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AP BIOLOGY

Big Idea 1
Part C

August 2012

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Big Idea 1: Part C

Click on the topic to go to that section

- Modern Synthesis
- Population Genetics
- Macroevolution
- Reproductive Isolation

Modern Synthesis

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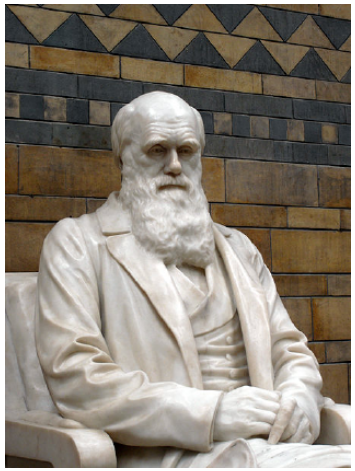
The Modern Synthesis of Evolution

Today the work of Darwin has been combined with thework of Mendel and new discoveries about the nature of genes and heredity to form the **modern synthesis.**

This represents our best knowledge of how populations evolve and how new species come to be on this planet.



Darwin

Natural History Museum, London

+

Mendel

University of Agriculture and Forestry
Brno,Czech Republic.

?

Sheep/ Goat genetic hybr
Created by geneticists,

University of California

The Modern Synthesis of Evolution

Mendel and Darwin began a branch of study that was at the time hard to believe for many, and it was incomplete.

Mendelian genetics needed to be reconciled with gradual evolution by means of natural selection as proposed by Darwin.

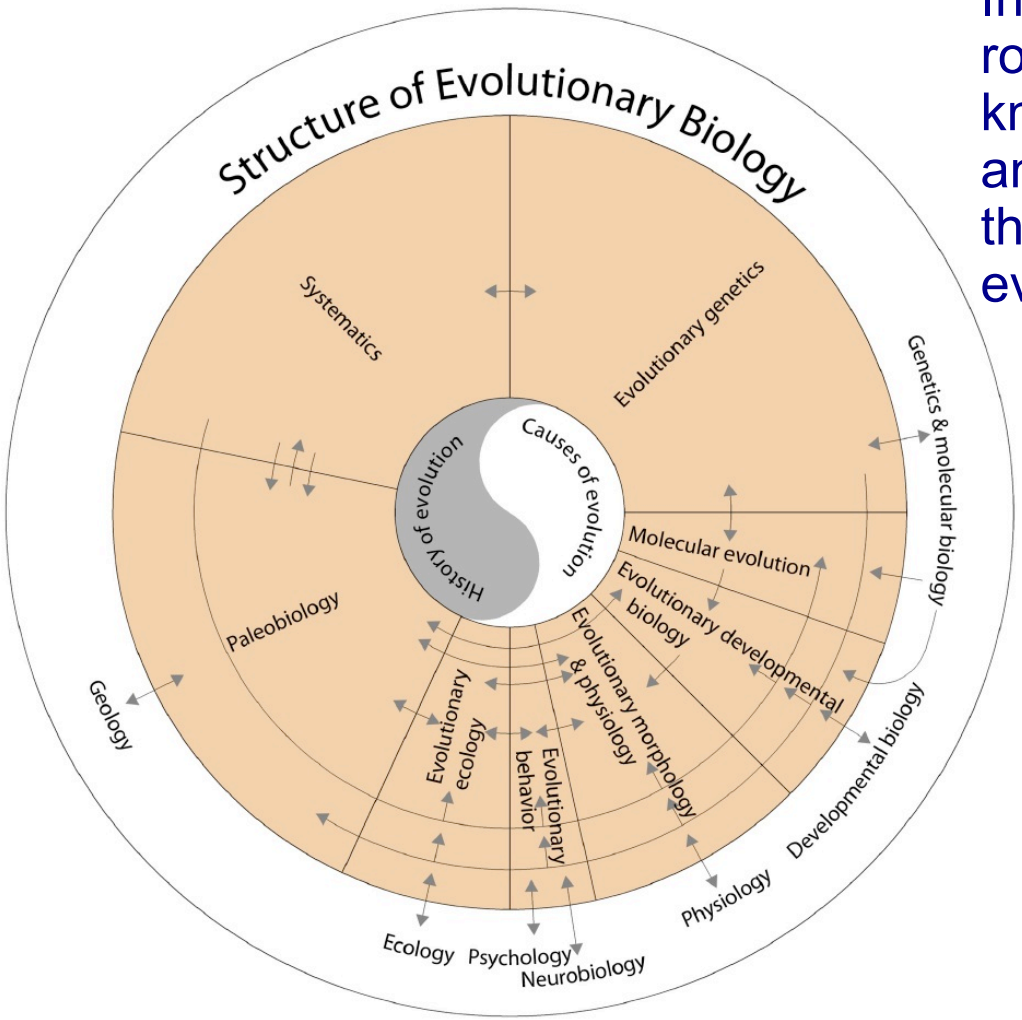
Another issue was whether the broad-scale changes, or **macroevolution** seen in the fossil record could be explained by changes seen in populations (**microevolution**).

The Modern Synthesis of Evolution

The synthesis drew together ideas from several branches of biology including genetics, biochemistry, systematics, botany, morphology, ecology and **paleontology**, the study of prehistoric life.

The modern synthesis includes evidence from biologists, trained in genetics, who studied populations in the field and in the laboratory. These studies were crucial to evolutionary theory.

The Modern Synthesis of Evolution



In fact all sciences that have a root in biology stem from the knowledge gained by Darwin and Mendel and contribute to the new understanding of evolution.

What We Have Learned Since Darwin and Mendel

The following is a short list of some of the important discoveries that helped to clarify parts of evolutionary theory after the time of Darwin.

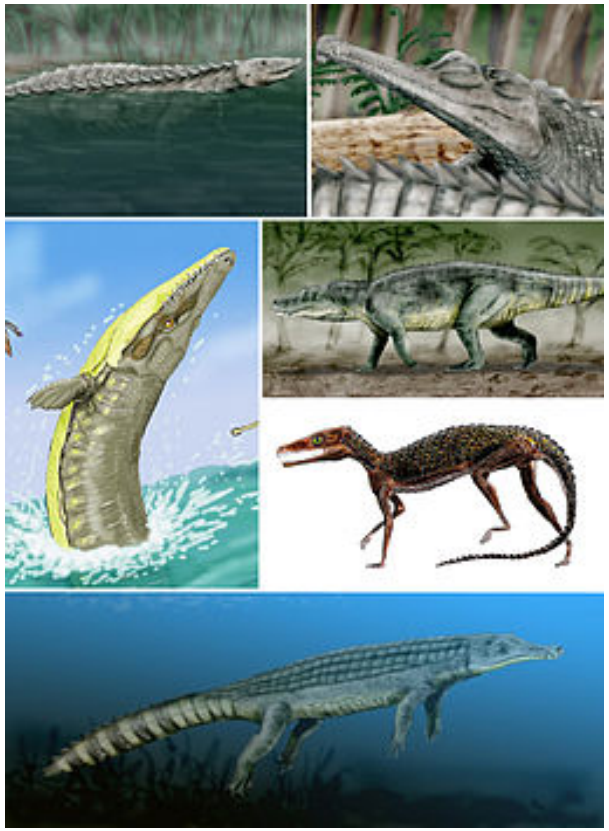
- The age of the Earth has been more precisely dated
- Continental drift discovered, leading to the idea of **Pangea**, a single original land mass
- A massive expansion of the fossil record that now includes remains of early microbial life as well as countless more examples of transitional organisms

Other understandings have clarified evolution further, but these 3 points transformed our understanding of the natural world independently of Darwin's theory. Each is partly responsible for strengthening the theory of biological evolution.

