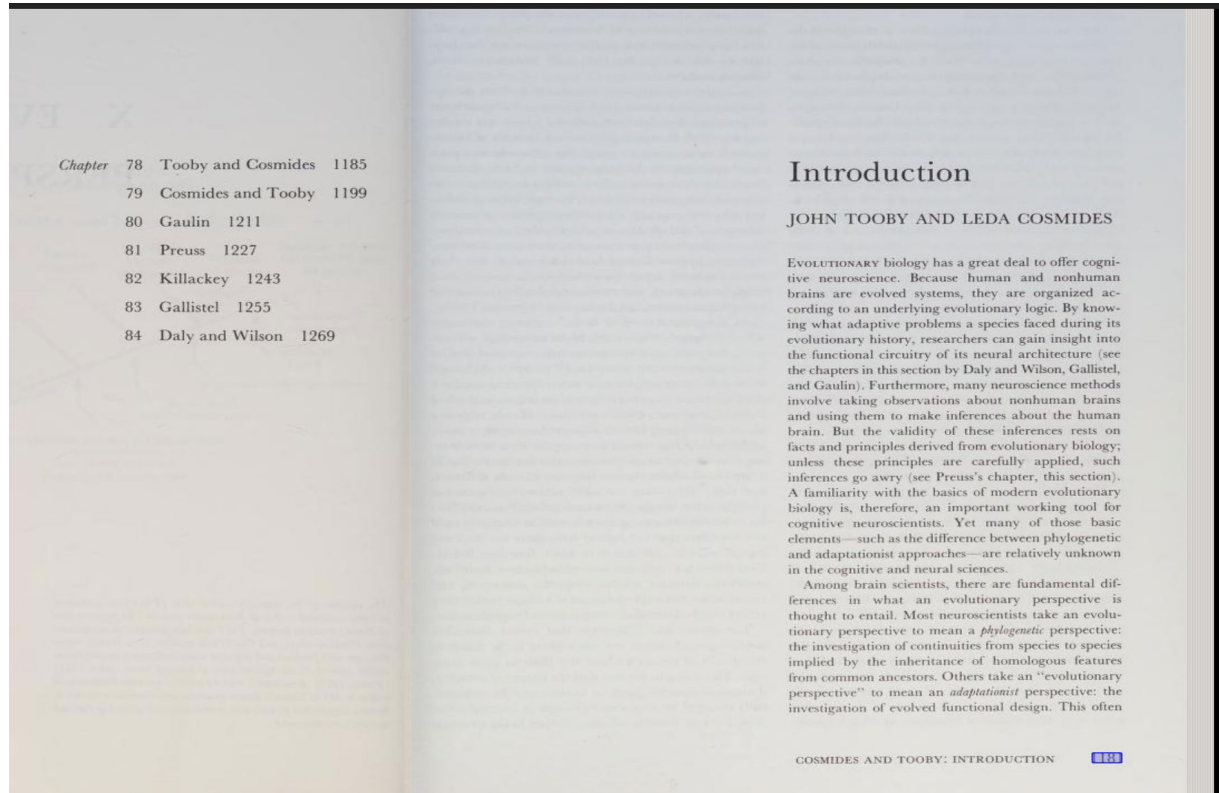


Introduction to the Evolution Section in *The Cognitive Neurosciences*. (1995) Michael S. Gazzaniga (Editor-in-Chief.). Cambridge, MA: MIT Press. (Tooby & Cosmides, Section Editors)



entails the functional analysis of niche-differentiated cognitive and neural machinery that is unique to the species being investigated.

One can see the interplay of these sentiments in the controversy over ape language and its implications for primate neuroanatomy. Half the scientific audience cheers for the apes, expecting them to duplicate human linguistic feats; the other half is confident that the apes' linguistic abilities will prove very limited. Scientists with a phylogenetic perspective form the apes' cheering section: They reason that if a human can learn a language, then our nearest relatives should be able to do so as well; after all, common descent ensures that their neuroanatomy will be similar to our own. Scientists with an adaptationist perspective are skeptics in the ape language controversy. They (correctly, in our view) see the acquisition of language as a species-specific computational ability, requiring highly complex and specialized cognitive and neural mechanisms. Other primates, who were not selected to participate in a linguistic form of communication, are unlikely to share these brain mechanisms.

Within neuroscience, the adaptationist approach has largely been ignored because many neuroscientists have implicitly adopted a biologically obsolete linear model of phylogenetic continuity. According to this view, the human brain is qualitatively similar to the brains of other primates and, for that matter, of other mammals; though differing in scale, they share a single basic plan. But if brain architectures are fundamentally the same between species, then how could they contain functional specializations for solving adaptive problems that are specific to each species?

