

## Developmental Process and Dynamic Systems

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Biological growth often consists of profound changes in body structure and morphology and in behavior. For example, human babies begin life unable to control their body in even the most rudimentary ways. Yet, quite dramatically and rapidly, they change – they visually track objects, then reach for them, then crawl, then walk. They progress from crying to babbling to talking, from reflexes to impulsivity to self-control. Development is fundamentally about the origin of new forms. This is a daunting theoretical problem in any domain, but it is particularly daunting when it is about ourselves, about behavior, about mind. Theories of mental development, in particular, have not dealt successfully with the origins of new forms. Instead, they have focused on simple answers that presume the pre-existence of new forms either in the organism from the start (nativism) or in the world (most empiricist accounts). Dynamic systems theories of developmental process are providing new insights into mechanisms of change in neural and bodily development, motor development, and most recently in mental development. This chapter will provide an overview of these advances.

We will begin with an overview of nativist and empiricist approaches and then also consider traditional developmental theories in the constructivist and ecological frameworks as these provide a bridge to newer dynamic systems approaches. We will then consider development from a complex systems perspective. We will consider the developmental process in several domains but will emphasize issues in cognitive development. However, one major point will be that a complex systems perspective offers a new conceptual structure that can integrate data across levels of organization -- cellular, neurological, behavioral, as well as cognitive. We outline several of the main points below:

**Traditional theories.** Two philosophical traditions, nativism and empiricism, have shaped approaches to mental development. These traditions offer distinct perspectives on what is the structuring element in development. The nativist tradition proposes that new forms are inherent and prior to experience, whereas, the empiricist tradition proposes that new forms are structured by the environment and thus are a product of experience. The extreme ends of these perspectives are no longer common, however, this dichotomy still has a strong influence on how most researchers think about development. We will illustrate how these traditions may limit researchers' questions and answers. In particular, within these traditions, cognition is either a representational or knowledge structure and little effort is made to consider how knowledge is acquired and utilized. Cognition has become merely a structural capacity and development a disjoint set of points. We will also consider historical attempts to move beyond these views – Piagetian constructivism and the ecological psychology of the ethology tradition. We will also consider examples from bodily and motor development – domains that have not been so hampered by the classical theoretical dichotomy – that suggest the value of viewing developmental process in terms of complex systems ideas.

**Complex systems.** A complex systems perspective provides an alternative conceptualization of development as a process. In order to understand development as a process, two concepts seem especially significant: self-organization and nested time scales. Biological organisms are systems

composed of multiple interacting levels of organization and when this heterogeneous, hierarchical system interacts with a complex dynamic environment new behavioral patterns emerge. Within this interaction neither component, organism nor environment, has a privileged casual role but rather new behaviors are emergent properties of the entire interaction. Human development occurs on the time scale of months and years, but an individual behavior occurs on the time scale of seconds and minutes. Since time flows in a single direction the amplification of small changes to how the organism interacts with the environment in the moment may drive development. From this perspective cognition is a real-time process, not a structural capacity, so examining the temporal patterns of behavior, not just the result of a behavior, should provide insight into the mechanisms of cognition and developmental change.

The formal framework of complex systems is composed of three theories: 1. dynamic systems theory, 2. information theory, and 3. computation. We will review core concepts of these theories and how they can be used to characterize the process of development.

Applications. We will overview recent applications of dynamical systems – both in formal theory and in metaphoric theories – to developmental process. We will specifically consider the development of spatial abilities in infants and toddlers, the development of walking, and also the development of higher level cognition such as categories.

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