Time

Time was a big problem for Darwin. In his day it was believed that the Earth was about 6,000 years old.

This was a problem for Darwin's theory because this small amount of time would not be enough for all of the diversity of life we see on this planet to have come into existence.



Pan-crocodilians. If all evolved from a common ancestor it would have require millions of years.

Time

Modern geology, by **radiometric dating** and study of the Earth's **strata** (layers of rocks and soil), has shown that the earth is about 4.6 billion years old.

That is about 766,667 x 6,000. This is more than enough time to account for the diversity of life by Darwin's and Mendel's theories.

Time: Radiometric Dating

By measuring the decay of radioactive particles that are present in all organisms and the ground in which fossils are found, scientists can accurately determine the age of life and layers in the Earth.

Click here to see a video that will explain **carbon dating** which is one of the most useful forms of dating for biologists.

Time: Strata

Over the Earth's history sediment has been deposited over and over again forming the crust of our planet. Large scale changes in atmosphere, catastrophic events and the processes of the Earth have formed layers of rock that are universal to the entire planet.

The Grand Canyon was formed by erosion, exposing millions of years of Earth's history.

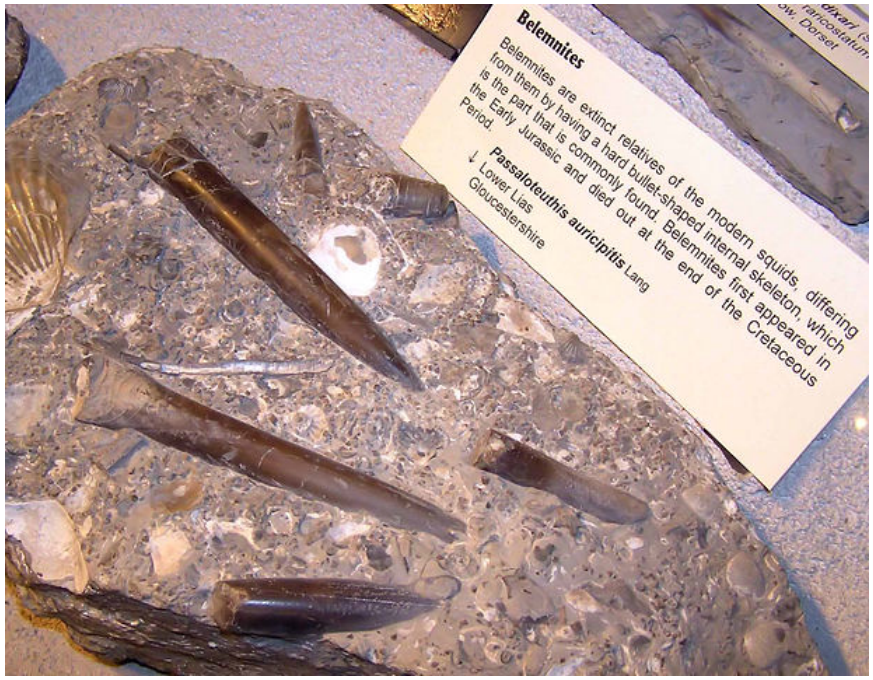
The Grand Canyon

Click here to see a video that will explain **strata formation** in the Grand Canyon.

Time: Strata

Since these layers in our planets crust form a timeline of events, paleontologists can accurately date fossils that are seen in each layer.

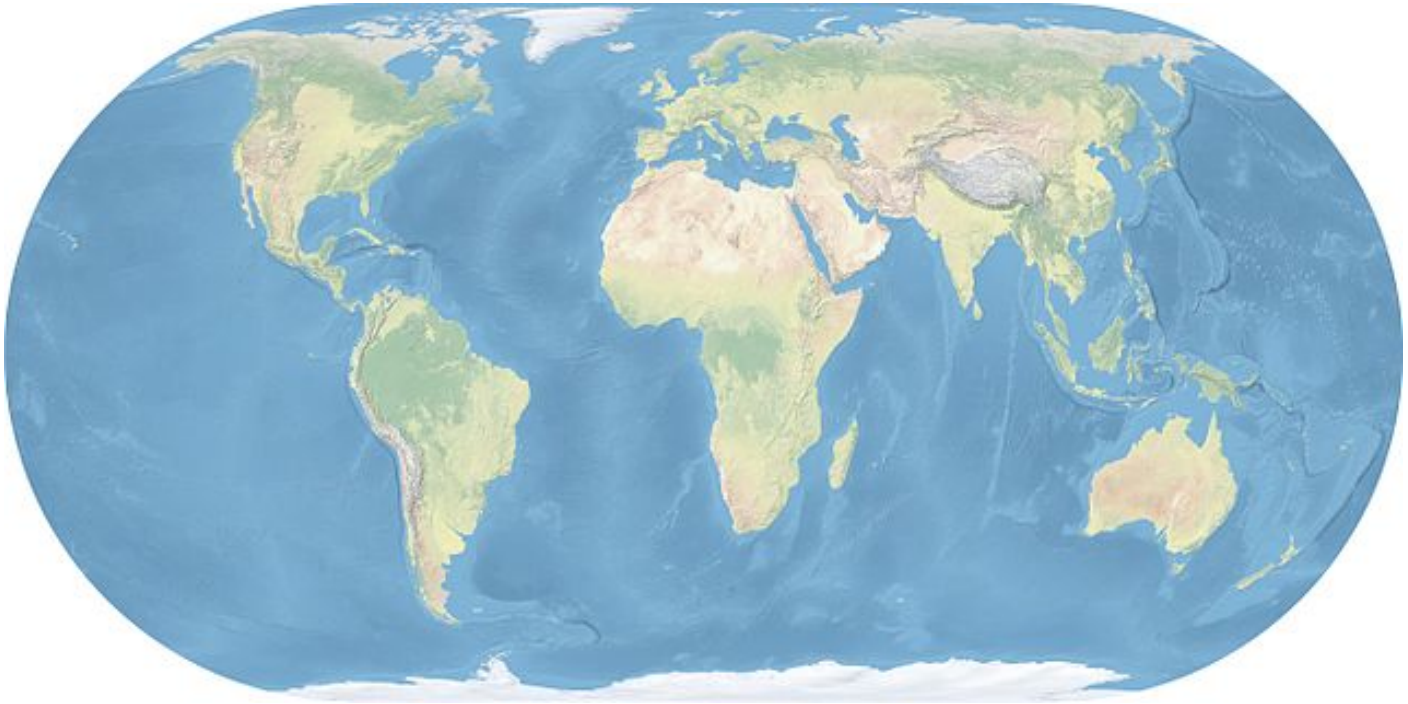
They can also determine when species come into existence and when they go extinct in reference to the Earth's history.



