



# The Origins of Evolutionary Innovations: A Theory of Transformative Change in Living Systems

By *Andreas Wagner*

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## **The Origins of Evolutionary Innovations: A Theory of Transformative Change in Living Systems** By Andreas Wagner

The history of life is a nearly four billion year old story of transformative change. This change ranges from dramatic macroscopic innovations such as the evolution of wings or eyes, to a myriad of molecular changes that form the basis of macroscopic innovations. We are familiar with many examples of innovations (qualitatively new phenotypes that can provide a critical benefit) but have no systematic understanding of the principles that allow organisms to innovate. This book proposes several such principles as the basis of a theory of innovation, integrating recent knowledge about complex molecular phenotypes with more traditional Darwinian thinking. Central to the book are genotype networks: vast sets of connected genotypes that exist in metabolism and regulatory circuitry, as well as in protein and RNA molecules. The theory can successfully unify innovations that occur at different levels of organization. It captures known features of biological innovation, including the fact that many innovations occur multiple times independently, and that they combine existing parts of a system to new purposes. It also argues that environmental change is important to create biological systems that are both complex and robust, and shows how such robustness can facilitate innovation. Beyond that, the theory can reconcile neutralism and selectionism, as well as explain the role of phenotypic plasticity, gene duplication, recombination, and cryptic variation in innovation. Finally, its principles can be applied to technological innovation, and thus open to human engineering endeavours the powerful principles that have allowed life's spectacular success.

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## **The Origins of Evolutionary Innovations: A Theory of Transformative Change in Living Systems** By Andreas Wagner Bibliography

- Sales Rank: #1758852 in Books
- Published on: 2011-09-15
- Original language: English
- Number of items: 1
- Dimensions: 7.40" h x .70" w x 9.60" l, 1.72 pounds
- Binding: Paperback
- 272 pages

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### **Editorial Review**

#### Review

This book will surely be influential with the next generation of evolutionary biologists, who will be able to digest and then apply the significance of a network-centric view of adaptation. Such a perspective will be essential for interpreting the increasing number of empirical studies that recapitulate evolutionary innovations in laboratory experiments. But even those molecular and evolutionary biologists who do not actively work on problems of innovation will benefit from the clarity of Wagner's theoretical arguments, and the inspiring wealth of empirical examples that demonstrate a new way to think of the dynamics of adaptation. Bioessays

#### About the Author

Andreas Wagner is professor in the department of biochemistry at the University of Zurich in Switzerland, and External Professor at the Santa Fe Institute for the study of Complex Systems. His main research interest is the evolution of biological systems, from genes to complex biological networks with thousands of components. He received his Ph.D. in 1995 at Yale University, and has since held research fellowships at several institutions, such as the Institute for Advanced Studies in Berlin, Germany, and the Institut des Hautes Etudes in Bures-sur-Yvette, France. Author of more than 100 scientific publications and two books, he has lectured widely worldwide. He is a member of the Faculty of 1000 Biology, as well as of the editorial boards of several scientific journals, including Bioessays, B.M.C. Evolutionary biology, Molecular Genetics and Genomics, and Molecular and Developmental Evolution.

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