THE SCIENCE OF SELF-ORGANIZATION AND ADAPTIVITY

Francis Heylighen,

Center "Leo Apostel", Free University of Brussels, Belgium

Summary: The theory of self-organization and adaptivity has grown out of a variety of disciplines, including thermodynamics, cybernetics and computer modelling. The present article reviews its most important concepts and principles. It starts with an intuitive overview, illustrated by the examples of magnetization and Bénard convection, and concludes with the basics of mathematical modelling. Self-organization can be defined as the spontaneous creation of a globally coherent pattern out of local interactions. Because of its distributed character, this organization tends to be robust, resisting perturbations. The dynamics of a self-organizing system is typically non-linear, because of circular or feedback relations between the components. Positive feedback leads to an explosive growth, which ends when all components have been absorbed into the new configuration, leaving the system in a stable, negative feedback state. Non-linear systems have in general several stable states, and this number tends to increase (bifurcate) as an increasing input of energy pushes the system farther from its thermodynamic equilibrium. To adapt to a changing environment, the system needs a variety of stable states that is large enough to react to all perturbations but not so large as to make its evolution uncontrollably chaotic. The most adequate states are selected according to their fitness, either directly by the environment, or by subsystems that have adapted to the environment at an earlier stage. Formally, the basic mechanism underlying self-organization is the (often noise-driven) variation which explores different regions in the system's state space until it enters an attractor. This precludes further variation outside the attractor, and thus restricts the freedom of the system's components to behave independently. This is equivalent to the increase of coherence, or decrease of statistical entropy, that defines self-organization.

1. Introduction

Science, and physics in particular, has developed out of the Newtonian paradigm of mechanics. In this world view, every phenomenon we observe can be reduced to a collection of atoms or particles, whose movement is governed by the deterministic laws of nature. Everything that exists now has already existed in some different arrangement in the past, and will continue to exist so in the future. In such a philosophy, there seems to be no place for novelty or creativity.

Twentieth century science has slowly come to the conclusion that such a philosophy will never allow us to explain or model the complex world that surrounds us. Around the middle of the century, researchers from different backgrounds and disciplines started to study phenomena that seemed to be governed by inherent creativity, by the spontaneous appearance of novel structures or the autonomous adaptation to a changing environment. The different observations they made, and the concepts, methods and principles they developed, have slowly started to coalesce into a new approach, a science of self-organization and adaptation. The present article will first present a quick, intuitive overview of these