

How Reproductive Isolation Leads To Speciation

How Reproductive Isolation Leads to Speciation: A Comprehensive Guide

Introduction:

Have you ever wondered how the incredible diversity of life on Earth came to be? The answer lies, in part, in a fascinating process called speciation – the formation of new and distinct species. While mutation and natural selection drive the changes within a population, it's reproductive isolation that truly seals the deal, creating the irreversible boundaries between species. This comprehensive guide will delve deep into the mechanisms of reproductive isolation, exploring how these barriers prevent gene flow and ultimately lead to the emergence of new species. We'll examine various isolating mechanisms, their impact on populations, and provide real-world examples to solidify your understanding. Get ready to unlock the secrets behind the spectacular biodiversity of our planet!

1. Understanding Speciation: The Birth of New Species

Speciation isn't a sudden event; it's a gradual process that unfolds over generations. It requires the interruption of gene flow – the exchange of genetic material between populations. Without this exchange, distinct populations diverge genetically, accumulating different adaptations and ultimately becoming reproductively incompatible. This reproductive incompatibility is the defining characteristic of a new species. We can visualize this as branching lineages on the tree of life, each branch representing a distinct species.

2. The Key Role of Reproductive Isolation

Reproductive isolation is the cornerstone of speciation. It refers to any biological factor that prevents two groups within a species from exchanging genes. This isolation can be prezygotic (occurring before fertilization) or postzygotic (occurring after fertilization). The effectiveness of these barriers determines how quickly speciation occurs. A strong barrier will lead to rapid speciation, while weaker barriers may result in slower divergence.

3. Prezygotic Isolating Mechanisms: Preventing Fertilization

Several mechanisms prevent mating or fertilization from ever occurring. These are:

Habitat Isolation: Two species may live in the same geographic region but occupy different habitats, preventing them from encountering each other for mating. Think of a terrestrial species and an aquatic species within the same area.

Temporal Isolation: Species may breed at different times of day or year, preventing interbreeding. For example, some plants may flower at different times, preventing pollination between them.

Behavioral Isolation: Differences in mating rituals or courtship displays can prevent successful reproduction. Bird species with unique songs or mating dances are a prime example.

Mechanical Isolation: Incompatibility in reproductive structures prevents mating. The genitalia of different insect species, for example, may be physically incompatible.

Gametic Isolation: Even if mating occurs, the gametes (sperm and egg) may be incompatible and unable to fuse, preventing fertilization. This often involves chemical incompatibilities between the gametes.

4. Postzygotic Isolating Mechanisms: Preventing Viable or Fertile Offspring

Even if fertilization occurs, postzygotic barriers can prevent the formation of viable or fertile offspring:

Reduced Hybrid Viability: The hybrid offspring may be weak or unable to survive.

Reduced Hybrid Fertility: Even if the hybrid offspring survive, they may be sterile, unable to reproduce. Mules (offspring of a horse and a donkey) are a classic example.

Hybrid Breakdown: First-generation hybrids may be fertile, but subsequent generations experience reduced fertility or viability.

5. Allopatric Speciation: Geographic Isolation Drives Divergence

Allopatric speciation is arguably the most common form of speciation. It occurs when populations become geographically separated, preventing gene flow. This separation can be caused by various events, such as the formation of mountains, the rise of sea levels, or continental drift. Once separated, populations evolve independently, accumulating genetic differences through natural selection, genetic drift, and mutation. Over time, these differences may lead to reproductive isolation, even if the populations were to come back into contact.

6. Sympatric Speciation: Speciation Without Geographic Isolation

Sympatric speciation is more rare and occurs when new species arise within the same geographic area. This can happen through various mechanisms, including:

Polyploidy: This is a common mechanism in plants, involving the duplication of entire chromosome sets. Polyploid individuals are often reproductively isolated from their diploid parents.

Sexual Selection: Different mating preferences within a population can lead to the divergence of distinct groups. For instance, if females prefer males with a specific trait, this can lead to the evolution of that trait in one group, while the other group diverges.

Habitat Differentiation: Even within the same geographic area, populations may exploit different resources or microhabitats, leading to reproductive isolation.

