Chapter 6
A Research Roadmap

In Chapter 1 we discussed the principles of developmental cognitive systems in general, and of enactive systems in particular. Chapters 2, 3, and 4 identified the constraints arising from the developmental psychology and neurophysiology of neonates, while Chap. 5 revealed a number of insights derived from several computational models of cognition. Now we weave all of these constraints, requirements, and insights together to produce a comprehensive list of functional, organizational, and developmental guidelines for an artificial system that is capable of developing cognitive abilities. These guidelines provide the basis for the design of an enactive cognitive architecture and its practical deployment. In other words, they define a roadmap for the development of cognitive abilities in a humanoid robot, a roadmap which embraces both phylogeny and ontogeny. In the next chapter, we describe the current status of a project to implement these guidelines in a cognitive architecture for the iCub humanoid robot. This cognitive architecture, together with the physical robot, provides the platform for the development of cognitive abilities. The developmental process — or ontogenesis — must proceed in a structured manner. Consequently, we will draw heavily on the material in Chap. 3 on the development of human infants to inform this structure and present a roadmap for ontogenesis. Thus, our roadmap has two sides: the phylogenetic side, informed by enaction, developmental psychology, neurophysiology, and computational modelling, and the ontogenetic side, informed by developmental psychology (see Fig. 6.1). We begin by addressing the phylogeny of the system in Sect. 6.1 and then turn to its ontogeny in Sect. 6.2.

Before proceeding, a note on research roadmaps is in order. Arguably, the term roadmap has become somewhat debased in recent years due to it frequently being used to define over-ambitious research agenda. Nonetheless, a properly-constituted research roadmap has an important role to play in advancing challenging new disciplines, such as artificial cognitive systems. As Sloman has pointed out, understanding the requirements of cognitive systems research is in itself a major research activity and a research roadmap provides a way of expressing an agreed specification of what the problems are and it helps research planning by identifying milestones.
One of Sloman’s main points is that “even people who disagree on mechanisms, architectures, representations, etc. may be able to agree on requirements”. He argues for the collection of many possible scenarios based on observation of “feats of humans (e.g. young children, playing, exploring, communicating, solving problems) and other animals (e.g. nest-building birds, tool makers and users, berry-pickers and hunters)”. These scenarios should be described in detail and then analysed in depth to produce requirements which, together with the scenarios, should be ordered by difficulty and by dependence. Sloman conjectures that

“the most general capabilities of humans, which are those provided by evolution, and which support all others, develop during the first few years of infancy and childhood. We need to understand those in order to understand and replicate the more ‘sophisticated’ and specialised adults that develop out of them. Attempting to model the adult competences directly will often produce highly specialised, unextendable, and probably very fragile systems – because they lack the child’s general ability to accommodate, adjust, and creatively re-combine old competences”.

While not following the exact methodology for creating a research roadmap advocated by Sloman, the roadmap described in this book nonetheless adheres strongly to this philosophy, basing the requirements encapsulated in the guidelines and scenarios below on cognitive development in human infants.