

## **PHY-468 Astrobiology**

**Credit Hours:** 3-0

**Prerequisite:** None

**Course Objective:**

Astrobiology is a multidisciplinary field that studies the origin, evolution, distribution, and future of life in the Universe. Students will grasp the areas that fall inside its bounds. These topics include the formation of planets and stars, the development of habitable conditions on planets, the genesis of life, the evolution of life, life's limits in harsh environments, and the possibility of life on other planets. The course provides a framework for presenting a variety of topics in astronomy, physics, earth sciences, chemistry, and biology at the beginning level. Lectures discuss the structure of life, the genesis of life, past and contemporary conditions on Mars and frozen worlds such as Europa, the search for extrasolar planets, and the prospect of discovering life signals.

**Course Contents:**

Basic Properties of Matter: Behaviour of gases, liquids and solids; Properties and relationships of life: Biological molecules, cells, Energy acquisition by life; The tree of life (phylogenetics); Planets and star formation: Exoplanets; Planet and star formation; Solar System dynamics; Detection of extrasolar planets, methods to find them and detect biosignatures; Origin of life: Conditions during the first billion years of Earth history (Hadean); Hypotheses for the origin of life; Life in Extremes: Thermodynamics of life in extremes; Biophysical adaptations to extreme; Physical properties of extreme environments; History of Earth and Life and their co-evolution: Major geological periods in Earth history; Radiometric and relative age dating of rocks (e.g. isochron method); Isotopic and other methods to find preserved life; The reasons for the rise of oxygen; Mechanisms and significance of mass extinctions; Habitability of planets: The habitable zone and conditions for liquid water; Carbonate-silicate cycle and other factors that control habitability; Conditions, past and present, on Mars and icy moons of the Solar System; Methods to search for life beyond Earth; Possibility of intelligence elsewhere.

**Detailed Course Contents:**

Astrobiology and life, what is astrobiology?, history of astrobiology, what is life?, matter and life, we are made up of "ordinary matter", summarizing the basic biology

and chemistry needed, Microbial Mats – Energy-driven Zonation in Life, The Thermodynamics of Energy and Life, life in extremes, a vast diversity of life, the tree of life, classifying organisms Homology and analogy, Building a Phylogenetic Tree, Complications in Building the Universal Tree of Life, The Last Universal Common Ancestor, molecular clocks, alien life, The biospace, the importance of biospace for astrobiology, the edges of biospace and the domination of microbes, life at high temperature, life at low temperature, salt loving organisms, pH extremes, life under high pressure, tolerance to high radiation, life in toxic brews, life on the rocks, Polyextremophiles – dealing with Multiple Extremes, Life underground, Dormancy in Extreme Conditions, Eukaryotic Extremophiles, are there other biospaces, the limits of life: Habitability revisited

The formation and evolution of stars, The Formation of the Elements of Life, astrochemistry: the molecules of life, different environments in space, how are compounds formed?, Interstellar grains, forming carbon atoms, Polycyclic Aromatic Hydrocarbons, Even More Carbon Diversity, laboratory experiments and observing the molecules, The astrobiology of Earth, early earth and its evolution, Early Thoughts on the Origin of Life: Spontaneous Generation, Some Possible Ideas for the Origin of Life, The Synthesis of Organic Compounds on the Earth, The habitability of planets, habitable zones, Surface Liquid Water, Habitability and Intelligence, Worlds More Habitable than the Earth?, the fate of Earth

Mars and astrobiology, Martian history, The Deterioration of Mars, missions to mars, mars and life, Trajectories of Martian Habitability, The Viking Programme and the Search for Life, Martian Meteorites, Mars Analogue Environments, Panspermia – Transfer of Life Between Planets? The Moons of Jupiter: Europa, The Moons of Jupiter: Ganymede and Callisto, The Moons of Jupiter: Io, The Moons of Saturn: Enceladus, The Moons of Saturn: Titan, Other Icy Worlds, Exoplanets and Life, detecting exoplanets, astrometry, exoplanet properties, using direct detections to study protoplanetary discs, detecting life.