7. The Tempo and Mode of Speciation: Gradualism vs. Punctuated Equilibrium

The rate at which speciation occurs can vary. The gradualism model proposes that speciation occurs slowly and steadily over long periods, with small changes accumulating over time. In contrast, the punctuated equilibrium model suggests that speciation can occur rapidly in bursts, followed by long periods of stasis. The actual tempo and mode of speciation likely vary depending on the species and environmental context.

8. Examples of Reproductive Isolation Leading to Speciation

Many examples illustrate the principles of reproductive isolation and speciation. The Galapagos finches, famously studied by Darwin, show how adaptive radiation (the rapid diversification of a lineage into multiple species) can occur through natural selection acting on populations experiencing different environmental pressures, resulting in different beak shapes and subsequently reproductive isolation. Similarly, the cichlid fishes of the African Great Lakes have undergone extensive speciation due to habitat isolation and sexual selection.

9. Conclusion: The Ongoing Story of Speciation

Reproductive isolation is a crucial mechanism driving the diversification of life. Understanding the different forms of reproductive isolation, their interactions, and their consequences provides valuable insights into the evolutionary processes that shape biodiversity. The ongoing research into speciation continues to reveal the complexity and dynamism of life's history, emphasizing the intricate interplay of genetic, ecological, and geographic factors in the creation of new species.

Article Outline:

Title: How Reproductive Isolation Leads to Speciation

Introduction: Hooking the reader and overview of the topic.

Chapter 1: Understanding Speciation: Defining species and the process of speciation.

Chapter 2: The Central Role of Reproductive Isolation: Prezygotic and postzygotic barriers.

Chapter 3: Prezygotic Isolation Mechanisms: Habitat, temporal, behavioral, mechanical, and gametic isolation with examples.

Chapter 4: Postzygotic Isolation Mechanisms: Reduced hybrid viability, fertility, and breakdown with examples.

Chapter 5: Allopatric Speciation: Geographic isolation and its impact.

Chapter 6: Sympatric Speciation: Speciation without geographic separation (polyploidy, sexual selection, habitat differentiation).

Chapter 7: Tempo and Mode of Speciation: Gradualism vs. Punctuated Equilibrium.

Chapter 8: Real-world examples: Galapagos finches, cichlid fishes.

Conclusion: Summary and broader implications.

(The above outline is reflected in the detailed article already provided.)

FAQs:

1. What is the difference between prezygotic and postzygotic isolation? Prezygotic isolation prevents

mating or fertilization, while postzygotic isolation occurs after fertilization, affecting hybrid viability or fertility.

2. Can reproductive isolation occur without geographic isolation? Yes, sympatric speciation demonstrates that reproductive isolation can arise within the same geographic area.
3. What is the role of natural selection in speciation? Natural selection drives the adaptation of populations to different environments, contributing to genetic divergence and potentially reproductive isolation.
4. How does genetic drift affect speciation? Genetic drift, the random fluctuation of gene frequencies, can lead to genetic divergence between isolated populations, even in the absence of natural selection.
5. What is polyploidy, and how does it contribute to speciation? Polyploidy is the duplication of entire chromosome sets, often resulting in reproductive isolation from diploid ancestors.
6. What are some examples of behavioral isolation? Bird songs, mating dances, pheromones, and courtship rituals are examples of behavioral isolation mechanisms.
7. How can habitat isolation lead to speciation? If two populations occupy different habitats within the same area, they may rarely interact, leading to genetic divergence and eventual reproductive isolation.
8. What is hybrid breakdown? Hybrid breakdown refers to reduced fertility or viability in later generations of hybrids, even if the first generation is fertile.
9. How long does it take for speciation to occur? The time required for speciation varies greatly depending on factors such as the strength of reproductive isolation, generation time, and environmental conditions.

Related Articles:

1. Adaptive Radiation: Explores the rapid diversification of a lineage into multiple species, often driven by environmental pressures.
2. The Biological Species Concept: Examines the definition of a species based on reproductive isolation.
3. Phylogenetic Species Concept: Discusses the definition of species based on evolutionary lineages and shared ancestry.
4. Genetic Drift and Speciation: Delves into the role of random genetic changes in driving speciation.
5. The Role of Mutation in Speciation: Explores how mutations can contribute to genetic diversity and subsequent speciation.
6. Sexual Selection and Speciation: Examines how mate choice and sexual competition contribute to reproductive isolation and speciation.

