Capra Course

Summary of Lecture 4:

The Systems View of Evolution

(with references to the corresponding sections in the textbook *The Systems View of Life* by Capra and Luisi)

One of the most rewarding features of the systems view of life is a new systemic understanding of evolution. Rather than seeing evolution as the result of only random mutations and natural selection, we are beginning to recognize the creative unfolding of life in forms of ever-increasing diversity and complexity as an inherent characteristic of all living systems. Although mutation and natural selection are still acknowledged as important aspects of biological evolution, the central focus is on creativity, on life's constant reaching out into novelty.

To begin with, the systems view recognizes that evolution did not begin with the first living cell but millions of years earlier with a process known as molecular, or "prebiotic" evolution. Our detailed ideas about this prebiotic evolution are still very speculative, but most biologists and biochemists do not doubt that the origin of life on Earth was the result of a sequence of chemical events, subject to the laws of physics and chemistry and to the nonlinear dynamics of complex systems. (*Section 10.3*)

The key idea is that very early on, *before* the increase of molecular complexity, certain molecules assembled into primitive membranes that spontaneously formed closed bubbles (as discussed in Lecture 3), and that the evolution of molecular complexity took place inside these bubbles, rather than in a structureless "chemical soup" (*Section 10.4*). My coauthor, Pier Luigi Luisi, is one of the world leaders in this research on the origin of life, and in our book he wrote a very detailed chapter about this fascinating new field of science (*Chapter 10*).

As far as biological evolution is concerned, the classical view maintains that all evolutionary variation results from random mutations, followed by natural selection. The systems view, by contrast, recognizes three avenues of evolution: random mutations of genes, horizontal genetic transfers among bacteria (also known as "gene

trading"), and finally the creation of new forms of life through acquisition of entire genomes in a process known as symbiogenesis. (*Section 9.3.5*)

All these processes are subject to the physical and chemical constraints of the organism's environment — in other words, to natural selection. When new genetic patterns are created, they need to be integrated into their cellular environment. This involves a complex dynamic of an entire network of chemical reactions, in which only a limited number of new forms and functions are possible. The entire process is far from random; it is complex and highly ordered. It is an integral part of life's self-organization. (*Section 9.10*)

The evolutionary unfolding of life over billions of years is a breathtaking story. Driven by the creativity inherent in all living systems, expressed through the avenues of mutation, gene trading, and symbiosis, and honed by natural selection, the planetary web of life expanded and complexified into forms of ever-increasing diversity.

In this majestic unfolding of life, the human species arrived on the planet very late. To demonstrate how late, I present an ingenious narrative, devised by the Californian environmentalist David Brower, in which the age of the Earth (4.5 billion years) is compressed into the six days of the biblical creation story (*Section 11.1*). In this time scale, all visible forms of life evolve on Saturday, the last day of creation. The modern human species, appears in Africa and Asia 11 seconds before midnight and in Europe 5 seconds before midnight. Written human history begins around two thirds of a second before midnight.

A special nexus in human evolution occurred about 4 million years ago with the emergence of the genus *Australopithecus*. At that time, rapid brain growth triggered the simultaneous evolution of language, reflective consciousness, the ability to make and use tools, and organized social relations. This means that our inner world of thought and language is tightly linked to technology and to social relations. They all evolved together at the dawn of the human species (*Section 11.2*).

The recent sensational discovery of magnificent and highly sophisticated paintings in the Chauvet cave in southern France, which are at least 30,000 years old, has forced archaeologists to radically revise their ideas about the evolution of cave art (*Section 11.2*).

The unexpectedly early date of those paintings means that high art was an integral part of the evolution of modern humans from the very beginning. In other

words, the emergence of the modern human species is the emergence of the story-teller and the artist. This means that a proper understanding of human evolution is impossible without understanding the evolution of language, art, and culture. In other words, we must turn our attention to mind and consciousness, the subject of the next lecture.