Instructor's Manual

CARL T. BERGSTROM • LEE ALAN DUGATKIN

evolution

SECOND EDITION

Matthew E. Gruwell

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Carl T. Bergstrom and Lee Alan Dugatkin's

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Instructor's Manual by
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Table of Contents

Chapter 1

An Overview of Evolutionary Biology

Chapter Summary and Discussion Points

Introduction

Charles Darwin evolved biology when he theorized that all organisms share a common ancestry and that an organism's fitness within its environment is the result of natural selection. Darwin's evolutionary theory led to a natural explanation for the diversity of life and, thus, a paradigm shift in biological thought that now reaches every subdiscipline of biology. For example, when anatomy students now study the structure of bones in the human wrist, it is possible to extrapolate their understanding of skeletal structures to other tetrapods and find bones of the same origin being used in similar or very different ways.

Section 1.1: A Brief Introduction to Evolution, Natural Selection, and Phylogenetics

As a primer to the ensuing chapters, this section explains the idea of descent with modification as being the way in which all organisms change over time due to natural or artificial selection, leading to the premise that all life is subject to the principles of evolution. For example, to truly understand a species such as *Homo sapiens*, one must study and understand primates, their closest relatives. This section offers students a refresher on some of the basics of genetics, which sets the stage for defining selection. Artificial selection is covered using multiple examples of crops, including a detailed figure of human selection of many different food crops over thousands of years, as well as a more specific example involving strawberries. These examples are then contrasted with an example of natural selection involving pesticide resistance in insects. Antibiotic resistance also is explored as a problem that will be solved only by using the principles of evolutionary biology. Lastly, to help students see that evolutionary principles aid in the study of conservation biology, the authors introduce the concept of tree thinking using the phylogenetic tree of life and extinction. This section concludes with the Key Concept Question (see Key Concept Question 1.1): Can you think of other ways that evolutionary thinking might affect studies in conservation biology?

Discussion Points:

- What two things did Darwin originally notice and how did that lead to his theory? What are some examples from the natural world that confirm Darwin's idea?
- How do artificial and natural selection differ? How does artificial selection demonstrate the reality of evolution? When are examples of human influence

causing change in a system still considered natural selection?
- Why is antibiotic resistance a serious threat to modern medicine? How will the principles of evolutionary biology help control this problem?

Section 1.2: Empirical and Theoretical Approaches to the Study of Evolution
This section divides the types of research conducted in evolutionary biology into two major methods: empirical and theoretical. Empirical research is further divided into observation or manipulation of a natural system. Observation studies involve gathering data from a system without manipulating it and include studies such as research on the fossil record, inferring phylogeny from genetic sequences, or observing behavior. This is demonstrated by comparing similarities between chimps and humans in anatomy and genomics to show common ancestry and determine what separates them genetically. Manipulation of natural systems is explained by a second example of empirical study, which involves breeding systems and testes size in 33 species of primates. Theoretical biology is introduced as a major discipline in evolutionary biology through the work of Ronald A. Fisher and William D. Hamilton, in which they utilized mathematical models to predict and understand sex ratios. This is followed by an actual example of changing sex ratios in the blue moon butterfly on the Samoan islands.

Discussion Points:
- Of the two research methods discussed, which would be most useful in testing specific hypotheses?
- What is the usefulness of theoretical studies in evolutionary biology?

Answers to Review Questions

1. Paradigm shifts represent fundamental changes in the way we think about and study nature from a scientific perspective.

2. (1) All species are descended from one or a few ancestral life-forms. (2) A process Darwin dubbed *natural selection* explains the fit of organism to environment.

3. This evidence includes, but is not limited to, molecular genetic, anatomical, physiological, behavioral, developmental, and hormonal data. Such data can be amassed from fossils or contemporary organisms.

4. Artificial selection is the human-driven analog to the process of natural selection. In artificial selection, we selectively breed individuals with traits that are beneficial to us.

