

Course Syllabus

Time: Human Views on the Progress of Existence

Language of Instruction: English

Professor: Jordi Garcia-Ojalvo

Professor's Contact and Office Hours: jordi.g.ojalvo@upf.edu, from 9h to 17h

Course Contact Hours: 15 hours

Recommended Credit: 2 ECTS credits

Weeks: 1

Course Prerequisites: There are no prerequisites for the course.

Language Requirements: None

Course Description

The concept of time is deeply ingrained within the human mind. We experience the passage of time innately, and feel a natural difference between the past, the present, and the future. Yet, some of the descriptions of the universe that science offers us provide no reasons for which the past and the future should be different, and in some others the need for the concept of time itself is not at all evident. This course aims to present an overview of how time is understood by different sciences, in particular physics and biology, and how it relates to the way in which we humans experience the progress of existence. We will discuss concepts such as the arrow of time, the multiverse, embryonic development, and aging. The discussions will also refer to the view of time from the perspective of the arts, including literature, painting, and music. Finally, we will explore how we humans measure time, both with artificial devices that we have built over the last centuries, and with our own genes.

Learning Objectives

- To gain a basic knowledge of the different ways in which science understands the concept of time.
- To relate the concepts of time provided by physics and biology.
- To become familiar with a variety of artistic works that deal with time in non-standard ways, and to relate these views with recent scientific advances.
- To understand the different ways in which we measure time, including our innate ability to establish the time of day through our circadian clock.

Course Workload

During the course, students will be required to read papers, essays, or book fragments, and to work on a term paper addressing one or more of the topics discussed in class. The students' work will be presented at the end of the course.

Methods of Instruction

The course will consist of lectures, discussions sessions, and student presentations. All course materials, including slides, handouts and readings will be made available either in advance or right after class.

Method of Assessment

Participation in lectures and debates: 30%

Term paper / essay: 40%

Final Exam: 30%

Absence Policy

Attending class is mandatory and will be monitored daily by professors. The impact of absences on the final grade is as follows:

Absences	Penalization
Up to one (1) absence	2 points subtracted from final grade (on a 10-point scale)
Two (2) absences	The student receives an INCOMPLETE for the course

The BISS attendance policy does not distinguish between justified or unjustified absences. The student is deemed responsible to manage his/her absences.

Emergency situations (hospitalization, family emergency, etc.) will be analyzed on a case-by-case basis by the Academic Director of the UPF Summer School.

Classroom Norms

- No food or drink is permitted
- There will be a ten-minute break during the class
- Students must come to class fully prepared

Course Contents

1. From absolute to relative time
 - 1.1. From classical mechanics to special relativity
 - 1.2. Time as a fourth dimension: the space-time continuum
2. The arrow of time
 - 2.1. From microscopic reversibility to macroscopic irreversibility
 - 2.2. Entropy and the second law of thermodynamics
 - 2.3. Cosmological time: from the big bang to the heat death of the universe
3. The garden of forking paths
 - 3.1. Fermat's principle and light refraction
 - 3.2. Feynman's quantum paths: The principle of least action
 - 3.3. The many-worlds interpretation of quantum mechanics
4. Geological and evolutionary time
 - 4.1. The timeline of earth
 - 4.2. The timeline of life on earth
 - 4.3. The molecular clock
5. Organism time
 - 5.1. Developmental time
 - 5.2. Aging of cells
 - 5.3. Aging of organisms
6. Measuring time
 - 6.1. Human-made clocks through history
 - 6.2. Biological timekeeping: circadian clocks and other genetic oscillators
 - 6.3. Synthetic biological clocks

Required Readings

The professor will indicate mandatory readings during the course.

Recommended bibliography

Borges, Jorge Luis. "The garden of forking paths". *Collected fictions*. Penguin, 1962.

Carroll, Sean M. *From eternity to here: the quest for the ultimate theory of time*. Penguin, 2010.

Feynman, Richard Phillips, Robert B. Leighton, and Matthew Sands. *The Feynman lectures on physics*, vol. 2, chap. 19. Addison-Wesley, 1979.

Glass, Leon, and Michael C. Mackey. *From clocks to chaos: the rhythms of life*. Princeton University Press, 1988.

Halpern, Paul. *The quantum labyrinth: how Richard Feynman and John Wheeler revolutionized time and reality*. Hachette, 2017.

Kreitzman, Leon, and Russell Foster. *The rhythms of life: The biological clocks that control the daily lives of every living thing*. Profile books, 2011.

Kumar, Sudhir. "Molecular clocks: four decades of evolution." *Nature Reviews Genetics* vol. 6, no. 8: 654, 2005.

Marrison, Warren A. "The evolution of the quartz crystal clock." *Bell System Technical Journal* 27, no. 3: 510-588, 1948.

Palmer, John D. *The living clock: The orchestrator of biological rhythms*. Oxford University Press, 2002.

Rovelli, Carlo. *The order of time*. Penguin, 2018.

Fitzgerald, F. Scott. *The curious case of Benjamin Button*. Colliers, 1922.

Sobel, Dava. *Longitude: The true story of a lone genius who solved the greatest scientific problem of his time*. Macmillan, 2005.

Winfree, Arthur T. *The geometry of biological time*. Springer, 2001.