How did life originate?
Until surprisingly recently - common theory was that of spontaneous generation... life arises from non-living matter whenever conditions are favorable. Disproved by experiments by Pasteur (1864): life does not arise spontaneously in closed, sterilized containers.

Is there life elsewhere in the Universe?
Habitability of Mars was discussed in late 19th century: Martian canals - proven not to exist in 1965 with first flybys of Mars

Overview
How can we define “life”?
“The quality which people, animals and plants have when they are not dead...” (Collins English dictionary)
“Dead: A person, animal or plant that is dead is no longer living...”

NASA Exobiology program definition:
“Life is a self-sustaining chemical system capable of undergoing Darwinian evolution”

What is extraterrestrial life?
Life (extant or fossil) beyond the Earth
In the case of Mars / Earth, extraterrestrial life could (in principle) have single point of origin
Discovering life that had an independent origin would be most exciting
Extraterrestrial life may or may not resemble life on Earth, certainly need not be intelligent
Properties of life on Earth
As sole example, life on Earth is template for understanding
- requires water, energy and source of nutrients
- working definition of "habitability"
- probably arose very early in Earth's history (3 - 3.8 billion years ago vs Earth age of 4.6 billion yr)
- has evolved via natural selection
- now appears very diverse (plants, microbes, humans) and permeates almost all terrestrial environments

But... all life on Earth is amazingly similar:
- based on same set of chemicals: DNA, RNA, proteins...
- transmits genetic information
- occurs within structures - cells

All existing life on Earth had a common ancestor
+ viruses, prions...

Problem of the origin of life
Hypothesis: origin of life must have involved "living" organisms with a simpler biochemistry than any present (identified?) on Earth today
What were they?

Extraterrestrial life in the Solar System
Mars: liquid water likely to have been present for an undetermined period in Martian history, and possibly is present today
Extraterrestrial life in the Solar System

Jupiter’s moon Europa may possess a subsurface ocean.

Plumes of water ice from Enceladus, possibly indicating liquid subsurface water? Liquid water is unlikely to exist on any other bodies in the Solar System.

Life on extrasolar planets?

Sun is one of ~100 billion \((10^{11})\) stars in the Milky Way galaxy.

Around \(10^{11}\) galaxies in the Universe - enormous number of stars that might host habitable worlds.

Surveys of nearby stars show 5-10% host detectable planets - mostly massive planets due to observational limitations.

Abundance of Earth-like, potentially habitable planets is unknown - probably these are very common too.

• How can we detect these planets?
• How to search for life on them?

Is intelligent extraterrestrial life common?

Fermi paradox:

• Sun is 4.6 billion years old - much younger than many other stars in the Milky Way (~10 billion years old)
• After ~few thousand years of modern civilization, we can communicate with other stars, and can conceive of sending a probe to nearby systems
• If intelligent life is common, many civilizations must be millions (billions!) of years more advanced than us, so why aren’t they here already?