The ethical barrier to using invasive techniques to investigate humans has inclined many researchers toward the linear phylogenetic view, by making it convenient to assume and to believe that there are few qualitative differences between the human brain and the "primate brain" or even the "mammalian brain." If this assumption of phylogenetic continuity were true, then the careful study of a few species such as rats and rhesus monkeys would be sufficient to deduce the important features of human neural organization. Modern adaptationists, in contrast, recognize that the design of each species is unique in many ways, and that assumptions based on direct leaps from one species to another will often be wrong. Natural selection tends to specialize and improve the design of circuits that solve important adaptive problems, and each species

has faced a somewhat different array of adaptive problems over the course of its evolutionary history. Neuroscientists who take an adaptationist perspective have found strong evidence of functional circuitry that differs from species to species (for examples, see the chapters in this section by Daly and Wilson, Gallistel, Gaulin, and Preuss).

A modern evolutionary framework resolves the apparent tension between phylogenetic and adaptationist approaches. Animals from different species are similar to each other in neural architecture because of inheritance from common ancestors, the same selection pressures operating on different species, or both. Animals from different species differ in neural architecture because of independent descent, the operation of different selection pressures on different species, or random divergence. Adaptationist and phylogenetic analyses are complementary components of an integrated evolutionary approach, and both have value. But their relative validity depends on which brain mechanism is being investigated, and at what level of resolution (for extended discussion, see Tooby and Cosmides, 1989).

At the grossest level of brain anatomy, continuity will seem largely vindicated. More differences will appear, however, as more species are examined and as brain structures are more finely mapped. Although these differences will become more apparent the finer the scale of investigation, there is no reason to think of them as functionally "fine" or minor. Hands, anteaters claws, seal flippers, bat wings, horse hooves, tiger paws, and elephant legs are all homologous structures sharing a certain basic architecture across mammals. But at a finer level of description they are all very different, and these differences are often related to functional problems that are specific to each group. Neural differences between mammals do not seem so dramatic until one considers that behavioral differences are the most logical assay of differences in brain function. Behavioral differences between bats, chimpanzees, mole rats, meerkats, humans, whales, leopards, macaques, and tamarins are not mild variations of a single model; they reflect highly diversified computational organizations.

The anatomical differences that create diversified cognitive mechanisms are more likely to be found in the details of circuit architecture than in gross anatomy. This is due to the fact that the output of complex, dynamical systems (such as brains) can be dramatically changed by only minor changes in internal structure. Because natural selection shapes brain structure

based on its effects on behavior, the behavioral output of the neural architecture can readily be shaped by adaptive demands over evolutionary time, even though the modification of the neural substrate necessary to create adaptively major changes may be anatomically minor. Thus, the nature of complex neural design makes the search for commonalities among animal species (including humans) helpful and illuminating at a gross neuroanatomical level, where structural homologies are easily recognizable and readily traceable through related species. Equally, cellular-level processes seem to be conserved across species, making cross-species inferences highly reliable for this class of features. Between these two extreme scales, however, continuity breaks down. The computational properties of neural circuits depends critically upon the exact arrangement of microlevel elements. At this level, an adaptationist perspective—more specifically, the careful analysis of specific adaptive information-processing problems—will be necessary to understand neural structure in functional terms and at its most detailed level. Even more obviously, phylogenetic continuity is powerless to explain or to illuminate the zoologically unique features of the cognitive or neural architecture of any species, and humans exhibit many zoologically unique properties. To understand many aspects of human brain function (such as language, tool use, imitation, and coalition formation), it will be necessary to consider the niche-differentiating, species-specific selection pressures hominids encountered during human evolutionary history (e.g., Tooby and DeVore, 1987). To elucidate the human cognitive architecture and how it is physically implemented, adaptationist analyses are therefore essential.

The news that human brains cannot be thought of as "scaled-up" versions of macaque brains has been un-

welcome and resisted by many neuroscientists. But it shouldn't be. Not only can more sophisticated versions of phylogenetic inference be practiced (see Preuss's chapter), but by trading in an obsolete model of linear continuity, neuroscientists will get an expanded set of inferential tools in exchange. Indeed, one of the most powerful tools a cognitive neuroscientist can have is a sophisticated appreciation for adaptation-driven phylogenetic diversity. Gaulin's work on spatial cognition describes how sibling species that have been subjected to different selection pressures can be used to test hypotheses about the relationship between neural structures and cognitive functions. Moreover, functional analyses of adaptive problems can be used to discover neurocognitive systems that were previously unknown (see, e.g., the chapters in this section by Cosmides and Tooby, Daly and Wilson, Gallistel, and Gaulin). Evolutionary biology replaces a linear scale of nature with a rich matrix of relationships between species, selection pressures, behaviors, and neural structures. This matrix permits a far greater variety of methods for testing hypotheses, based upon the genuine diversity of structure-function relationships. As the contributions to this section should make clear, cognitive neuroscientists can find a wealth of new approaches to their research problems by exploring the numerous connections between their field and evolutionary biology.

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