5. Bacteria reproduce extremely rapidly—as fast as hourly or even faster. Bacterial population sizes are enormous, providing a vast supply of genetic variation. Natural selection imposed by antibiotic resistance is very strong.

For all of these reasons mutations conferring antibiotic resistance can quickly arise and rapidly spread through bacterial populations.

6. Phylogenetic diversity is a measure of diversity that takes into account how much of the evolutionary history of the group being studied is preserved.

7. The two basic ways to gather empirical evidence to test hypotheses are observational and experimental studies.

8. Neutral mutations are mutations that do not affect fitness.

9. Sex ratio measures the ratio of females to males in a given population.

10. Regardless of whether empirical work precedes theoretical work or vice versa, each of these informs the other, and this (ideally) leads to the generation of new, testable hypotheses.

Answers to Key Concept Application Questions

11. We can apply the exact same reasoning we used for the case of the evolution of antibiotic resistance in bacteria to the cases of antiviral resistance evolution by viruses and antifungal resistance evolution by fungi. Similar arguments also apply in agriculture to the evolution of herbicide-resistant weeds and pesticide-resistant insects.

12. Answers will vary, but the theory of continental drift and plate tectonics represents one such paradigm shift. The theory of continental drift proposed that continents are drifting landmasses that move over geological time and therefore even the large-scale geography of the earth is dynamically changing. The theory of plate tectonics provided us with a mechanistic understanding of how continental drift takes place. Together, these theories provide an explanation of why surface of our planet looks the way that it does now, how large landmasses are created and destroyed, and so much more.

13. The study of descent with modification is the conceptual glue that unites all of the life sciences. Without adopting an evolutionary approach in the biological sciences, we have many potentially important, disparate facts, but no common theoretical perspective to unite them.

14. By selecting for traits that are either aesthetically pleasing or in some sense practical, humans have shaped everything from the size (think miniature poodle to Great Dane) to the behavior (herding, hunting, retrieving) of domesticated dog breeds.

15. Now that the molecular genetic techniques associated with studying gene expression are widely available, evolutionary biologists can study not just how differences between species in protein-coding DNA sequences are associated with evolutionary change, but also how differences in when genes are turned on and off are associated with evolutionary change.

16. As we noted in the chapter, a 1 female to 1 male sex ratio is so common that it is hard to imagine any other sex ratio, but what we want to understand is *why* a 1:1 sex ratio is so ubiquitous in the first place. To do that, we need to consider other possible sex ratios, and then examine which sex ratio is favored by natural selection and under what conditions. Once we make clear our assumptions, mathematical models give us the power to do exactly that.

Suggested Readings

This list of suggested readings is printed at the end of this chapter in the student textbook and reprinted here for your convenience and planning.

Birkhead, T. R., and T. Pizzari. 2002. Postcopulatory sexual selection. *Nature Reviews Genetics* 3: 262–273.

• This paper will give you a better understanding of the sperm competition and sperm allocation work we discussed in this chapter.

Engelstädter, J., and G. D. D. Hurst. 2009. The ecology and evolution of microbes that manipulate host reproduction. *Annual Review of Ecology, Evolution and Systematics* 40: 127–149.

• A detailed review on issues we discussed in the *Wolbachia*/blue moon butterfly sex ratio example.

Huxley, T. H. 1863. *Evidence of Man's Place in Nature*. D. Appleton, New York.

• Huxley—Darwin's colleague—presented evidence for human evolution in this book.

Kuhn, T. 1962. *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago.

• In this volume, a classic in the philosophy of science, Kuhn outlines the idea of a paradigm shift.

Varki, A., D. H. Geschwind, and E. E. Eichler. 2008. Explaining human uniqueness: genome interactions with environment, behavior, and culture. *Nature Reviews Genetics* 9: 749–763.

• An interesting discussion of how to understand what molecular genetic comparisons tell us (and don't tell us) about similarities and differences between humans and other primates.