

selection and speciation pogil

selection and speciation pogil is an essential topic in evolutionary biology that explores how natural selection drives the emergence of new species. This process is fundamental to understanding biodiversity and the mechanisms that influence genetic variation within populations. The selection and speciation POGIL (Process Oriented Guided Inquiry Learning) approach provides a structured framework for students and educators to investigate these concepts interactively. By focusing on key evolutionary principles such as genetic drift, isolation, and adaptation, this method enhances comprehension of how species diverge over time. This article delves into the core aspects of selection and speciation, highlighting the role of natural selection and reproductive barriers. Additionally, it examines various modes of speciation and the importance of POGIL activities in reinforcing these ideas. The discussion will also include practical examples and the significance of this approach in modern biological education.

- Understanding Natural Selection
- Mechanisms of Speciation
- Types of Speciation
- Role of Selection in Speciation
- The POGIL Approach in Evolutionary Biology

Understanding Natural Selection

Natural selection is a fundamental concept in evolutionary biology that explains how organisms with favorable traits are more likely to survive and reproduce. This process results in the gradual adaptation of populations to their environments. Natural selection operates on variations within a population, which arise from mutations, gene flow, and sexual reproduction. Over generations, advantageous traits become more common, shaping the genetic makeup of species. Understanding natural selection is crucial for grasping how speciation occurs, as it drives the divergence of populations through differential survival and reproduction.

Variation and Adaptation

Variation is the raw material for natural selection and exists in the form of genetic differences among individuals in a population. Adaptation refers to traits that improve an organism's chances of survival and

reproduction in a specific environment. These adaptations can be structural, behavioral, or physiological. Natural selection favors these traits, leading to increased fitness of individuals possessing them. The continuous process of adaptation underlies the evolutionary changes that can eventually lead to the formation of new species.

Selective Pressures

Selective pressures are environmental factors that influence which traits are advantageous. These can include predation, climate, food availability, and competition. Different selective pressures can lead to divergent evolution in separate populations, especially when they inhabit distinct environments. Understanding selective pressures helps explain how populations evolve differently, setting the stage for speciation.

Mechanisms of Speciation

Speciation is the evolutionary process through which new biological species arise. It occurs when populations of a single species become reproductively isolated, leading to genetic divergence. Several mechanisms contribute to this reproductive isolation and genetic differentiation. These include geographic separation, behavioral changes, temporal isolation, and genetic incompatibilities. Together, these mechanisms prevent gene flow between populations, allowing them to evolve independently.

Reproductive Isolation

Reproductive isolation is essential for speciation because it restricts interbreeding between populations. It can be prezygotic, occurring before fertilization, or postzygotic, occurring after fertilization. Prezygotic barriers include differences in mating behavior, habitat preferences, and breeding times. Postzygotic barriers involve hybrid inviability or sterility. The development of these barriers leads to the formation of distinct species by maintaining genetic separation.

Genetic Divergence

Once reproductive isolation is established, genetic divergence ensues as populations accumulate distinct mutations and undergo different selective pressures. Genetic drift and mutation contribute to this divergence, further differentiating the gene pools. Over time, these genetic changes can result in the emergence of new species with unique characteristics, adapted to their specific ecological niches.

Types of Speciation

Speciation can occur through various modes depending on the geographic and reproductive context of populations. The main types of speciation include allopatric, sympatric, parapatric, and peripatric speciation. Each type involves different mechanisms of isolation and genetic differentiation, offering insights into the diverse pathways through which species evolve.

Allopatric Speciation

Allopatric speciation occurs when populations are geographically separated by physical barriers such as mountains, rivers, or distance. This isolation prevents gene flow, allowing populations to evolve independently. Over time, genetic divergence and reproductive isolation develop, leading to speciation. Allopatric speciation is considered the most common form of speciation in nature.

Sympatric Speciation

Sympatric speciation takes place within a shared geographic area, without physical barriers. It often results from ecological niche differentiation, polyploidy (especially in plants), or behavioral isolation. Despite living in the same area, reproductive barriers emerge due to factors such as habitat preferences or mating behaviors, enabling speciation without geographic separation.

Other Modes of Speciation

Parapatric speciation occurs when populations are adjacent but experience different selective pressures, leading to divergence along a cline. Peripatric speciation involves a small isolated population at the edge of a larger population's range, where genetic drift and selection can rapidly drive speciation. These modes illustrate the complexity and variability of evolutionary processes.