Pangea

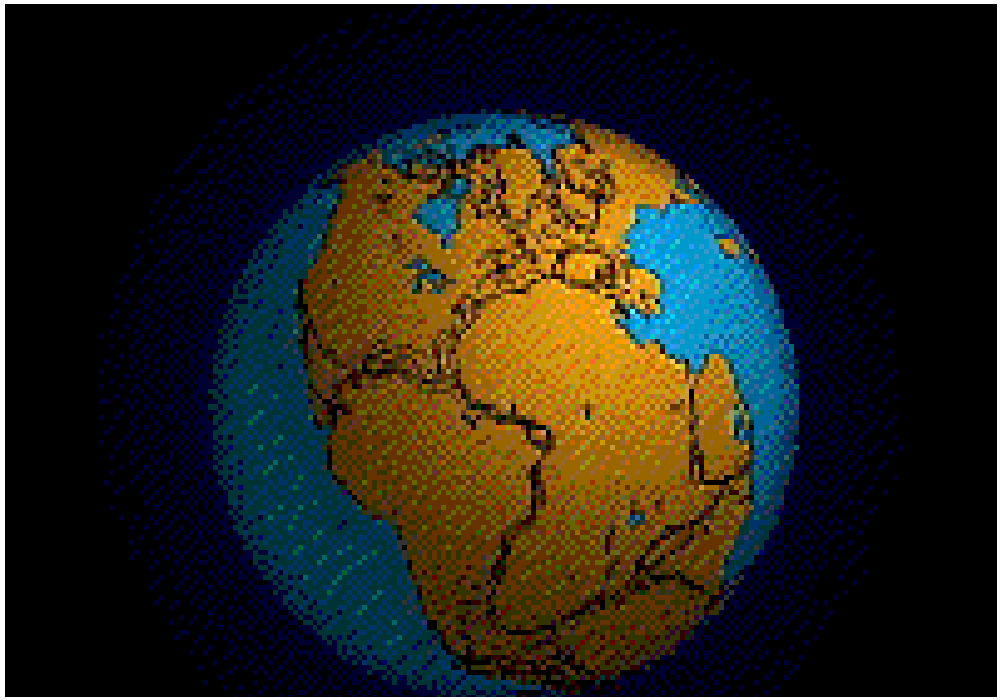
Another problem for Darwin, during his time the common belief was that the continents were fixed land masses.

How could species that seem to be related, be located on different continents if they could not travel by boat or swim?



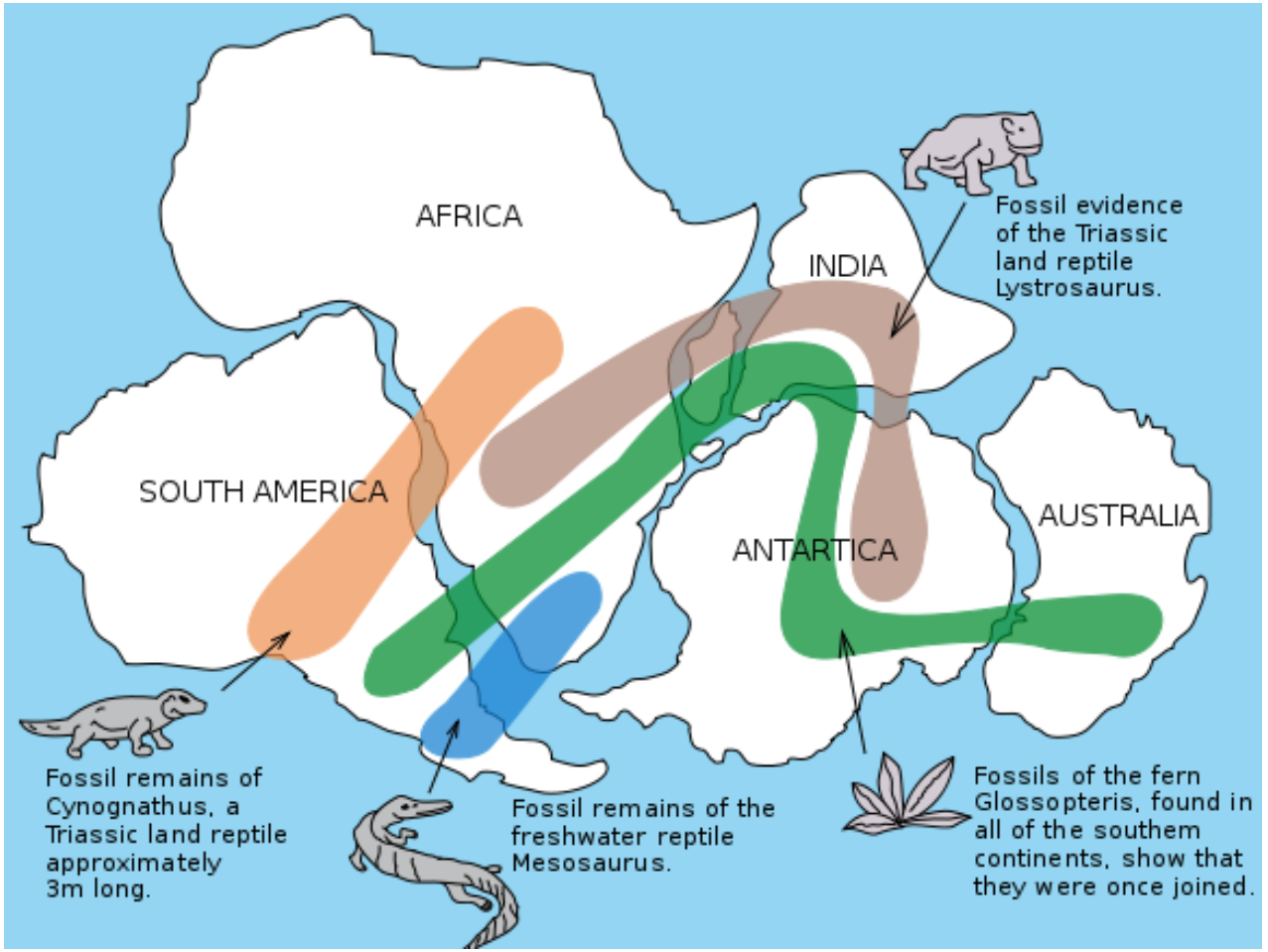
Pangea

Geologists since Darwin's time discovered continental drift. Plate tectonics, the study of large scale motion of floating plates that make up the Earth's crust, showed that all the continents were one large mass about 300 million years ago.