7. Allopatric vs. Sympatric Speciation: Compares and contrasts these two major modes of speciation.
8. Speciation in Plants: Focuses on the unique mechanisms and patterns of speciation in plant populations.
9. Speciation and Conservation Biology: Explores the implications of speciation for understanding and conserving biodiversity.

how reproductive isolation leads to speciation: In the Light of Evolution National Academy of Sciences, 2007 The Arthur M. Sackler Colloquia of the National Academy of Sciences address scientific topics of broad and current interest, cutting across the boundaries of traditional disciplines. Each year, four or five such colloquia are scheduled, typically two days in length and international in scope. Colloquia are organized by a member of the Academy, often with the assistance of an organizing committee, and feature presentations by leading scientists in the field and discussions with a hundred or more researchers with an interest in the topic. Colloquia presentations are recorded and posted on the National Academy of Sciences Sackler colloquia website and published on CD-ROM. These Colloquia are made possible by a generous gift from Mrs. Jill Sackler, in memory of her husband, Arthur M. Sackler.

how reproductive isolation leads to speciation: Sexual Selection and Animal Genitalia William G. Eberhard, 2013-10-01

how reproductive isolation leads to speciation: Bird Species Dieter Thomas Tietze, 2018-11-19 The average person can name more bird species than they think, but do we really know what a bird "species" is? This open access book takes up several fascinating aspects of bird life to elucidate this basic concept in biology. From genetic and physiological basics to the phenomena of bird song and bird migration, it analyzes various interactions of birds - with their environment and other birds. Lastly, it shows imminent threats to birds in the Anthropocene, the era of global human impact. Although it seemed to be easy to define bird species, the advent of modern methods has challenged species definition and led to a multidisciplinary approach to classifying birds. One outstanding new toolbox comes with the more and more reasonably priced acquisition of whole-genome sequences that allow causative analyses of how bird species diversify. Speciation has reached a final stage when daughter species are reproductively isolated, but this stage is not easily detectable from the phenotype we observe. Culturally transmitted traits such as bird song seem to speed up speciation processes, while another behavioral trait, migration, helps birds to find food resources, and also coincides with higher chances of reaching new, inhabitable areas. In general, distribution is a major key to understanding speciation in birds. Examples of ecological speciation can be found in birds, and the constant interaction of birds with their biotic environment also contributes to evolutionary changes. In the Anthropocene, birds are confronted with rapid changes that are highly threatening for some species. Climate change forces birds to move their ranges, but may also disrupt well-established interactions between climate, vegetation, and food sources. This book brings together various disciplines involved in observing bird species come into existence, modify, and vanish. It is a rich resource for bird enthusiasts who want to understand various processes at the cutting edge of current research in more detail. At the same time it offers students the opportunity to see primarily unconnected, but booming big-data approaches such as genomics and biogeography meet in a topic of broad interest. Lastly, the book enables conservationists to better understand the uncertainties surrounding "species" as entities of protection.

how reproductive isolation leads to speciation: Endless Forms Daniel J. Howard, Stewart H. Berlocher, 1998 Speciation is one of the great themes of evolutionary biology. It is the process through which new species are born and diversity generated. Yet for many years our understanding of the process consisted of little more than a perception that if populations are isolated geographically, they will diverge genetically and may come to form new species. This situation

began to change in the 1960s as an increasing number of biologists challenged the exclusivity of allopatric speciation and began to probe more deeply into the actual process by which divergence occurs and reproductive isolation is acquired. This focus on process led to many new insights, but numerous questions remain and speciation is now one of the most dynamic areas of research in modern evolutionary biology. This volume presents the newest research findings on speciation bringing readers up to day on species concepts, modes of speciation, and the nature of reproductive barriers. It also discusses the forces that drive divergence of populations, the genetic control of reproductive isolation, and the role played by hybrid zones and hybridization in speciation.

