



## **Chapter IX**

# **Emergence in Agent-Based Computational Social Science: Conceptual, Formal, and Diagrammatic Analysis**

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## **Abstract**

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*This chapter provides a critical survey of emergence definitions both from a conceptual and formal standpoint. The notions of downward/backward causation and weak/strong emergence are specially discussed for application to complex social system with cognitive agents. Particular attention is devoted to the formal definitions introduced by Müller (2004) and Bonabeau*

*and Dessalles (1997), which are operative in multi-agent frameworks and make sense from both cognitive and social point of view. A diagrammatic 4-Quadrant approach allows us to understand complex phenomena along both interior/exterior and individual/collective dimensions.*

## Introduction

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The concept of “emergence,” first discussed in philosophy, is also widely used in complex adaptive systems literature especially in computer sciences (Holland, 1998) and related fields (multi-agent systems, artificial intelligence, artificial life...) as well as in physics, biology, and cognitive sciences. Particular applications are the social and human sciences, and consequently the design of “artificial society” or “agent-based computational economics” (ACE) framework by means of multi-agent systems (MAS). For instance in a pioneering book on artificial society and multi-agent simulations in social sciences, Gilbert and Conte (1995) put the emphasis on emergence as a key concept of such an approach: “Emergence is one of the most interesting issues to have been addressed by computer scientists over the past few years and has also been a matter of concern in a number of other disciplines from biology to political science” (op.cit. p. 8). More recently, comprehensive discussion of emergence issues can be found in Gilbert (2002) and Sawyer (2001a, 2004, 2005) for the social science and Sawyer (2002a) for the psychology. In economics, ACE put also the emphasis on the question of emergence (see e.g., Axtell, Epstein, & Young, 2001; Epstein, 1999, 2006; Tesfatsion, 2002a, 2002b; Tesfatsion & Judd, 2006). In all these works, cognition and societies are viewed as complex systems.

The present chapter discusses the impact of emergence on both “downward” and “upward” effects, with applications to the social sciences. MAS allow us to formalize in a single framework both bottom-up and top-down processes. In multi-agent frameworks, properties of the “whole” system result from the collective interactions between the parts (agents) by upward causation (bottom-up process, compatible with methodological individualism); but, to some extent, agents may be constrained by the whole top-down process, compatible with holism or structuralism methodological point of view. This downward effect may arise by means of the social dimension of beliefs (Phan & Ferber, 2007) through the agents’ perception of social phenomena

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