Pangea

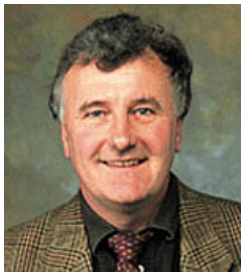
Over the next 100 million years the continents drifted apart and broke apart populations of life that existed at the time.



The Fossil Record

"The fossil record has yielded many secrets since the times of Charles Darwin. There were many missing '**intermediate forms**' in Darwin's time, as he recognized, but these have been found in the subsequent century. Notably, fossils have been found supporting the connection between marine and terrestrial organisms, and outlining the early ancestors of humankind."

- Richard Fortey, Natural History Museum Paleontologist

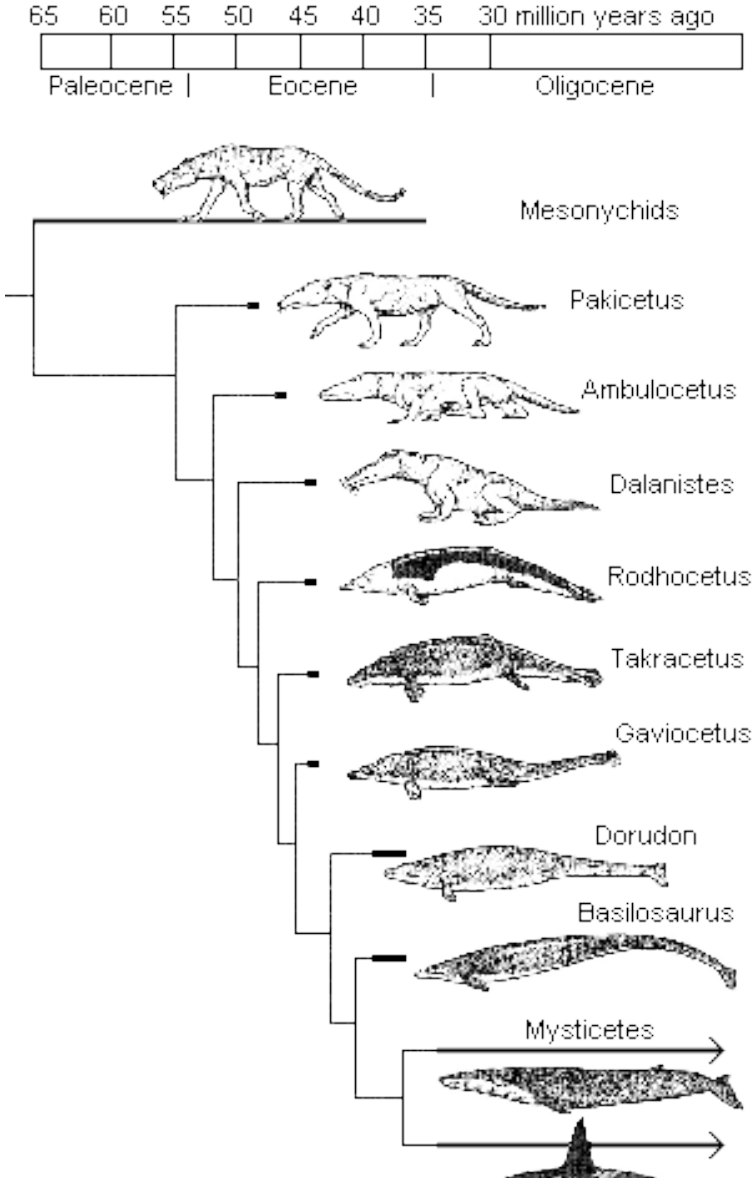


The Fossil Record: Example

Whale ancestors walked on land:

Darwin knew that mammals had evolved on land and could not show how whales, water dwelling mammals, could have evolved.

Paleontologist have discovered a fossil record of intermediate species showing the progression of land mammals evolving into species that relied on water hunting, then into ocean dwelling mammals.



To Sum Up the Modern Synthesis...

The Earth is home to life as we know it. Our better understanding of Earth's evolution shows that life had to evolve with the planet in order to survive.

We now know that large tracts of time, and geographic changes that created barriers and challenges for the populations that lived on it, helped form the diversity of life we see today.

Mathematics to Show Evolution

The section that follows uses mathematical models to show how Mendel's mechanisms of inheritance drive the change and diversity brought about by Darwin's theory of evolution.

But first we will review some key ideas and vocabulary.

1 A variation of a gene is known as

- A mutation
- B allele
- C genotype
- D phenotype

answer

2 Red hair would be an example of

- A mutation
- B allele
- C genotype
- D phenotype

answer

3 Heterozygous, homozygous recessive are terms for

- A mutations
- B alleles
- C genotypes
- D phenotypes

answer

4 Which of these is a population?

- A The species Rattus norvegicus (brown rats)
- B The life in the sewage system of New York City
- C The life in the sewage system of New York City plus the water
- D The brown rats living in the sewage system of NYC

answer

5 Which of these are conditions that must be met in order to keep a population from evolving? (multiple answers)

- ☐ A Large population
- ☐ B Small population
- ☐ C Non-random mating
- ☐ D Random mating
- ☐ E Gene flow
- ☐ F No gene flow
- ☐ G No mutations
- ☐ H Mutations
- ☐ I No Natural Selection
- ☐ J Natural selection

answer

6 The smallest unit of evolution is

- A an individual organism
- B a species
- C a population
- D a community

answer

7 If a sexually reproducing population's size is 350,000 individuals, then the total gene pool (number of alleles) for a single gene trait within the population is_____.

answer

8 What is the expected phenotypic ratio of a monohybrid cross (2 heterozygous individuals) for a trait that shows complete dominance?

- A 1:2
- B 1:3
- C 1:4
- D not enough information

answer

9 AaBb X AaBb

What would be the expected phenotypic ratio for the above cross if the 2 traits are linked?

- A 1:1
- B 3:1
- C 9:3:3:1
- D not enough information

answer

10 AaBb X AaBb

What would be the expected phenotypic ratio for the above cross if the 2 traits are unlinked and show complete dominance?

- A 1:1
- B 3:1
- C 9:3:3:1
- D not enough information

answer

Population Genetics

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Population Genetics

To practice the concepts of population genetics try to explain the observations below.

In 1932 a large pine tree forest in upstate New York suddenly began to die. Scientists identified a disease microbe that was responsible but could not find a cure. In 5 years 96% of the original population perished.

Population Genetics

A scientist noticed that some of the trees were unaffected and began to record data. He observed the trees that survived the epidemic began to produce new trees quickly.

Within 50 years the pine tree forest returned to its original population size.

Population Genetics

Suggest a reason as to why a small number of trees survived this epidemic.

Population Genetics

In 2005 a few trees had perished in the same forest. Fearing the worst, biologists tested the dead trees and found the disease had returned. However, by 2010 only about 10% of the trees perished.