Role of Selection in Speciation

Selection plays a pivotal role in the speciation process by promoting adaptations that contribute to reproductive isolation and genetic divergence. Natural selection can act on traits influencing mate choice, habitat use, and survival, reinforcing barriers between populations. This process, known as reinforcement, strengthens reproductive isolation and accelerates speciation.

Adaptive Radiation

Adaptive radiation is an evolutionary phenomenon where a single ancestral species rapidly diversifies into

multiple new species, each adapted to different ecological niches. This process is driven by natural selection acting on variations that provide advantages in distinct environments. Adaptive radiation exemplifies how selection can lead to extensive speciation and biodiversity.

Sexual Selection and Speciation

Sexual selection, a form of natural selection based on mate preferences, can drive speciation by favoring traits that influence reproductive success. Differences in mating signals or behaviors can create prezygotic isolation, preventing gene flow between populations. Sexual selection thus contributes significantly to the diversification of species.

The POGIL Approach in Evolutionary Biology

The Process Oriented Guided Inquiry Learning (POGIL) method is an instructional strategy that promotes active learning through structured inquiry. In the context of selection and speciation, POGIL activities engage students in exploring evolutionary mechanisms by analyzing data, making predictions, and constructing explanations. This hands-on approach fosters deeper understanding and retention of complex biological concepts.

Benefits of POGIL for Learning Selection and Speciation

POGIL enhances comprehension by encouraging critical thinking and collaboration. Students work in small groups to investigate evolutionary scenarios, interpret evidence, and apply theoretical knowledge. This method helps clarify the dynamic nature of selection and speciation, making abstract concepts more accessible and relevant.

Examples of POGIL Activities

- Analyzing genetic data to identify patterns of natural selection
- Modeling reproductive isolation mechanisms through case studies
- Simulating speciation events using environmental variables
- Evaluating the impact of selective pressures on population genetics

These activities illustrate how POGIL supports mastery of selection and speciation concepts by integrating

empirical data and critical analysis.

Frequently Asked Questions

What is the main focus of a Selection and Speciation POGIL activity?

The main focus of a Selection and Speciation POGIL activity is to help students understand the mechanisms of natural selection and how they contribute to the formation of new species through interactive, guided inquiry.

How does natural selection drive speciation according to POGIL exercises?

Natural selection drives speciation by favoring certain traits that increase survival and reproduction in specific environments, leading to genetic divergence between populations and eventually the formation of new species.

What role do mutations play in the Selection and Speciation POGIL?

Mutations introduce genetic variation within populations, providing the raw material upon which natural selection can act, and are essential for the process of speciation.

How are reproductive barriers explained in the context of speciation in POGIL activities?

Reproductive barriers are mechanisms that prevent different populations from interbreeding, such as behavioral, temporal, or geographical isolation, and are key concepts in POGIL activities to explain how speciation occurs.

What types of speciation are typically explored in a Selection and Speciation POGIL?

The POGIL typically explores allopatric speciation, where populations are geographically separated, and sympatric speciation, which occurs without physical barriers but through mechanisms like polyploidy or behavioral isolation.

How do POGIL activities help students understand fitness in natural selection?

POGIL activities engage students in analyzing data and scenarios to determine which traits increase an organism's fitness, thereby illustrating how natural selection favors those traits over time.

Can Selection and Speciation POGIL be used to teach about genetic drift?

Yes, many Selection and Speciation POGIL activities include discussions on genetic drift as a random evolutionary force that can influence allele frequencies and contribute to speciation, especially in small populations.

What is the significance of allele frequency changes in POGIL lessons on selection?

Changes in allele frequencies represent evolution in populations, and POGIL lessons emphasize tracking these changes to understand how selection pressures lead to adaptation and speciation.

How do POGIL activities incorporate real-world examples in teaching speciation?

POGIL activities often use case studies, such as Darwin's finches or cichlid fishes, to provide concrete examples of selection and speciation processes, helping students connect theoretical concepts to observable phenomena.

Additional Resources

1. *Evolutionary Analysis: Selection and Speciation in Populations*

This book provides a comprehensive overview of the mechanisms driving evolution, focusing on natural selection and speciation processes. It integrates theoretical models with empirical data to explain how species diverge and adapt. The text is ideal for students and researchers interested in evolutionary biology and population genetics.

