



# INBORN PREFERENCES AND YOU:

*What 'innate' behaviors and perceptions tell us about ourselves and our world*



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## Abstract

Many behaviors are learned and modified by exposure to environmental stimuli throughout development (pre- and post-natal), yet many aspects of those behaviors seem to be immutable and well stereotyped. In our studies of the neurobiology that underlies the development of species differences in auditory preferences in birds, we have been exploring the very nature of the “nature

versus nurture” issue. Through the use of embryonic neural transplants between two bird species, we have demonstrated that a congenital auditory preference resides in the nervous system and is transferable. The transfer of the auditory preference does not influence the vocalizations of the resulting animals (called chimeras), suggesting that auditory self-stimulation is not an explanation for the behavioral change. Such information allows researchers insight into how behaviors might be hard-wired in an organism and how genetic and environmental factors might influence their development and emergence. This article demonstrates the immutability of a specific perceptual process whose underlying biology is established early in brain development.

## Explaining the Emergence of Complex Behaviors

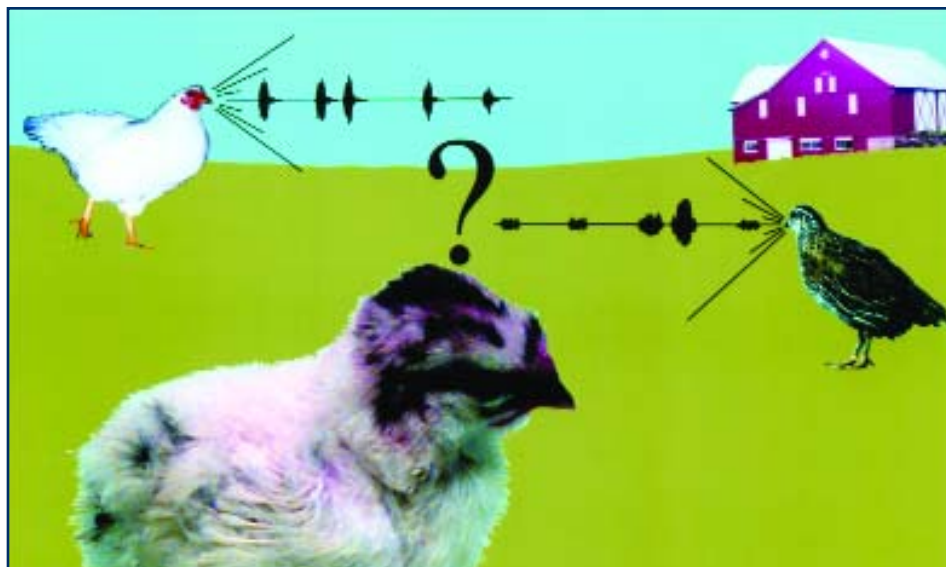
The age-old “nature versus nurture” argument about behavioral traits has

created a distinct dichotomy of viewpoints and expectations concerning the emergence and control of behavior, but neither adequately explains much of the complicated behavior seen in animals as diverse as bugs, birds, or human babies. Many behaviors have strong learning components, and others seem not at all influenced by experiential factors. The recent view in developmental biology suggests that the emergence of simple and complex behaviors is a result of interplay between gene expression, pre- and post-birth development, and environmental influences, including, but not limited to, sensory experience (Gilbert, 1994; Kandel et al., 2000). Thus, the appearance of behavioral traits falls along a continuum between strictly genetically controlled (nature) pathways and fully experientially controlled (nurture) pathways, with the majority of behaviors having some components of both. Indeed, genes do not generate behaviors in a vacuum,

and environmental influences on gene expression and embryological development are common, despite the apparent lack of variation in the resulting behavioral phenotype of interest. Environmental influences (including sensory experiences) may occur continuously or periodically throughout development, spanning embryological and post-partum stages. The neuronal arrangement and tuning of human binocular vision is a good example of a system that requires sensory input at critical times to generate a species-typical perceptual phenotype. Given 'normal' sensory input, there seems to be little variation among individuals in the consistency of such phenotypes. However, significant changes in the development of this system can occur when sensory input or timing is manipulated, as has been shown in binocular deprivation studies (Hubel et al., 1977).