In terms of our modern understanding of biology, suggest a hypothesis for the change in death rate for exposure to this disease. Then briefly outline a procedure for testing your hypothesis.

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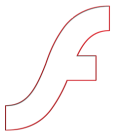
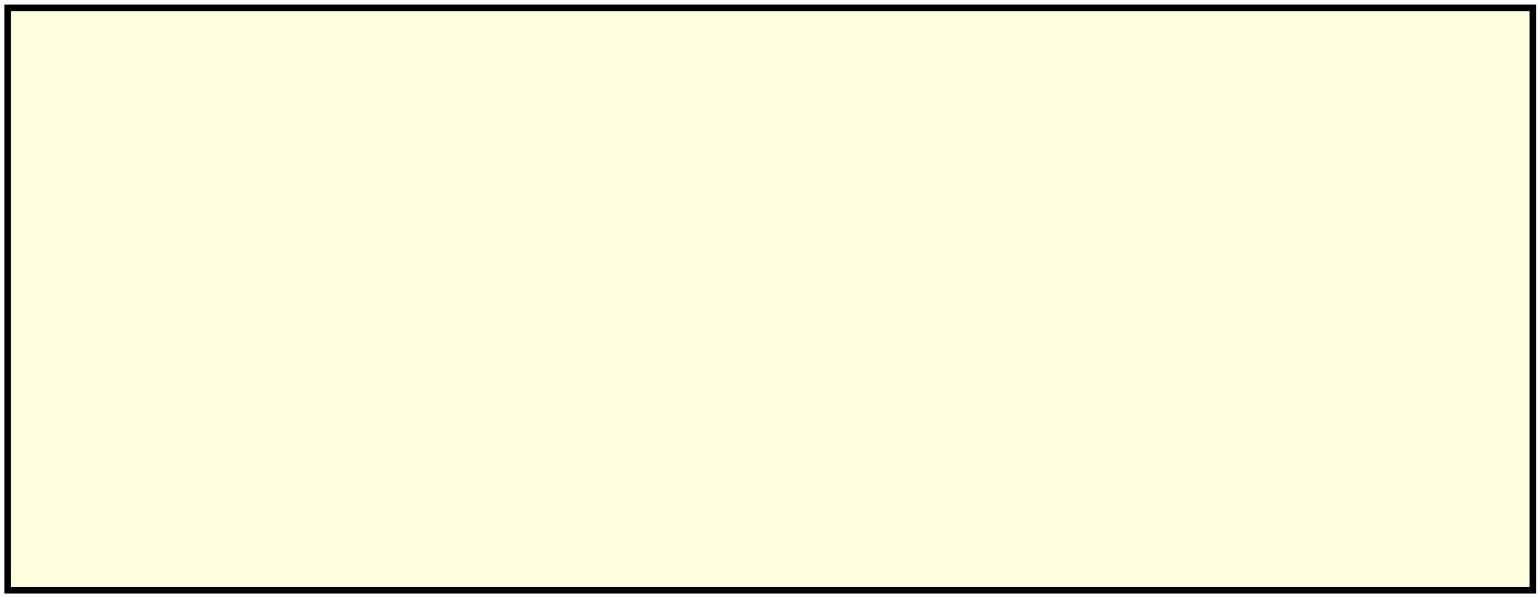


Population Genetics

Click below to compare your ideas to the real story.



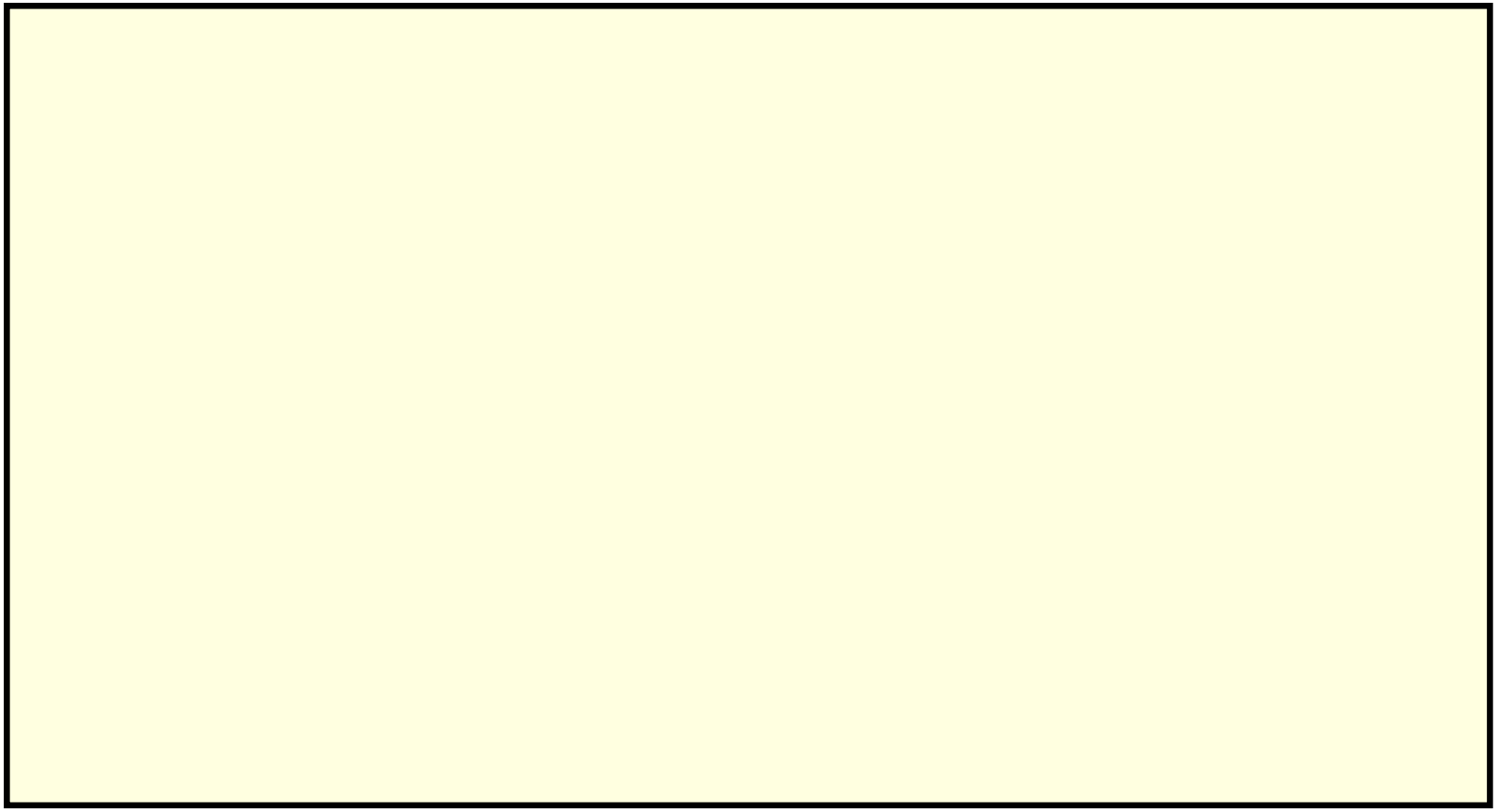
Population Genetics

The researchers labeled the alleles D+ for having the mutation that causes immunity, and D- for no immunity. Curious to know why some of the trees died even though all of them are descendants from immune trees, the biologists did controlled test crosses.