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how reproductive isolation leads to speciation: *Speciation in Birds* Trevor Price, 2008 In *Speciation in Birds*, Trevor Price, a University of Chicago professor and leading expert in the field, has written the most authoritative and modern synthesis on the subject to date. In clear and engaging prose and through beautiful illustrations, Price shows us why the field is as exciting and vibrant as ever. He evaluates the roles of natural selection and sexual selection. He asks how speciation contributes to some of the great patterns in species diversity such as the large number of species in the tropics, and the many endemic species on isolated islands. Throughout the book, Price emphasizes the integration of behavior, ecology, and genetics.

how reproductive isolation leads to speciation: Ecological Speciation Patrik Nosil, 2012-03-15 The origin of biological diversity, via the formation of new species, can be inextricably linked to adaptation to the ecological environment. Specifically, ecological processes are central to the formation of new species when barriers to gene flow (reproductive isolation) evolve between populations as a result of ecologically-based divergent natural selection. This process of 'ecological speciation' has seen a large body of particularly focused research in the last 10-15 years, and a review and synthesis of the theoretical and empirical literature is now timely. The book begins by clarifying what ecological speciation is, its alternatives, and the predictions that can be used to test for it. It then reviews the three components of ecological speciation and discusses the geography and genomic basis of the process. A final chapter highlights future research directions, describing the approaches and experiments which might be used to conduct that future work. The ecological and genetic literature is integrated throughout the text with the goal of shedding new insight into the speciation process, particularly when the empirical data is then further integrated with theory.

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Charles Darwin, 2020-12-04 On the Origin of Species (or, more completely, On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life),[3] published on 24 November 1859, is a work of scientific literature by Charles Darwin which is considered to be the foundation of evolutionary biology.[4] Darwin's book introduced the scientific theory that populations evolve over the course of generations through a process of natural selection. It 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.

how reproductive isolation leads to speciation: *Concepts of Biology* Samantha Fowler, Rebecca Roush, James Wise, 2023-05-12 Black & white print. *Concepts of Biology* is designed for the typical introductory biology course for nonmajors, covering standard scope and sequence requirements. The text includes interesting applications and conveys the major themes of biology, with content that is meaningful and easy to understand. The book is designed to demonstrate biology concepts and to promote scientific literacy.

how reproductive isolation leads to speciation: *Evolution's Wedge* David Pfennig, Karin Pfennig, 2012-10-25 Evolutionary biology has long sought to explain how new traits and new species

arise. Darwin maintained that competition is key to understanding this biodiversity and held that selection acting to minimize competition causes competitors to become increasingly different, thereby promoting new traits and new species. Despite Darwin's emphasis, competition's role in diversification remains controversial and largely underappreciated. In their synthetic and provocative book, evolutionary ecologists David and Karin Pfennig explore competition's role in generating and maintaining biodiversity. The authors discuss how selection can lessen resource competition or costly reproductive interactions by promoting trait evolution through a process known as character displacement. They further describe character displacement's underlying genetic and developmental mechanisms. The authors then consider character displacement's myriad downstream effects, ranging from shaping ecological communities to promoting new traits and new species and even fueling large-scale evolutionary trends. Drawing on numerous studies from natural populations, and written for a broad audience, *Evolution's Wedge* seeks to inspire future research into character displacement's many implications for ecology and evolution.

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how reproductive isolation leads to speciation: Adaptive Diversification Michael Doebeli, 2011-08-01 Understanding the mechanisms driving biological diversity remains a central problem in ecology and evolutionary biology. Traditional explanations assume that differences in selection pressures lead to different adaptations in geographically separated locations. This book takes a different approach and explores adaptive diversification--diversification rooted in ecological interactions and frequency-dependent selection. In any ecosystem, birth and death rates of individuals are affected by interactions with other individuals. What is an advantageous phenotype therefore depends on the phenotype of other individuals, and it may often be best to be ecologically different from the majority phenotype. Such rare-type advantage is a hallmark of frequency-dependent selection and opens the scope for processes of diversification that require ecological contact rather than geographical isolation. Michael Doebeli investigates adaptive diversification using the mathematical framework of adaptive dynamics. Evolutionary branching is a paradigmatic feature of adaptive dynamics that serves as a basic metaphor for adaptive diversification, and Doebeli explores the scope of evolutionary branching in many different ecological scenarios, including models of coevolution, cooperation, and cultural evolution. He also uses alternative modeling approaches. Stochastic, individual-based models are particularly useful for studying adaptive speciation in sexual populations, and partial differential equation models confirm the pervasiveness of adaptive diversification. Showing that frequency-dependent interactions are an

important driver of biological diversity, Adaptive Diversification provides a comprehensive theoretical treatment of adaptive diversification.