Often, more complex behaviors are likely to be composed of both strongly genetically controlled (and less variable) components and developmentally elastic (and extremely variable) components, easily changed by experiential learning. The human propensity for language is a good example of such behaviors. The acquisition of language would probably not proceed so quickly if infants did not have a predisposition for listening to speech. Thus the convention of labeling behaviors as innate or learned has not only lost its descriptive power, but dangerously assumes a level of underlying steadfast wiring, the nature of which is often little-known. Researchers tend to avoid the term innate with its connotations altogether, opting instead for the term inborn, which includes both genetic and experiential unspecified factors.

In studying the nature of inborn behaviors, we explored the ability of the developing brain to organize specific and complex behaviors. The research described in this paper demonstrates that certain inborn behaviors are wired early in development, restricted to rela-



**Figure 1.** Chimeric chicken chick (with quail forebrain) shown in foreground with adult female chicken and quail with their species maternal calls shown in the background. The calls are shown as an oscillogram with the amplitude variation in the calls displayed as a function of time.

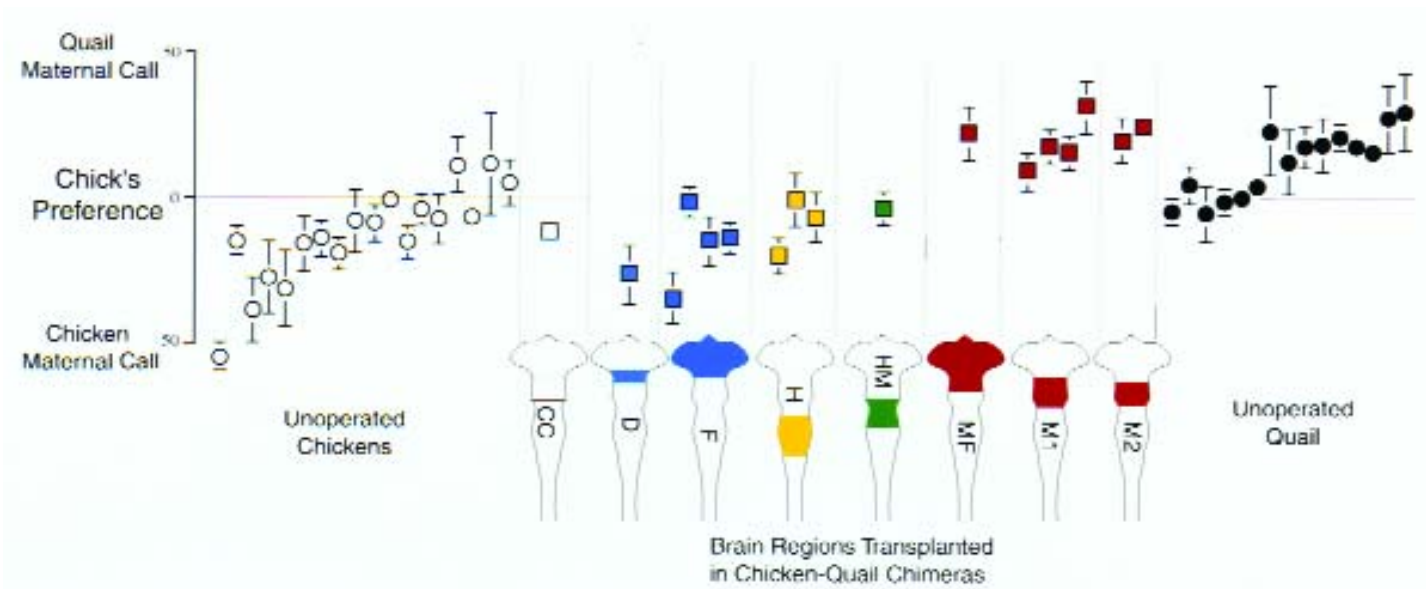
tively small regions of the brain, and can be transplanted to another species. This research was conducted by surgical transplantation of specific developing brain regions between bird species *in ovum*.