2. *Population Genetics and Speciation: Understanding Evolutionary Dynamics*

Delving into the genetic basis of speciation, this book explores how genetic variation and selection pressures contribute to the formation of new species. It covers key concepts such as gene flow, genetic drift, and reproductive isolation. Readers will find detailed case studies that illustrate the practical application of population genetics in evolutionary studies.

3. *Speciation and Selection: Mechanisms and Models*

Focusing on the theoretical frameworks of speciation, this book examines different modes of speciation including allopatric, sympatric, and parapatric. It discusses the role of natural selection and sexual selection in driving species divergence. The text also reviews mathematical models that predict speciation outcomes under various conditions.

4. *Principles of Evolution: Selection, Speciation, and Adaptation*

A foundational text that introduces core evolutionary principles, emphasizing the interplay between

selection and speciation. The book is structured to facilitate learning through clear explanations, diagrams, and review questions. It is well-suited for undergraduate courses in evolutionary biology.

5. Speciation: The Origin of Species in the 21st Century

This modern treatment of speciation incorporates recent advances in genomics and molecular biology to understand how species form. It highlights the role of ecological factors and genetic architecture in speciation events. The book is enriched with contemporary research findings and theoretical insights.

6. Selection and Speciation in Evolutionary Biology: A POGIL Approach

Designed as an interactive learning resource, this book employs the Process-Oriented Guided Inquiry Learning (POGIL) method to teach concepts related to selection and speciation. It encourages active participation through structured activities and critical thinking exercises. Ideal for classroom settings, it helps students grasp complex evolutionary ideas effectively.

7. Genetics of Speciation and Natural Selection

This text explores the genetic underpinnings of speciation and how natural selection shapes genetic diversity within and between populations. It discusses molecular mechanisms such as chromosomal rearrangements and gene regulation changes. The book provides a detailed examination of empirical studies supporting genetic theories of speciation.

8. Evolutionary Mechanisms: Selection, Speciation, and Beyond

Covering a broad range of evolutionary processes, this book emphasizes how selection drives speciation alongside other mechanisms like genetic drift and mutation. It integrates ecological and evolutionary perspectives to provide a holistic view of species formation. The text includes computational models and experimental data to support its discussions.

9. Adaptive Radiation and Speciation: Patterns and Processes

Focusing on adaptive radiation as a key mode of speciation, this book analyzes how environmental factors and selection pressures lead to rapid species diversification. It reviews classic and recent examples of adaptive radiation across different taxa. The book serves as a resource for understanding the dynamic relationship between adaptation and speciation.

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Selection and Speciation: A POGIL Approach

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Selection and Speciation: A POGIL Approach

Introduction: Defining Selection and Speciation

The processes of natural selection and speciation are fundamental concepts in evolutionary biology. Natural selection, the driving force behind adaptation, describes the differential survival and reproduction of individuals based on heritable traits. Those individuals with traits better suited to their environment are more likely to survive and pass those advantageous traits to their offspring. This differential reproductive success leads to changes in the genetic makeup of a population over time. Speciation, on the other hand, is the process by which new and distinct species arise. It's the culmination of evolutionary changes that result in reproductive isolation, preventing gene flow between populations and leading to the formation of distinct lineages. Understanding the interplay between these two processes is crucial to comprehending the incredible biodiversity observed on Earth. This POGIL (Process Oriented Guided Inquiry Learning) approach will guide you through the mechanisms and nuances of selection and speciation.

Chapter 1: Mechanisms of Natural Selection

Natural selection operates through several key mechanisms: variation, inheritance, differential survival and reproduction, and adaptation. Variation refers to the presence of different traits within a population. This variation arises from genetic mutations, gene flow (movement of genes between populations), and sexual reproduction (reshuffling of existing genes). Inheritance ensures that these traits are passed from parents to offspring. Differential survival and reproduction means that individuals with certain traits have a higher chance of surviving and reproducing than others. Finally, adaptation is the evolutionary process where a population becomes better suited to its environment over time. This is not a conscious process; it's simply the result of natural selection favoring beneficial traits.

