

## Natural selection of asymmetric traits operates at multiple levels

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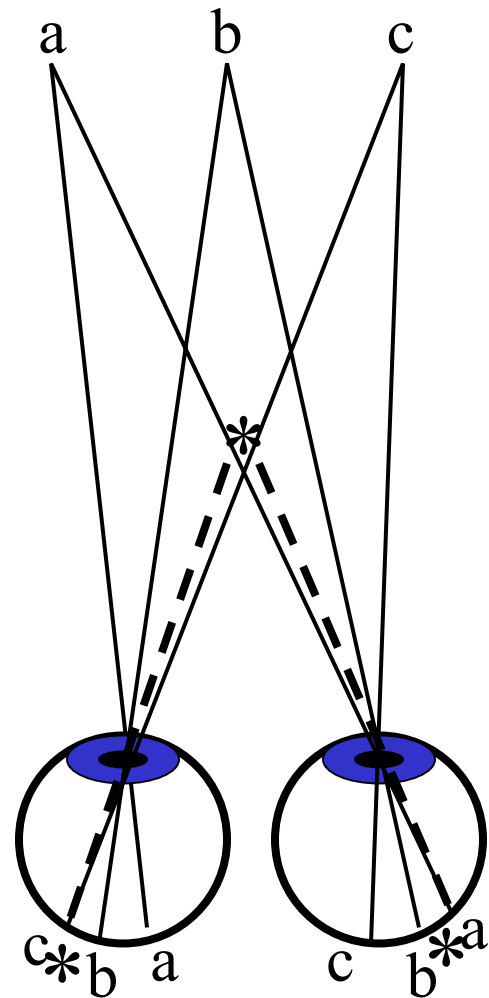
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**Abstract:** Natural selection of asymmetric traits operates at multiple levels. Some asymmetric traits (like having a dominant eye) are tied to more universal aspects of the environment and are coded genetically, others (like pedestrian turning biases) are tied to more ephemeral patterns and are largely learned. Species-wide trends of asymmetry can be better modeled when different levels of natural selection are specified.

In their target article on asymmetric functioning, Vallortigara and Rogers present examples of lateralization in a wide array of forms for a wide variety of species. They propose that species-wide lateralizations of functioning occur because they represent evolutionarily stable strategies (ESSs) that are naturally selected. Vallortigara and Rogers argue for an interdisciplinary approach that integrates neuropsychology with evolutionary biology, but they emphasize that lateralization need not be entirely genetically determined. Here, we extend this line of reasoning, and further articulate that natural selection of traits occurs at several levels of robustness. We characterize three distinct levels: (i) Macroevolution, or natural selection of new genetic characteristics introduced through mutation, (ii) Microevolution, or natural selection of population distributions in the gene pool, without adding any new genetic characteristics, and (iii) Social Evolution, or natural selection of culturally learned patterns, without changing the genetic distributions in the population. We suggest that an evolution-based model of species-wide asymmetry should not treat asymmetric functioning as a unified concept, but instead should specify the level of natural selection associated with specific asymmetric traits (Gilbert, Opitz, & Raff, 1996; Raff, 1996).

Vallortigara and Rogers note that there have always been selective advantages to symmetric functioning. This is consistent with findings that virtually all life forms are largely symmetric with stationary organisms tending to be approximately circularly symmetric and locomoting organisms bilaterally symmetric (e.g. see Haeckel, 1974). Presumably, throughout evolution the universality of gravity has made asymmetric bodies less stable (McBeath, Schiano, and Tversky, 1997). This tendency is further inbred by evolutionary mechanisms like sexual selection that make symmetric individuals appear more sexually attractive in a variety of species (Møller, 1992; Pennisi, 1995). Gravity and physical laws of balance are universal principles, so it is consistent that biological symmetry is favored at the most robust genetic level, across species.

Some symmetric functions, like the occurrence of two eyes and stereoscopic vision, appear to have evolved along diverse, independent evolutionary pathways ranging from insects to mammals. Clearly, the presence of two eyes is a symmetric adaptation that allows organisms to utilize the abundant terrestrial light energy to discern important three-dimensional spatial information about the environment. Stereoscopic organisms have the advantage of multiple “dual-eye” perspective for discerning shapes and distances, but at the expense of needing to integrate the two images. Therefore, stereovision leads to virtually universal geometric constraints.



**Figure 1.** Need for a Dominant Eye. When simultaneously imaging distant and close stimuli (e.g. *abc* vs. \*), the geometry of stereo optics produces image disparity between the two eyes (e.g. the \* is lined up with *c* in the left eye and *a* in the right). A dominant eye is needed to reduce the perception of a double image.