Suggest a hypothesis for why some trees still die from the disease and suggest test crosses that will help support or refute your ideas.

Population Genetics

Click below to compare your ideas to the real story.



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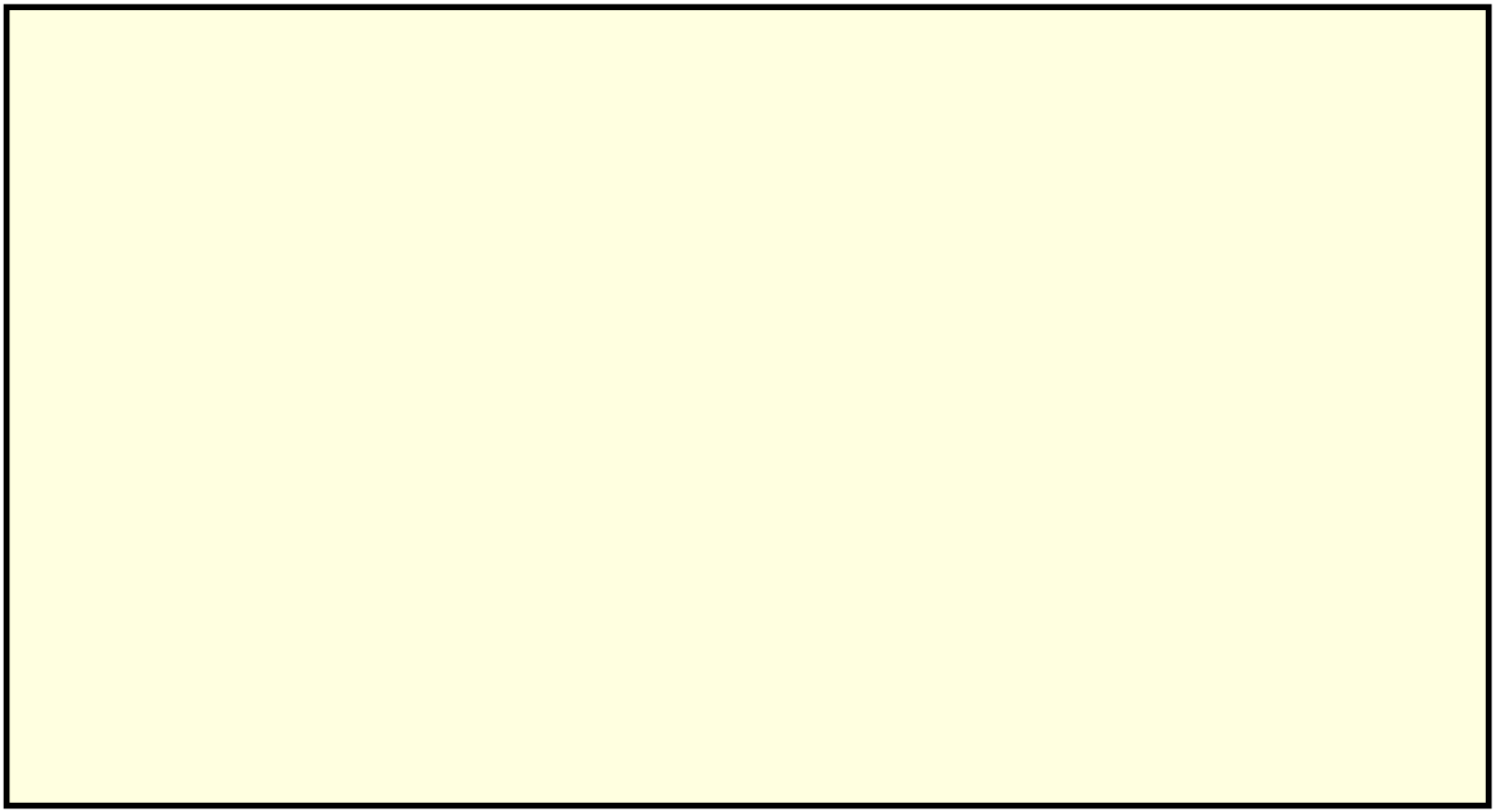
Population Genetics

Click below to compare your ideas to the real story.



Population Genetics

That same year, 2010, a forest fire ripped through the ill fated pine lot. In 2012 the same researcher returned to test what effect the fire had on the immunity gene of the population. He tested the immunity of over 1,000 individual saplings.

Population Genetics

He used the Hardy - Weinberg equation to see if the population had evolved.

Remember:

- Changes in allelic frequency of a population means that the population has evolved.

- The population is considered a whole so it equals 1

- p = the allelic frequency of the dominant allele (D+)
- q = the allelic frequency of the recessive allele (D-)
- p^2 = the proportion of individuals who are homozygous dominant (D+D+)
- 2pq = the proportion of individuals who are heterozygous carriers (D+D-)
- q^2 = the portion of individuals who are homozygous recessive (D-D-)

- The first equation: **$p^2 + 2pq + q^2 = 1$ (whole population)**

- The second equation: **$p + q = 1$ (whole population)**

Population Genetics

The data collected about the forest (Table A):

Year	sample size	number of non immune
1932	unknown	96% of total
2010	3,375	283
2012	1,112	178

Before proceeding to the questions on the next slides, prepare a data table that will allow you to compare the allelic frequency of the immunity gene when the calculations are done (Table B).

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11 What proportion of the population in 1932 was homozygous recessive?