Chapter 2: Types of Selection (Directional, Stabilizing, Disruptive)

Natural selection can act in different ways, leading to various patterns of evolutionary change:

Directional selection: Favors one extreme phenotype over others. For example, if a population of moths lives in a darkened forest, darker moths might be favored over lighter moths because they are better camouflaged from predators. Over time, the average phenotype shifts towards the favored extreme.

Stabilizing selection: Favors the intermediate phenotype, while selecting against both extremes. For instance, in human birth weight, intermediate weights are associated with higher survival rates than extremely low or high birth weights. This type of selection maintains the existing phenotype frequency.

Disruptive selection: Favors both extremes, selecting against the intermediate phenotype. This can lead to the development of two distinct phenotypes within a population, potentially setting the stage for speciation. A classic example is the Darwin's finches with beak sizes adapted to different food sources.

Chapter 3: Genetic Drift and Gene Flow

While natural selection is a deterministic process, other factors can influence the genetic makeup of populations:

Genetic drift: Random fluctuations in allele frequencies, particularly pronounced in small populations. This can lead to the loss of alleles, even advantageous ones, purely by chance. The bottleneck effect and founder effect are prime examples of genetic drift.

Gene flow: The movement of alleles between populations. This can introduce new alleles into a population, increasing genetic variation, or homogenize allele frequencies between populations, hindering speciation. The extent of gene flow significantly affects the rate and pattern of speciation.

Chapter 4: Reproductive Isolation: Pre- and Postzygotic Barriers

Reproductive isolation is crucial for speciation. It prevents gene flow between populations, allowing them to diverge genetically and ultimately become distinct species. Reproductive isolating mechanisms are broadly categorized as prezygotic and postzygotic:

Prezygotic barriers: Prevent mating or fertilization from occurring. These include habitat isolation, temporal isolation (different breeding seasons), behavioral isolation (different mating rituals), mechanical isolation (incompatible genitalia), and gametic isolation (incompatible egg and sperm).

Postzygotic barriers: Occur after fertilization and result in hybrid inviability (hybrid offspring do not survive), hybrid sterility (hybrid offspring are sterile), or hybrid breakdown (hybrid offspring are fertile in the first generation, but subsequent generations are infertile).

Chapter 5: Modes of Speciation (Allopatric, Sympatric, Parapatric)

Speciation can occur through different modes:

Allopatric speciation: Occurs when populations are geographically separated, preventing gene flow. This isolation allows the populations to diverge independently due to genetic drift, natural selection, or mutations, eventually leading to reproductive isolation.

Sympatric speciation: Occurs within the same geographic area. This is less common and requires mechanisms such as disruptive selection, polyploidy (chromosome duplication), or sexual selection to lead to reproductive isolation.

Parapatric speciation: Occurs when populations are adjacent to each other and experience a cline – a gradual change in environmental conditions and associated traits – across their range. This can lead to partial reproductive isolation.

Chapter 6: Case Studies of Speciation

Numerous examples illustrate the different modes and mechanisms of speciation. The Darwin's finches in the Galapagos Islands are a classic example of allopatric speciation driven by adaptive radiation. The apple maggot fly represents sympatric speciation through host preference. The grass species *Anthoxanthum odoratum* demonstrates parapatric speciation, adapted to different soil metal concentrations. Examining these case studies helps in understanding the complexities of speciation.

Chapter 7: The Role of Adaptation in Speciation

Adaptation, driven by natural selection, plays a critical role in speciation. As populations adapt to different environments or exploit different resources, they may diverge genetically, eventually leading to reproductive isolation. The degree and speed of adaptation influences the rate of speciation. Adaptation can be driven by environmental changes, competition, or the emergence of

new ecological opportunities.

Conclusion: The Interplay of Selection and Speciation

Selection and speciation are intimately linked. Natural selection drives adaptation within populations, and the accumulation of these adaptations, coupled with reproductive isolation, leads to the formation of new species. Understanding the mechanisms of natural selection and the different modes of speciation provides a framework for interpreting the immense diversity of life on Earth. This POGIL approach encourages an active, inquiry-based learning process, promoting a deeper understanding of these foundational evolutionary concepts.