### Searching for a Brain Locus for Behavioral 'Hardwiring'

If inborn behaviors do not seem to have a strong learned component, one might expect a distinct brain locus that controls the phenotype. Correspondingly, different variants of the same behavior, either within species or across species, should be reflected in differences in that brain region. Although the basis for some inborn behaviors have been described in detail (for instance, J. P. Ewert's work on worm-feature detector mechanisms in frogs), the neurobiology underlying many complex perceptual behaviors and how they might differ across species remains elusive. Even with advances in the understanding of genetics, development, and environmental influences on the emergence of behaviors, it is often unclear how and where in the brain such cognitive traits can be hard-wired.

Our laboratory has been studying the biological basis for differences between

species in behaviors that are strongly inborn. One such behavior is the distinct preference young chicks have for their own species' maternal call, regardless of whether they have had any prior exposure to that call (Park & Balaban, 1991). We have attempted to localize brain regions that bias the preference for maternal calls of a given species. We studied the localization of these inborn maternal call preferences in chicken and quail hatchlings by transplanting specific portions of the developing brain at very early embryonic stages from quail to chicken embryos. These transplant operations yield healthy hatchlings with "chimeric" (mixed species) brains (Balaban et al., 1988). We hoped that by transplanting particular regions of the developing brain, we might also transplant the preference behavior from quail to chick (Figure 1). In this case, a chimeric chicken would respond preferentially to the calls of a quail mother. Evan Balaban and colleagues' (1988, 1990, 1997) pioneering work on behaving chimeras already demonstrated that species-specific crowing behavior could be transplanted between species, and that the head movement and acoustic components of this complex behavior could be dissociated as



**Figure 2.** Simultaneous auditory choice test results. Individual chicks' preferences are arbitrarily plotted as positive for the quail maternal call and negative for the chicken maternal call. Open circles = mean values for individual unoperated chickens; filled circles = mean values for unoperated quail; rectangles = chimeric animals. Fill color corresponds to type of surgery performed, illustrated on schematic embryonic neural tubes (center). Bars:  $\pm 1$  standard deviation. CC = chick-donor, chick-host rostral mesencephalon/caudolateral diencephalon (M1 type) surgery; D = quail-donor, chick-host rostral diencephalon surgery; F = quail-donor, chick-host forebrain/rostromedial diencephalon surgery; H = quail-donor, chick-host rostral hindbrain surgery, HM = quail-donor, chick-host rostral hindbrain/caudal midbrain surgery; MF = quail-donor, chick-host rostral midbrain/diencephalon/forebrain surgery; M1, M2 = quail-donor, chick-host rostral mesencephalon/caudolateral diencephalon (M2 smaller than M1). Modified from Long et al., 2001.

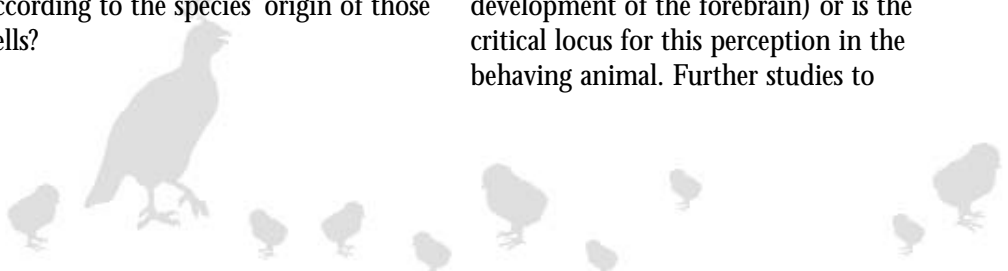
well. They attempted to extend the original research to transplant inborn perceptual preferences between species.

