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Focus on hearing

Ears capable of picking up airborne sounds appear to have evolved separately and repeatedly among the ancestors of modern mammals, birds, frogs, turtles and lizards; being able to hear is pretty important for the survival of animals in many different environments. In humans, hearing is also fundamental for language. Yet humans are also uniquely prone to losing their ability to hear, with 36 million adults reporting hearing loss in the United States alone (birds, on the other hand, can regenerate damaged auditory cells). We are proud to present this special focus on the neurobiology of hearing, with seven Perspectives and Reviews discussing recent advances in our understanding of how sounds are converted into neural signals, and how these processes go wrong in hearing loss in humans.

Work on the auditory system has historically seen divisions between clinicians working with patients suffering from various hearing disorders and basic scientists who are more interested in the biology of the auditory system. However, communication between these different groups can be mutually beneficial. In their Review, Christine Petit and Guy Richardson illustrate how clinical work has helped answer many of the questions that basic scientists are asking. They describe how the identification of the genetic causes of many forms of human deafness has provided unprecedented insight into the molecular mechanisms of hearing in the peripheral auditory system. Specifically, this Review discusses how combining these genetic insights with mouse models has provided clues about the formation and functioning of the hair bundle as a mechanotransducer. Similarly, in their Perspective article, David Moore and Robert Shannon suggest that further performance improvements in patients fitted with cochlear implants (artificial devices that convert sounds into nerve signals) are likely to come from developing the ability of the brain to use the implant. Basic research on plasticity in auditory systems is thus crucial to future advancement in this kind of applied clinical work.

Of late, there has been much controversy about how small differences in the arrival time of sounds to the two ears are used for sound localization. The traditional Jeffress model posits that individual neurons are maximally excited by different interaural time delays, creating a topological map of preferred interaural time delays, but this has been contradicted by other recent work in mammals. In their review of the various evolutionary strategies for dealing with the problem of hearing, Jan Schnupp and Catherine Carr suggest that both theories may be equally correct; because binaural hearing has evolved more than once, different groups of animals may use different strategies, perhaps according to the particular ecological niche that they occupy.

This kind of responsiveness to the environment is a frequent feature of the auditory system, which can be transformed remarkably fast by stimuli in the environment. Karl Kandler, Amanda Claus and Jihyun Noh review the recent evidence indicating that the organization of tonotopy in the developing auditory brainstem undergoes refinement at both the circuit and cellular level. Given the tonotopic precision present at very early stages of development in auditory brainstem pathways, it was believed that synaptic reorganization contributes little to the construction of these maps. The authors review the evidence that contradicts this hypothesis of a developmentally hardwired map and suggest that the emergence of precise tonotopy also depends on experience-dependent circuit refinement.

Much of this basic work has been in nonhuman animals and it is often thought that this kind of work cannot be informative about functions that are unique to humans, such as language. A Review by Josef Rauschecker and Sophie Scott demonstrates just how untrue this statement is: work on how nonhuman primates process species-specific vocalizations not only provides clues to how language may have evolved, but also suggests possible structures for language processing. Although work in human patients only suggested the existence of specific areas with discrete functions (such as Broca's and Wernicke's area), this Review describes how primate and human imaging work indicates a much more sophisticated language network, with maps and streams of processing being distributed throughout the brain.

Stefan Heller and John Brigande also provide an overview of something else that seems to be uniquely human: hearing loss. In their Perspective, the authors argue that hearing loss is essentially a modern-day phenomenon, with increasing life-spans exposing a deficit that was irrelevant for most of human evolution. The deficit is the loss of the ability to self-repair damage to the adult mammalian cochlea, which seems to be intact in some other animals. It would be interesting to speculate on the evolutionary pressures that led to the loss of this seemingly adaptive ability, but the existence of limited hair cell repair potential in the developing inner ear and the early neonate raises the hope that it may be possible to kick-start regenerative processes to reverse mammalian hair cell loss.

Similarly, we hope that this collection of articles will aid progress in the field. That is certainly the aim of the Perspective by Andrew King and Israel Nelken, who offer a critical analysis of why our understanding of auditory processing has lagged behind the advances made in other comparable fields. In particular, after a perusal of recent advances in the understanding of the visual system, even the most enthusiastic auditory neuroscientist may be forgiven for feeling a little forlorn. King and Nelken suggest that only some of this delay may be a result of some of the approaches that have dominated auditory research and describe important differences between the auditory and visual systems that have made work on the auditory system more challenging. We are confident that the auditory research community is up to this challenge. ■

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