FAQs

1. What is the difference between microevolution and macroevolution? Microevolution refers to small-scale evolutionary changes within a population, while macroevolution encompasses large-scale evolutionary changes, including speciation and the formation of higher taxa.
2. Can speciation occur rapidly? Yes, rapid speciation can occur, particularly through mechanisms like polyploidy in plants or in response to sudden environmental changes.
3. Is natural selection the only mechanism driving speciation? No, genetic drift and gene flow also play important roles, particularly in small populations or those with limited gene flow.
4. How can we test hypotheses about speciation? Phylogenetic analysis, comparative studies of different species, and experimental studies in the lab or field can help test hypotheses about speciation.
5. What is the significance of reproductive isolation in speciation? Reproductive isolation prevents gene flow between populations, allowing them to diverge genetically and ultimately become separate species.
6. How does hybridization affect speciation? Hybridization can sometimes lead to speciation through the formation of new lineages, but it can also prevent speciation by increasing gene flow between populations.
7. What role do mutations play in speciation? Mutations provide the raw material for genetic variation upon which natural selection can act, ultimately contributing to speciation.
8. What are some challenges in studying speciation? The long timescales involved, the complexity of interacting factors, and the difficulty of observing speciation in real-time are some challenges.
9. How does speciation contribute to biodiversity? Speciation is the primary mechanism through which new species arise, generating and increasing biodiversity.

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presented a body of evidence that the diversity of life arose by common descent through a branching pattern of evolution. Darwin included evidence that he had gathered on the Beagle expedition in the 1830s and his subsequent findings from research, correspondence, and experimentation.

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quantitative reasoning in ways that will make your students better at evaluating product claims and news reports. Second, its 51 case studies are a great way to get students engaged in science. Who wouldn't be glad to skip the lecture and instead delve into investigating cases with titles like these: • "A Can of Bull? Do Energy Drinks Really Provide a Source of Energy?" • "ELVIS Meltdown! Microbiology Concepts of Culture, Growth, and Metabolism" • "The Case of the Druid Dracula" • "As the Worm Turns: Speciation and the Maggot Fly" • "The Dead Zone: Ecology and Oceanography in the Gulf of Mexico" Long-time pioneers in the use of educational case studies, the authors have written two other popular NSTA Press books: *Start With a Story* (2007) and *Science Stories: Using Case Studies to Teach Critical Thinking* (2012). *Science Stories You Can Count On* is easy to use with both biology majors and nonscience students. The cases are clearly written and provide detailed teaching notes and answer keys on a coordinating website. You can count on this book to help you promote scientific and data literacy in ways to prepare students to reason quantitatively and, as the authors write, "to be astute enough to demand to see the evidence."

selection and speciation pogil: Chemistry Education Javier García-Martínez, Elena Serrano-Torregrosa, 2015-05-04 Winner of the CHOICE Outstanding Academic Title 2017 Award This comprehensive collection of top-level contributions provides a thorough review of the vibrant field of chemistry education. Highly-experienced chemistry professors and education experts cover the latest developments in chemistry learning and teaching, as well as the pivotal role of chemistry for shaping a more sustainable future. Adopting a practice-oriented approach, the current challenges and opportunities posed by chemistry education are critically discussed, highlighting the pitfalls that can occur in teaching chemistry and how to circumvent them. The main topics discussed include best practices, project-based education, blended learning and the role of technology, including e-learning, and science visualization. Hands-on recommendations on how to optimally implement innovative strategies of teaching chemistry at university and high-school levels make this book an essential resource for anybody interested in either teaching or learning chemistry more effectively, from experience chemistry professors to secondary school teachers, from educators with no formal training in didactics to frustrated chemistry students.

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substantial revision that maintains the rigor of previous editions but reflects the exciting modern developments taking place in chemistry today. Authors David W. Oxtoby and H. P. Gillis provide a unique approach to learning chemical principles that emphasizes the total scientific process 'from observation to application' placing general chemistry into a complete perspective for serious-minded science and engineering students. Chemical principles are illustrated by the use of modern materials, comparable to equipment found in the scientific industry. Students are therefore exposed to chemistry and its applications beyond the classroom. This text is perfect for those instructors who are looking for a more advanced general chemistry textbook.