We chose to work with Japanese quail (*Coturnix coturnix japonica*) and the domestic chicken (*Gallus gallus domesticus*) because 1.) the two bird species are closely related, which yields better success in transplantation, and 2.) donor and host brain regions can be identified anatomically because it is

possible to tell single chicken and quail cells apart with a tissue-staining technique (Le Douarin & Renaud, 1969). We found that transplanting one particular region of the brain from quail into chicken embryos (the developing anterior midbrain) yielded chimeric chickens that preferred quail maternal calls (Long et al., 2001). Transplants of other neighboring regions from quail into chick did not produce this effect (Figure 2). Thus, it seems that this region of the brain is important in the development of preferences for maternal calls with certain species' characteristics. But development is by definition a dynamic process, with various cells and tissues changing their structures and functions according to genetic plans and environmental influences. Does the developing midbrain come to control the post-hatched behavior, or does it promote a neural wiring arrangement in some other brain region according to the species' origin of those cells?

### Midbrain or Forebrain Control of Call Preferences?

If some part of the midbrain in the hatched bird truly determines the saliency of a maternal call, one would expect neurons in that particular region to be differentially active when hearing their particular species' call. In a series of experiments, molecular markers were used to identify brain areas differentially active during maternal call presentation in non-chimeric chicks and quail (Long et al., 2002). Although staining was found in the midbrain, the levels were not different between heterospecific and conspecific call types. However, the researchers were surprised to find various regions in the forebrain that did differentially stain, suggesting that those areas must in some way be involved in saliency of the calls. It remains unclear whether the midbrain has only a developmental role in determining call saliency (by influencing the development of the forebrain) or is the critical locus for this perception in the behaving animal. Further studies to



determine whether transplants of the midbrain region would change the expression of our gene markers in the forebrain might suggest some kind of a remote inductive mechanism.

### **From Bird Brains to Baby Human Brains**

Transplants of behavioral traits between species via neural tissue transplant have given us unique insight into the nature of what defines an individual's or species' behavior. More consistent behavioral components of complex behavior tend to be viewed as species-typical, with other more variable components as a sign of the individual. Does this indicate an underlying immutable neural wiring? Clearly, some components of what are viewed as perceptual behaviors, like call saliency and face recognition, are determined prior to external experience and should be less variable. However, both auditory and visual preference behaviors in chicks turn out to be surprisingly variable, although the group average for the behavior is predictable (Park & Balaban, 1991; Johnson et al., 1985, 1992). Despite the apparent individual variation, these early inborn perceptions are generally adaptive in that they direct attention to valuable, survival-specific environmental stimuli that exist within a constantly changing montage of less-relevant or sometimes even dangerous environmental stimuli. Call saliency in quail and chicken chicks provides the initial orientation for the imprinting (learning) process which bonds baby to mother. The same can be said for face recognition behavior in chicks, and human babies as well. So, individuality in a given behavior or behavioral component may be a result of initial developmental variation (genetic or environmental) and/or experiential variation. There may be similar brain mechanisms that underlie the saliency for faces or calls in different species, and they may be strongly controlled by specific events in development that

restrict the level of variation. Excessive variation, whatever the cause during development, risks interference with the emergence of these behaviors and may well interrupt their function as, for example, has been reported for Autistic spectrum disorders.

### **Inborn Behavior and Learning**

A quick search in the educational psychology literature yields keywords such as environment, learning, mind/body connection, enrichment, individuality, and early development (for examples, see Bransford et al., 1999; Gregersen et al., 2001; Jacobs-Connell, 2000; Johnson et al., 2003; Shonkoff & Phillips, 2000). These terms are extremely relevant to educational theories, yet are difficult to define with respect to the underlying biology. It is reasonable that complex perceptual behaviors, including those we associate with learning, may well have strongly inborn components with sufficient environmentally induced variation to yield the diverse learning styles seen by educational psychologists. Perhaps, multiple intelligences theory (Gardner, 1983, 1993) and other progressive