### **Learning Outcomes:**

On completion of this course, the student will be able to:

- Demonstrate an understanding of basic properties of matter and life.

- Demonstrate a basic understanding of planet and star formation and the conditions that give rise to exoplanets and habitable conditions.
- Understand some of the hypotheses about the origin of life and evidence for early life in the rock record.
- Identify the evolutionary transitions in the history of life on Earth, including the rise of oxygen and mass extinctions, and assess the reasons for their occurrence.
- Evaluate scientific evidence using the discussions about life beyond Earth as a means to understand scientific hypotheses, critical thinking and the rigour of the scientific method.

#### Text Book:

- Astrobiology: Understanding Life in the Universe by Charles Cockell published by Wiley/Blackwell in 2015.

Weekly Breakdown		
<i>Week</i>	<i>Section</i>	<i>Topics</i>
<b>1</b>	CC 1.2 – 2.5	Astrobiology and life, what is astrobiology?, history of astrobiology, what is life?, matter and life, we are made up of “ordinary matter”, summarizing the basic biology and chemistry needed
<b>2</b>	CC 5.13 – 6.4	Microbial Mats – Energy-driven Zonation in Life, The Thermodynamics of Energy and Life, life in extremes, a vast diversity of life, the tree of life, classifying organisms
<b>3</b>	CC 6.5 – 6.13	Homology and analogy, Building a Phylogenetic Tree, Complications in Building the Universal Tree of Life, The Last Universal Common Ancestor, molecular clocks, alien life
<b>4</b>	CC 7.1 – 7.6	The biospace, the importance of biospace for astrobiology, the edges of biospace and the domination of microbes, life at high temperature, life at low temperature, salt loving organisms

<b>5</b>	CC 7.7 – 7.12	pH extremes, life under high pressure, tolerance to high radiation, life in toxic brews, life on the rocks, Polyextremophiles – dealing with Multiple Extremes
<b>6</b>	CC 7.13 – 7.17	Life underground, Dormancy in Extreme Conditions, Eukaryotic Extremophiles, are there other biospaces, the limits of life: Habitability revisited
<b>7</b>	CC Chapter 8 (summarized) – 9.4	The formation and evolution of stars, The Formation of the Elements of Life, astrochemistry: the molecules of life, different environments in space, how are compounds formed?
<b>8</b>	CC 9.5 – 9.13	Interstellar grains, forming carbon atoms, Polycyclic Aromatic Hydrocarbons, Even More Carbon Diversity, laboratory experiments and observing the molecules
<b>Mid Term Exams</b>		
<b>9</b>	CC 10.1 – 10.9	The astrobiology of Earth, early earth and its evolution, Early Thoughts on the Origin of Life: Spontaneous Generation, Some Possible Ideas for the Origin of Life, The Synthesis of Organic Compounds on the Earth
<b>10</b>	CC 16.1 – 16.10	The habitability of planets, habitable zones, Surface Liquid Water, Habitability and Intelligence, Worlds More Habitable than the Earth?, the fate of Earth
<b>11</b>	CC 17.1 – 17.6	Mars and astrobiology, Martian history, The Deterioration of Mars, missions to mars, mars and life, Trajectories of Martian Habitability
<b>12</b>	CC 17.7 – 18.2	The Viking Programme and the Search for Life, Martian Meteorites, Mars Analogue Environments, Panspermia – Transfer of Life Between Planets? The Moons of Jupiter: Europa

<b>13</b>	CC 18.3 – 18.8	The Moons of Jupiter: Ganymede and Callisto, The Moons of Jupiter: Io, The Moons of Saturn: Enceladus, The Moons of Saturn: Titan, Other Icy Worlds
<b>14</b>	CC 19.1 – 19.12	Exoplanets and Life, detecting exoplanets, astrometry, exoplanet properties, using direct detections to study protoplanetary discs, detecting life, The Search for Extraterrestrial Intelligence
<b>15</b>		Revisions