answer

12 Calculate the allelic frequency of D- and D+ in the 1932 population ?

answer

answer

13 Using data Table A calculate the proportion of the population that was homozygous recessive in 2010.

answer

14 Calculate the allelic frequency of D- and D+ in the 2010 population.

answer

answer

15 Using data Table A calculate the proportion of the population that was homozygous recessive in 2012.

answer

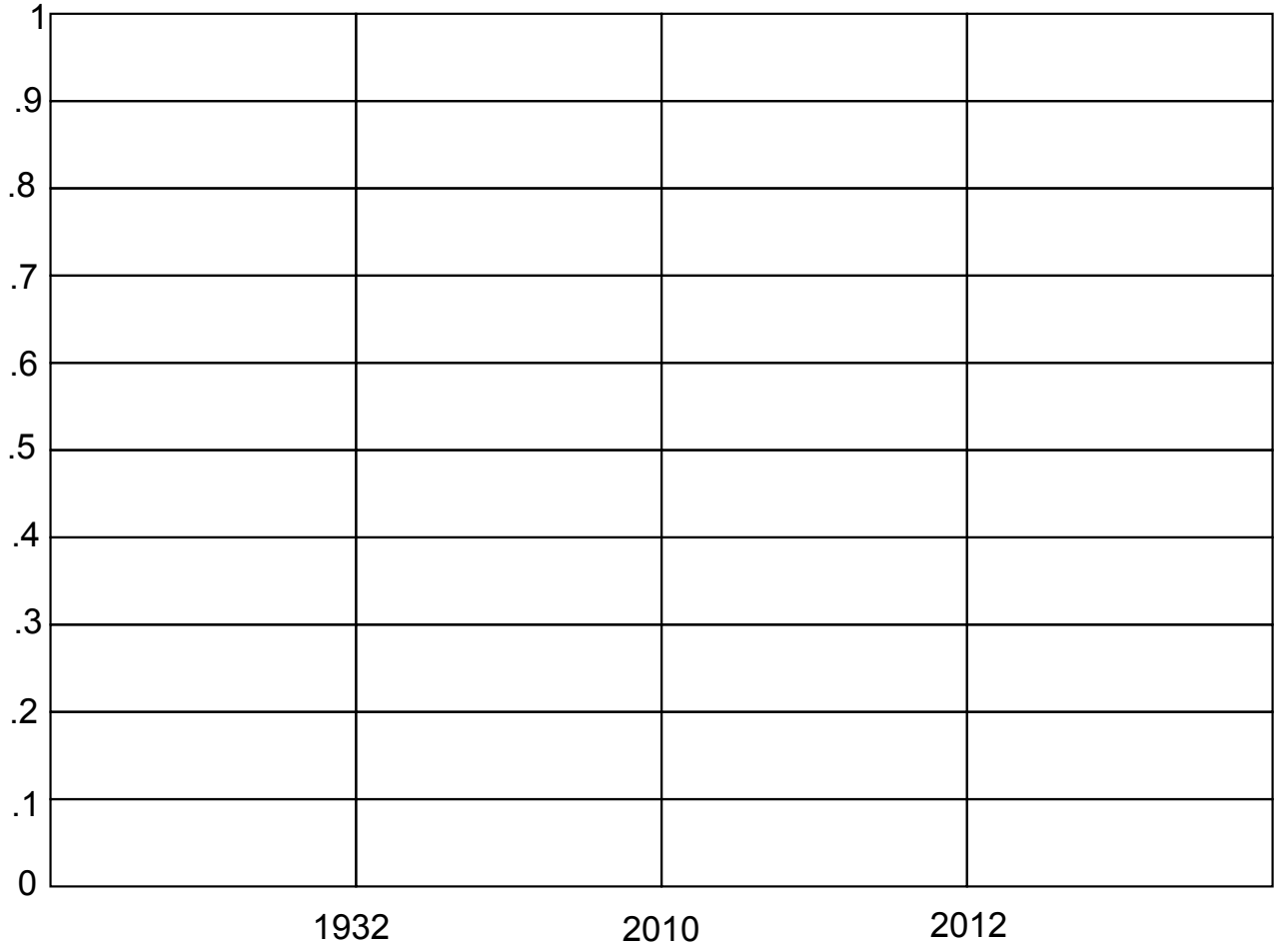
16 Calculate the allelic frequency of D- and D+ in the 2012 population.

answer

answer

Population Genetics

Create a point graph the data for allelic frequency against years of catastrophic events to compare the changes after each:



Population Genetics

Has this population evolved?

Write a statement that summarizes the evolution of the immunity gene in this population over time.

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Population Genetics

Just when the researcher thinks he is done studying this forest, a colleague asks if she can use the data for her study.

She is studying the heterozygosity of traits in pine trees in areas around New York and thinks your data can predict how many trees in this population are heterozygous for the immunity trait.

17 An estimate was done and the total individual trees in the pine forest was 50,000. How many heterozygous trees are in this population for 2012?

answer

Macroevolution

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What About Macroevolution?

The Hardy-Weinberg equation mostly accounts for evolution within a species, or microevolution.

Macroevolution is when a gene pool becomes so diverse that members of its population become new species.

A species is defined as an interbreeding population capable of producing viable offspring.

Bulldog bat
and
Leaf nosed bat

closely related but
not the same
species

What About Macroevolution?

The seperation of of a population into 2 distinct species comes about because the allelic variation becomes so great that contradicting behavior begins and portions of the population become reproductively isolated from one another.

This can be because:

- geographic barrier/location/habitat preference
- diverse mating rituals cause females to choose mates for different, consistent reasons
- a new food source produces opportunity that only a portion of the population takes advantage of.

Many other reasons can apply. Ultimately there is a separation in the gene pool that makes up the population

What About Macroevolution?

Choose one of the species below to use to plan an experiment to test the concepts of speciation.