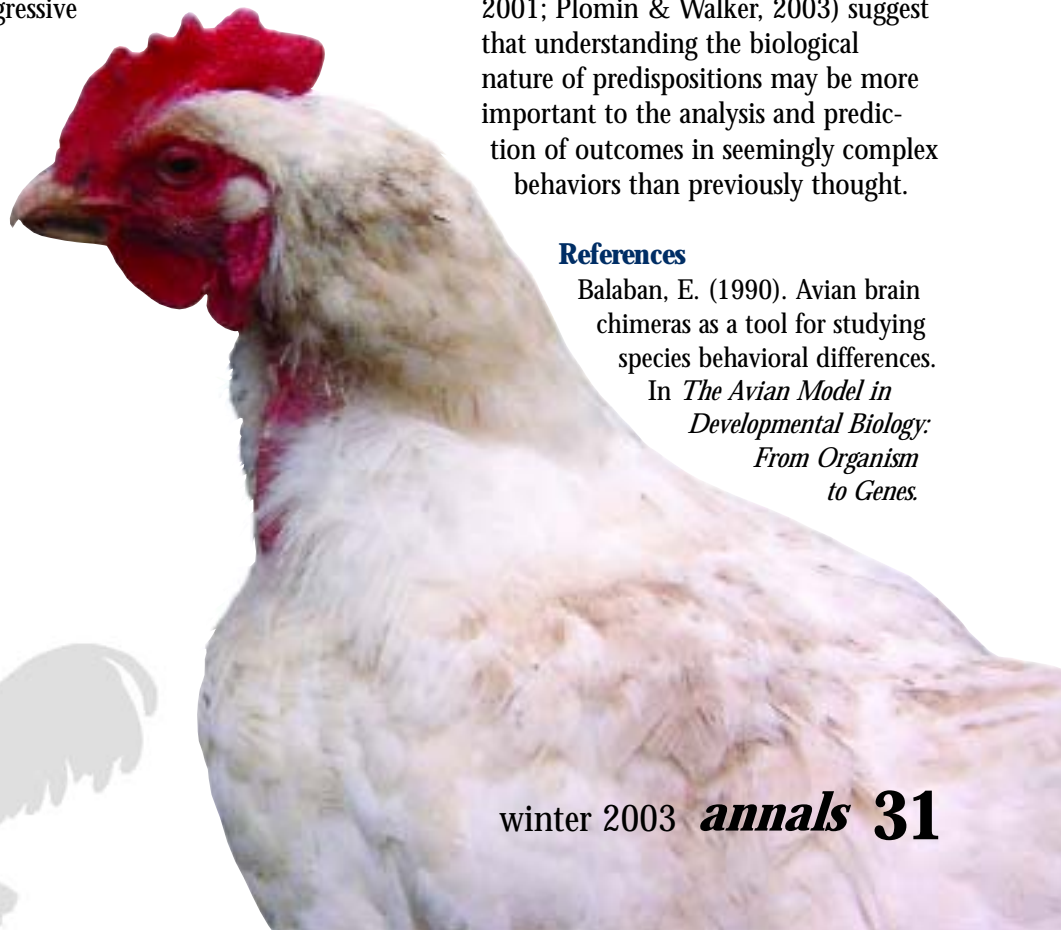
“brain-based” educational initiatives are proving successful because they exploit an individual's predisposition for certain learning styles or types of sensory information. It is clear that substantial variation in learning behaviors exists, and that such variation in their components reflects the results of numerous developmental battles between nature and nurture. Deciding which aspects of a complex behavior like learning are inborn, variable, and/or controllable is the pressing question.

### **Conclusion**

Our work shows that behaviors once thought of as too complicated for hardwiring can indeed have strongly inborn components, as is the case for the perception of maternal calls. This work demonstrates that complicated perceptual processes, which result in broadly variable behavior, can have a strong underlying and immutable biology in the form of early predispositions. Recent work on genetic correlates to psychophysiological disorders like alcoholism and addiction (Kendler et al., 1997; Nestler, 2000), and research on genetic correlates of learning (Kandel, 2001; Plomin & Walker, 2003) suggest that understanding the biological nature of predispositions may be more important to the analysis and prediction of outcomes in seemingly complex behaviors than previously thought.

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Kevin D. Long, Ph.D, is an experienced neuroscientist and educator. His research experience includes the study of the neurobiology underlying innate perceptions. His work also spans research in systems physiology, developmental neuroscience, behavior and evolutionary biology. His is an active member of the Society for Neuroscience in research and science education outreach as well as a teacher educator for K-12 curricula.

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