ASTROBIOLOGY
SISSA Lectures 2021
Giovanni Vladilo

1 – Introduction.
The multi-disciplinary science of astrobiology. The problem of life definition. The cell as the minimum structural unit of life.

2 - Physical properties and chemical ingredients of life.
Physics and life: thermodynamical properties. The atomic ingredients of terrestrial life: chemical elements and chemical bonds.

3 – Water and carbon in terrestrial life.
Unique properties of water and carbon and their relevance for life. Carbon-based biological macromolecules.

4 - Metabolic and genetic macromolecules.
Amino acids and proteins. Homochirality. Nucleo-bases and nucleic acids. Information coding and genetic code.

5 – Life in a cosmic context.
Common aspects of terrestrial life at the molecular level. Hypothetical, non-terrestrial biochemistries. Hydrogen bonds and life: constraints on viable biochemistries.

6 – Extremophiles: physico-chemical limits of life.
Extremophilic organisms and their importance in astrobiology. Physical and chemical limits of terrestrial life.

7 – Habitability.
Definition of planetary habitability. Impact of astronomical and geophysical factors on planetary habitability. Temperature and life molecular processes. Hydrogen bonds and life: constraints on habitability conditions.

8 – Planetary climate and circumstellar habitable zones.
Climate and habitability. Climate feedbacks and instabilities. The circumstellar habitable zone. Impact of astronomical and planetary factors on the location and extent of the habitable zone.

9 - Prebiotic chemistry.
The bottom-up approach in studies of the origin of life. Prebiotic chemistry in space and in protoplanetary disks. Delivery of organic material and water on planetary bodies. Experimental and theoretical studies of prebiotic chemistry.

10 – From molecular replicators to protocells.
Origin of metabolic and genetic macromolecules. The RNA world. The top-down approach in studies of the origin of life. Philogenetic trees and the last common ancestor.

11 - The terrestrial context for the origin of life

Time scales for the emergence of terrestrial life. Oldest traces of life on Earth. Atmosphere and climate of the primitive Earth. Delivery of water on the primitive Earth.

12 - Life evolution
Main stages of the evolution of terrestrial life. Evolution as a universal mechanism: chance and necessity. Lesson for the distribution of different types of life in the Universe.

13 - The inner Solar System
The case of Venus: evidence for a runaway greenhouse instability. The case of Mars: evidence for water at the present time and in the past; search for biosignatures. Planetary protection in Solar System missions.

14 - The outer Solar System
The case of Europa and Enceladus; analogies with terrestrial hydrothermal vents. The case of Titan; a laboratory for hypothetical biochemistries based on methane.

15 - Exoplanets: detection and characterization
Observational techniques and statistical results of exoplanet surveys. Characterization of extrasolar planets; spectra of exoplanet atmospheres.

16 - Exoplanets: habitability and biosignatures
Exoplanets in habitable zones. Habitability around M-type stars. Search for atmospheric biosignatures in exoplanet atmospheres. Appendix: the Galactic habitable zone.