selection and speciation pogil: *The Social Instinct* Nichola Raihani, 2021-08-31 Enriching—Publisher's Weekly Excellent and illuminating—Wall Street Journal In the tradition of Richard Dawkins's *The Selfish Gene*, Nichola Raihani's *The Social Instinct* is a profound and engaging look at the hidden relationships underpinning human evolution, and why cooperation is key to our future survival. Cooperation is the means by which life arose in the first place. It's how life progressed through scale and complexity, from free-floating strands of genetic material to nation states. But given what we know about evolution, cooperation is also something of a puzzle. How does cooperation begin, when on a Darwinian level, all the genes in the body care about is being passed on to the next generation? Why do meerkats care for one another's offspring? Why do babbler birds in the Kalahari form colonies in which only a single pair breeds? And how come some reef-dwelling fish punish each other for harming fish from another species? A biologist by training, Raihani looks at where and how collaborative behavior emerges throughout the animal kingdom, and what problems it solves. She reveals that the species that exhibit cooperative behaviour most similar to our own tend not to be other apes; they are birds, insects, and fish, occupying far more distant branches of the evolutionary tree. By understanding the problems they face, and how they cooperate to solve them, we can glimpse how human cooperation first evolved. And we can also understand what it is about the way we cooperate that makes us so distinctive—and so successful.

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selection and speciation pogil: *The Evolution of Feathers* Christian Foth, Oliver W. M. Rauhut, 2020-03-11 Feathers are one of the most unique characteristics of modern birds and represent the most complex and colourful type of skin derivate within vertebrates, while also fulfilling various biological roles, including flight, thermal insulation, display, and sensory function. For years it was generally assumed that the origin of flight was the main driving force for the evolution of feathers. However, various discoveries of dinosaur species with filamentous body coverings, made over the past 20 years, have fundamentally challenged this idea and produced new evolutionary scenarios for the origin of feathers. This book is devoted to the origin and evolution of feathers, and highlights the impact of palaeontology on this research field by reviewing a number of spectacular fossil discoveries that document the increasing morphological complexity along the evolutionary path to modern birds. Also featuring chapters on fossil feather colours, feather development and its genetic control, the book offers a timely and comprehensive overview of this popular research topic.

selection and speciation pogil: *Behavioural Responses to a Changing World* Ulrika Candolin, Bob B. M. Wong, 2012-06-14 Human-induced environmental change currently represents the single greatest threat to global biodiversity. Species are typically adapted to the local environmental conditions in which they have evolved. Changes in environmental conditions initially influence behaviour, which in turn affects species interactions, population dynamics, evolutionary processes and, ultimately, biodiversity. How animals respond to changed conditions, and how this influences

population viability, is an area of growing research interest. Yet, despite the vital links between environmental change, behaviour, and population dynamics, surprisingly little has been done to bridge these areas of research. Behavioural Responses to a Changing World is the first book of its kind devoted to understanding behavioural responses to environmental change. The volume is comprehensive in scope, discussing impacts on both the mechanisms underlying behavioural processes, as well as the longer-term ecological and evolutionary consequences. Drawing on international experts from across the globe, the book covers topics as diverse as endocrine disruption, learning, reproduction, migration, species interactions, and evolutionary rescue.

selection and speciation pogil: *Geographic Variation, Speciation and Clines. (MPB-10), Volume 10* John A. Endler, 2020-03-31 Geographic Variation, Speciation and Clines explores the origins and development of geographic variation, divergence, and speciation. In particular it is concerned with genetic divergence as it is usually found on continents, among groups of populations isolated only by distance. Although earlier writers on this topic considered the effects of geography and dispersal, intense geographic differentiation and speciation were thought to require complete isolation. Professor Endler shows how geographic differentiation and speciation may develop in spite of continuous gene flow. Following a review of the diverse and scattered literature on gene flow and population differentiation, the author discusses the relationships among gene flow, dispersal, and migration. He then summarizes the factors which limit the geographic extent of gene flow, and those which allow steep clines to develop in the absence of barriers to gene flow. His analysis draws on examples from the field, experiments, and single- and multiple-locus models. The mechanism and conditions for parapatric speciation are presented: steepening clines, development into hybrid zones, and the evolution of sexual isolation. In the final chapter the author considers the interpretation of natural clines and the associated geographic patterns of subspecies and species.

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selection and speciation pogil: *Representational Systems and Practices as Learning Tools* , 2009-01-01 Learning and teaching complex cultural knowledge calls for meaningful participation in different kinds of symbolic practices, which in turn are supported by a wide range of external representations, as gestures, oral language, graphic representations, writing and many other systems designed to account for properties and relations on some 2- or 3-dimensional objects.

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