally single-stranded but within a single strand Watson-Crick pairing can occur locally. When happens, it involves A—U and G—C pairing.

Weak bonds: Intermolecular or intramolecular bonds involving non-bonded atoms (atoms not bonded by covalent, coordination or electrostatic bonds). H-bonds are well known examples of weak bonds but Van der Waals forces and electrostatic interactions also contribute to weak bonds. The weak bonds play a fundamental role in the living world: they determine the conformation of molecules and more particularly the conformation(s) of biopolymers; they are responsible for the specificity of molecular recognition. The intermolecular association due to weak bonds is generally reversible

Weak force: One of the four fundamental forces of physics. Parity is violated for these forces. The coupling between weak forces and electromagnetic forces is at the origin of the very small energy difference between enantiomers (PVED for Parity Violation Energy Difference).

Weathering: See alteration.

White dwarf: Relict of a dead star with an initial mass $< \sim 8M_{\text{Sun}}$. Its gravity collapse is limited by electron degeneracy pressure.

Wind (*solar or stellar*): Flow of ionized matter ejected at high velocity (around 400 km/s) by a star. Solar wind mainly contains protons).

Wobble (*genetics*): Describes imprecision in base pairing between codons and anti-codons. It always involves position 3 of codon, mainly when the base is U.

X

Xenolith: Inclusion or enclave of foreign rock or mineral (xenocrystal), in a magmatic rock.

Y

Young sun paradox: Apparent contradiction between the lower brightness of the young Sun, (70% of the present-day intensity in the visible spectral range) and the early presence of liquid water (–4.4 Ga) on Earth. A strong greenhouse effect due to high concentrations of atmospheric CO₂ could account for this apparent paradox.

YSO (*Young Stellar Object*): Star which has not yet completed the process of star formation. YSO includes objects ranging from dense cores, (that can be detected in the submillimetric IR frequency range) to pre-main sequence stars (T Tauri, Herbig AeBe) and HII regions.

YSO: Young Stellar Object.

Z

Z (*astronomy*): Abundance of « heavy elements » i.e. all elements except H and He.

ZAMS (*Zero Age Main Sequence*): Ensemble of new-born stars in which H fusion has just started.

Zircon: Mineral. Nesosilicate (isolated SiO₄ tetrahedrons). [ZrSiO₄]. This mineral which also contains traces of Th and U is extremely resistant to weathering and alteration. These are the reason why it is commonly used to determine rock ages. The oldest zircon crystals so far dated gave an age of 4.4 Ga. They represent the oldest known terrestrial material.

Zodiacal light: Diffuse faint light observed in a clear sky close to the ecliptic. It is due to the diffusion of the solar radiation by the electrons and the interplanetary dusts. Also used for any light diffused by dust particles in a planetary system.