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interested nonspecialist, the college student, and the general reader.

how reproductive isolation leads to speciation: Brenner's Encyclopedia of Genetics Stanley Maloy, Kelly Hughes, 2013-03-03 The explosion of the field of genetics over the last decade, with the new technologies that have stimulated research, suggests that a new sort of reference work is needed to keep pace with such a fast-moving and interdisciplinary field. Brenner's Encyclopedia of Genetics, Second Edition, Seven Volume Set, builds on the foundation of the first edition by addressing many of the key subfields of genetics that were just in their infancy when the first edition was published. The currency and accessibility of this foundational content will be unrivalled, making this work useful for scientists and non-scientists alike. Featuring relatively short entries on genetics topics written by experts in that topic, Brenner's Encyclopedia of Genetics, Second Edition, Seven Volume Set provides an effective way to quickly learn about any aspect of genetics, from Abortive Transduction to Zygotes. Adding to its utility, the work provides short entries that briefly define key terms, and a guide to additional reading and relevant websites for further study. Many of the entries include figures to explain difficult concepts. Key terms in related areas such as biochemistry, cell, and molecular biology are also included, and there are entries that describe historical figures in genetics, providing insights into their careers and discoveries. This 7-volume set represents a 25% expansion from the first edition, with over 1600 articles encompassing this burgeoning field. Thoroughly up-to-date, with many new topics and subfields covered that were in their infancy or not in existence at the time of the first edition. Timely coverage of emergent areas such as epigenetics, personalized genomic medicine, pharmacogenetics, and genetic enhancement technologies. Interdisciplinary and global in its outlook, as befits the field of genetics. Brief articles, written by experts in the field, which not only discuss, define, and explain key elements of the field, but also provide definition of key terms, suggestions for further reading, and biographical sketches of the key people in the history of genetics.

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complements. Forsdyke argues that the chemical basis of the origin of species by physiological selection is actually the species-dependent component of the base composition of DNA, showing that Romanes thus anticipated modern biochemistry. Using this new perspective Forsdyke considers some of the outstanding problems in biology and medicine, including the question of how self is distinguished from not-self by members of different species. Finally he examines the political and ideological forces that led to Romanes' contribution to evolutionary biology remaining unappreciated until now.

how reproductive isolation leads to speciation: *Hybrid Zones and the Evolutionary Process* Richard Gerald Harrison, 1993 Hybrid zones--geographical areas in which the hybrids of two races are found--have attracted the attention of evolutionary biologists for many years, both because they are windows on the evolutionary process and because the patterns of animals and plant variation seen in hybrid zones do not fit the traditional classification schemes of taxonomists. Hybrid zones provide insights into the nature of the species, the way barriers to gene exchange function, the genetic basis of those barriers, the dynamics of the speciation process. *Hybrid Zones and the Evolutionary Process* synthesizes the extensive research literature in this field and points to new directions in research. It will be read with interest by evolutionary biologists, geneticists, and biogeographers.

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criticism than evasion of an issue, he does not hesitate to choose that interpretation of a controversial matter which to him seems most consistent with the emerging picture of the evolutionary process.

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how reproductive isolation leads to speciation: *The Importance of Chemical "Speciation" in Environmental Processes* M. Bernhard, F.E. Brinckman, P.J. Sadler, 2012-12-06 Report, the editors replaced the term speciation wherever it occurred by identification and quantification, or description of abundance, or reactivity, or transformation of a chemical species, according to whichever one of the four meanings the author had evidently meant to convey. In line with the Dahlem Workshop Model, this Report comprises the background papers written in advance of the meeting on the current status of problems in environmental research and on advanced analytical techniques for the identification and quantification of chemical species, as well as the group reports summarizing the results of the discussions held during the meeting. Each group report was prepared during the meeting by one rapporteur with the help of members of that group and finalized by the rapporteur (listed as the first author of the group report) after the meeting, taking into account both verbal comments made during the presentation of the reports in the plenary session at the end of the workshop and written comments received afterwards.

