PNAS LETTER

Symmetry and asymmetry in biological structures

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The recent paper in PNAS by Johnston et al. (1), "Symmetry and simplicity spontaneously emerge from the algorithmic nature of evolution," is focused on how symmetry and modularity emerge in biological structures. The authors suggest that symmetric structures in nature do not arise only because of natural selection but also because they are less complex to encode. Therefore, symmetric phenotypes are supposed to have a higher probability to appear through random mutations than asymmetric phenotypes.

The argument brought forward by the authors (1) is very compelling but omits a critical point. While symmetry may arise more commonly in biological structures with low complexity, there is evolutionary pressure to develop asymmetry in many biological structures with high complexity. The emergence of symmetry cannot be fully understood without considering the emergence of asymmetry as well. Take, for example, the human brain, one of the most complex biological structures on Earth. While the two halves of the brain look roughly symmetric at first glance, a recent large-scale neuroimaging study in PNAS (2) has shown that structural left–right asymmetries are the rule, rather than the exception, for cortical brain areas. In the study, Kong et al. showed that 91.1% of cortical regions showed significant asymmetries of their surface areas, and 76.5% of the regions showed significant asymmetries in cortical thickness. A comparable large-scale neuroimaging study focused on asymmetries in subcortical structures found similar results (3). Besides these structural asymmetries, the human brain shows functional asymmetries on many different levels, for example, left–right differences in how language, faces, or emotions are processed (4).

Importantly, the human central nervous system is not the only one that shows such striking asymmetries. Comparative research has shown that brain asymmetries are common across all major vertebrate groups (5) and can even be observed in the comparably simpler nervous systems of insects and other invertebrates (6). Why do nervous systems develop these asymmetries? In a highly complex and energy-hungry system like the brain, asymmetric organization has several advantages (7). These include improved multitasking capabilities, a more energy-efficient design by avoiding unnecessary redundancy of processing units, and improved action control by avoiding bilateral interference (7). This suggests that, for complex biological structures such as the brain, symmetry may not always be positive, as it would lead to reduced multitasking abilities, an unnecessarily high energy consumption, and issues in bilateral action control. Breaking symmetry is therefore a crucial step in the development of all nervous systems (8). In this context, it is particularly interesting that many neurodevelopmental and psychiatric disorders haven been associated with reduced brain asymmetries, for example, higher brain symmetry (9, 10).

Therefore, we argue that the view presented in the very interesting paper by Johnston et al. (1) is too one-sided. To fully understand how symmetry develops in biological systems, the trade-off between the spontaneous emergence of symmetry and evolutionary pressures toward asymmetry needs to be integrated in a balanced way.

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The authors declare no competing interest.

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