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The Biology of Language in the 21st Century

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Motivation

Human language is regarded by many as a premier example of a natural biological system. Its structural complexity, the rapidity and ease with which it is learned by young children, the importance of sensitive periods in acquisition over the lifetime, and its neural specificity all suggest that the system is highly specialized--finely tuned to fulfill a clear adaptive function. Understanding the nature of this biological system, its growth over development, its evolution, and its neural basis form some of the deepest questions that are currently addressed within cognitive science. This symposium brings together key figures in the study of language as a biological system to discuss recent advances in our understanding from the perspectives of linguistics, cognitive neuroscience, and philosophy. This symposium is the first in the new series, The Governing Board Symposium, sponsored by the Governing Board of the Cognitive Science Society, and intended to address the most significant topics of our time by drawing on the many disciplines that are at the heart of cognitive science.

Factors in Language Growth Noam Chomsky

Consider language as an internal biological system. Like others loosely termed "organs," its growth and development involves at least 3 factors: external data, the genetic endowment that maps these inputs to experience and guides the general course of development, and principles of more general applicability. The most elementary property of the language faculty is that each language delivers "sound with meaning" (in Aristotle's phrase); more specifically, it is a generative procedure that enumerates infinitely many structured expressions, each assigned an interpretation at two interfaces, sensorymotor and conceptual-intentional (thought and action). The second factor includes properties specific to human language (UG) along with those that underlie relevant neural and cognitive systems that enter into language growth. The earliest efforts to formulate UG in the 1950s postulated complex mechanisms, as appeared to be necessary for descriptive adequacy. The major task of the theoretical study of language since has been to show how this complexity can be reduced, both in order to deepen explanation and to offer some hope for an eventual study of the evolution of language. The greatest success in this endeavor has been through adding third factor considerations of computational

complexity. Progress in these efforts suggested a new research program: "approaching UG from below," that is, seeking to determine where UG hypotheses depart from an optimal solution to basic conditions of adequacy, and to overcome these departures where possible. One conclusion that seems increasingly plausible is that language should be regarded as meaning with sound, a revision of the familiar Aristotelian dictum with far-reaching consequences. I will review the grounds for these and related hypotheses and new problems that have been brought to light.

Brain and Language: Some Linking Hypotheses **David Poeppel**

The study of the neural foundations of speech and language reveals both straightforward and unexpected properties of brain function. Drawing on recent findings and classical results, some principles are highlighted that illuminate how the brain breaks down complex representational/computational tasks like speech perception and language comprehension. By distributing the subroutines in space (parallel anatomic streams) and time (concurrent processing on multiple time scales) and by deploying predictive mechanisms throughout -- enabled by the subtle stored knowledge each speaker/listener brings to the task -- the brain provides an architectural infrastructure consistent with representational primitives of a certain granularity. Focusing on these architectural principles helps sharpen the linking hypotheses between the 'parts list' of neurobiology and the 'parts list' of linguistics. If the overarching goal of the inquiry is to develop explanatory theories about how neural systems form the basis for linguistic computation, defining primitives at the appropriate granularity to link cognition and brain function is a prerequisite. With that in mind, the cognitive sciences should take a leading, more muscular role in defining the neurobiological agenda.

The Net Effect: Gene-networks, Neural Networks, and New Capacities **Patricia S Churchland**

Because human language capacities are biological at bottom, one useful approach to understanding those capacities is to take the perspective of genes, brain evolution, and brain organization. Genes belong to flexible *gene-networks*, and interact with each other, with the body and with the external environment. Neurons are organized into *networks*, which in all nervous systems appear to be designed according to "small-world" principles. Surprisingly, there are deep organizational similarities between fruit fly brains, bird

brains, and the brains of primates. Importantly, recent work shows that dramatic new capacities can emerge from small changes to genes that regulate the expression of other genes, where the end result is that neuron numbers in an area may expand or contract. Biophysical constraints on neural circuitry mean that new computational capacities may emerge as well. Via regional increase of neuron numbers, expanded brain areas for auditory or somatosensory processing, for example, may yield behavioral capacities that strike an observer as qualitatively different from those of the ancestor. This perspective helps in fostering new ideas about the links between human speech capacities, those probably enjoyed by earlier hominids, and to complex sequencing behavior seen in other species including birds.

Elissa Newport **Discussant**

The talks will be discussed in the context of historical, current, and future perspectives on the status of language as a biological system.