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seed production to take place, include some of the most varied and fascinating mechanisms in the whole world of living things. This edition is exclusive to newnaturalists.com The role of insects in pollinating flowers is today a commonplace - so that it is easy to forget that its discovery is little older than the invention of the steam engine: before that, we imagined that the concern of bees with flowers was simply a matter of collecting honey. But the methods by which pollen grains reach a stigma, enabling fertilization and seed production to take place, include some of the most varied and fascinating mechanisms in the whole world of living things. This book, an important addition to the New Naturalist series and to scientific literature, is a clear and thorough account of all the ways in which pollination is effected - by wind, water, even bats; but principally, in many curious ways, by diversity of insect species. The authors are both distinguished botanists - Dr. Proctor at Exeter University, Dr. Yeo at Cambridge - with a wide knowledge of insects. Illustrated with 134 of their own drawings, with 19 photographs in colour and 180 in black and white, the book offers a unique introduction to a complex yet easily accessible subject of great fascination.

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Comprehensive Virology. Chapters in that series contained physical-genetic maps but very little DNA sequence information. Now the complete DNA sequence is known for some phages, and the sequences for others will soon follow. During the past 10 years two phages have come into common use as reagents: A phage for cloning single copies of genes, and M13 for cloning and DNA sequencing by the dideoxy termination method. Also during that period the use of alternative sigma factors by RNA polymerase has become established for SP01 and T4. This seems to be a widely used mechanism in bacteria, since it has been implicated in sporulation, heat shock response, and regulation of nitrogen metabolism. The control of transcription by the binding of A phage CII protein to the -35 region of the promoter is a recent finding, and it is not known how widespread this mechanism may be. This rapid progress made me eager to solicit a new series of reviews. These contributions are of two types. Each of the first type deals with an issue that is exemplified by many kinds of phages; chapters of this type should be useful in teaching advanced courses. Chapters of the second type provide comprehensive pictures of individual phage families and should provide valuable information for use in planning experiments.

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When populations become reproductively isolated, they can evolve into two separate species. Reproductive isolation can develop in a variety of ways, including behavioral isolation, ...

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reproductive isolation prevents interbreeding and consequently gene flow between different species. In this article, different types of isolating mechanisms are defined and a few examples ...

Rapid experimental evolution of reproductive isolation from a ...

Here, we show that experimental evolution of parasite body size over 4 y (approximately 60 generations) leads to reproductive isolation in natural populations of feather lice on birds. ...

Reproductive isolation speciation flowering plants

Reproductive isolation that leads to speciation in flowering plants. Geophytology 43(1): 79-84 In sexually reproducing organisms, two different species are always separated by reproductive ...

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The objectives of this paper are as follows: (1) to summarize data on the nature of genic differences within and between species and their bearing on the causes of reproductive isolation.

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17.3 The Process of Speciation - Rancocas Valley Regional ...

May 12, 2010 · Identify the types of isolation that lead to the formation of new species. Describe the current hypothesis about Galápagos finch speciation. A. The chart below shows key terms ...

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Reproductive isolating mechanisms will eventually evolve in the absence of gene flow. Female choice can play an important role in species formation, as illustrated by the cichlid fishes and ...

Topic 10.3: SPECIATION - BioNinja

Reproductive isolation occurs when barriers prevent two populations from interbreeding (gene pools kept separate) • Without gene flow, the gradual accumulation of genetic

Reproductive isolation Hybrids Modes of speciation Other ...

Allopatric speciation \Separate homelands" A population is divided by a physical barrier, and the two parts evolve separately No selection for reproductive isolation Isolation can develop as a ...

9 Modes of speciation. The formation of new species requires ...

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Reproductive isolation combines traits that reduce gene flow, such as mate choice or fertilization barriers, with traits that select against genes that have flowed, such as hybrid incompatibility

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