When a stereoscopic organism views a surface (such as *a-b-c* in figure 1), an object at a different depth (such as the \*) will produce disparate images in the two eyes. The extent of the shift in the location of the \* can be used to determine its stereo depth, but it will also produce a double image with the \* appearing to be aligned with *c* in the left eye and with *a* in the right eye. Visual systems resolve this conflict by having a dominant eye. A dominant eye appears to be a geometric requirement to eliminate alignment double vision in stereoscopic organisms, and thus it makes sense that it be a genetically coded trait (Handa, Mukuno, Uozato, Niida, Shoji, & Shimizu, 2004). In short, physical universals lead to genetic hard wiring, in this case a genetically encoded trait of eye-dominance. If ESS are used to account for population imbalances of eye dominance, that is consistent with evolutionary natural selection at the genotype level, or an example of macroevolution.

Eye dominance in humans is generally clustered along with same side dominance of other functions such as brain activity and handedness, but this need not be true (Erdogan, Ozdikici, Aydin, Aktas, & Dane, 2002). Cross-eye dominance or eye dominance that opposes handedness occurs at significantly higher rates in some subpopulations like baseball players (Portal & Romano, 1988).

This type of natural selection is assumed to occur because batters typically stand with their dominant hand facing away from and their opposing eye facing toward the pitcher. Batting prospects with cross-eye dominance would therefore have a slight performance advantage. This would result in a population culling process that biases the genetic population distribution of this sample, yet clearly occurs at a much too rapid time scale to be credited as a genetic change. This is an example of microevolution, or a selection process in which certain genetic features are favored and cluster together, without introduction of any genetic change.

Finally, there are some types of asymmetric functioning that have a clear learning component, and species-wide patterns appear to be due to arbitrary social trends. Examples of these include the attentional side biases (Eviatar, 1995; Nachson, 1985) and motion perception direction biases that have been found to be associated with reading direction exposure (Morikawa & McBeath, 1992). People from areas that read from left to right have a bias to attend initially to the left, and to experience quick flashes of motion, like lightening, as traveling to the left. Those from areas that read from right to left experience the reverse. Similarly, walking-side and turning biases are correlated with handedness (lefties go left and righties go right), but are also strongly determined by driving side exposure. Pedestrians from right-side driving countries like the United States favor heading to the right, while those from left-side countries like Great Britain favor heading to the left (Scharine & McBeath, 2002). Clearly, such asymmetric functioning due to learned habits like reading direction or driving-side

exposure are behaviors that have been selected at a social and not a genetic level.

In summary, we outlined how asymmetric functioning may be due to different levels of natural selection. We agree that Vallortigara and Rogers question regarding the etiology of species-wide asymmetric functioning patterns is very intriguing, and the findings we cited remain consistent with their proposed *evolutionarily stable strategies* explanation. Our main point is that many asymmetric functioning patterns may be occurring differentially at a socially learned level rather than at a genetic level.

## References

- Erdogan, A. R., Ozdikici, M., Aydin, M. D., Aktas, O., & Dane, S. (2002). Right and left visual cortex areas in healthy subjects with right- and left-eye dominance. *International Journal of Neuroscience*, *112*(5): 517-523.
- Eviatar, Z. (1995). Reading direction and attention: Effects on lateralized ignoring. *Brain and Cognition*, *29*, 137-150.
- Gilbert, S. F., Opitz, J. M., & Raff, R. A. (1996). Resynthesizing evolutionary and developmental biology *Developmental Biology*, *173*(2): 357-372.
- Haeckel, E. (1974). *Art Forms in Nature*. Dover Publications: New York.
- Handa, T., Mukuno, K., Uozato, H., Niida, T., Shoji, N., & Shimizu, K. (2004). Effects of dominant and nondominant eyes in binocular rivalry. *Optometry and Vision Science* *81*(5): 377-382.
- McBeath, M. K., Schiano, D. J., & Tversky, B. (1997). Three-dimensional bilateral symmetry assumed in judging figural identity and orientation. *Psychological Science*. *8*(3). 217-223.
- Møller, A. P. (1992). Female swallow preference for symmetrical male sexual ornaments. *Nature*, *357*, 238-240.
- Morikawa, K. & McBeath, M.K. (1992). Lateral motion bias associated with reading direction. *Vision Research.*, *32* (6) 1137-1141.
- Nachson, I. (1985). Directional preferences in perception of visual stimuli. *International Journal of Neuroscience*, *25*, 161-174.
- Pennisi, E. (1995). Not simple symmetry: Does it really matter if the right ear is bigger than the left? *Science News*, *147*(3), 46-47.
- Portal, J. M. & Romano, P. E. (1988). Patterns of eye hand dominance in baseball players. *New England Journal of Medicine*, *319*(10): 655-656.
- Raff, R. A. (1996). *The Shape of Life: Genes, Development, and the Evolution of Animal Form*, University of Chicago Press: London.
- Scharine, A. A. & McBeath, M. K. (2002) Right handers and Americans favor turning to the right. *Human Factors*. *44*(1). 248-256.

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