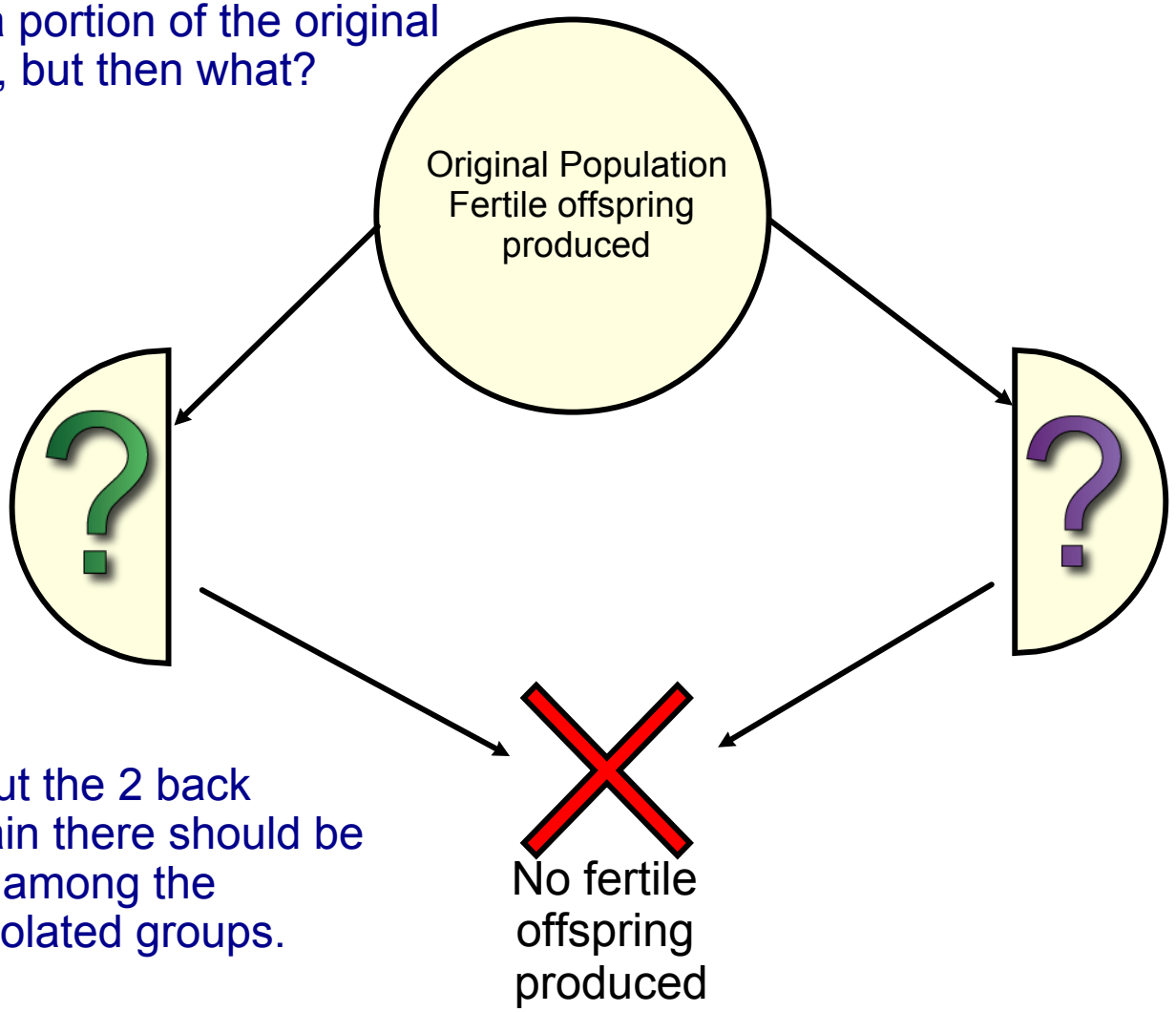
Lab Rats
Fruit Flies
Pea plants

What About Macroevolution?

You are given a population of your organism of choice, a fully equipped lab, and all the time you need. You want to see if you can coax your existing population into two separate, non breeding populations.

What About Macroevolution?

You realize your first step will be to isolate a portion of the original population, but then what?



When you put the 2 back together again there should be no breeding among the previously isolated groups.

What About Macroevolution?

Consider the factors that separate gene pools in nature and design your experiments.

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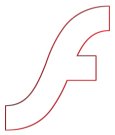


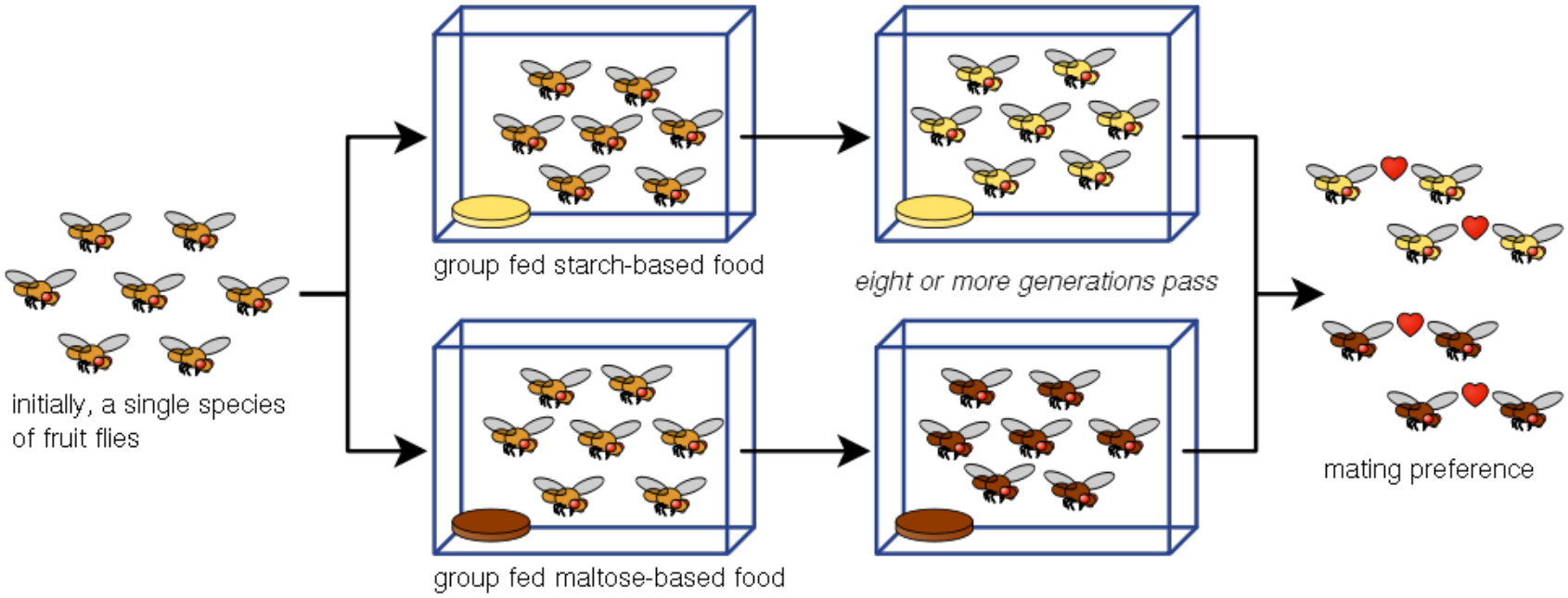
Dodd's Fruit Flies

An experiment demonstrating allopatric speciation in the fruit fly was conducted by Diane Dodd.

A single population of flies was divided into two, with one of the populations fed with starch-based food and the other with maltose-based food.

After the populations had diverged over many generations, the groups were again mixed; it was observed that the flies continued to prefer mating with others from the same original population.

Dodd's Fruit Flies



Consider that if these 2 groups no longer have sex or offspring, their separate gene pools will no longer be sharing mutations or the microevolutionary changes we have seen. Eventually their genetics will no longer be similar enough to produce offspring.

Allele Frequency is Influenced by Many Factors

We have seen many examples of a population evolving because the allele frequency is affected by some environmental influence.

However, we have just scratched the surface of possible factors that can change a population. Let's look at a few more to be sure that we get a big picture of how evolution drives unity and diversity.

Predator vs Prey

Most defenses and weapons that are found in nature exist because of **predation**, one species using another as food.

The impala has become faster over time because it is constantly hunted by big cats. Big cats have evolved speed, stealth and claws for grabbing to counter the improved speed of the impala.

Predator vs Prey

Take a moment and write down a paragraph that explains the evolution of the features of impalas in terms of alleles, gene pools and populations. Share your explanation with your group.

Remember:
If you are writing about the impala population then the cat is an environmental factor that selects alleles, this is known as a **selective pressure**. When writing about the cat population the impala is the selective pressure.

Genetic Drift

Genetic Drift happens when the allelic frequencies in a population change due to chance events.

We will look at 2 examples of genetic drift.

1. The bottleneck effect

2. The founder effect

Bottleneck Effect

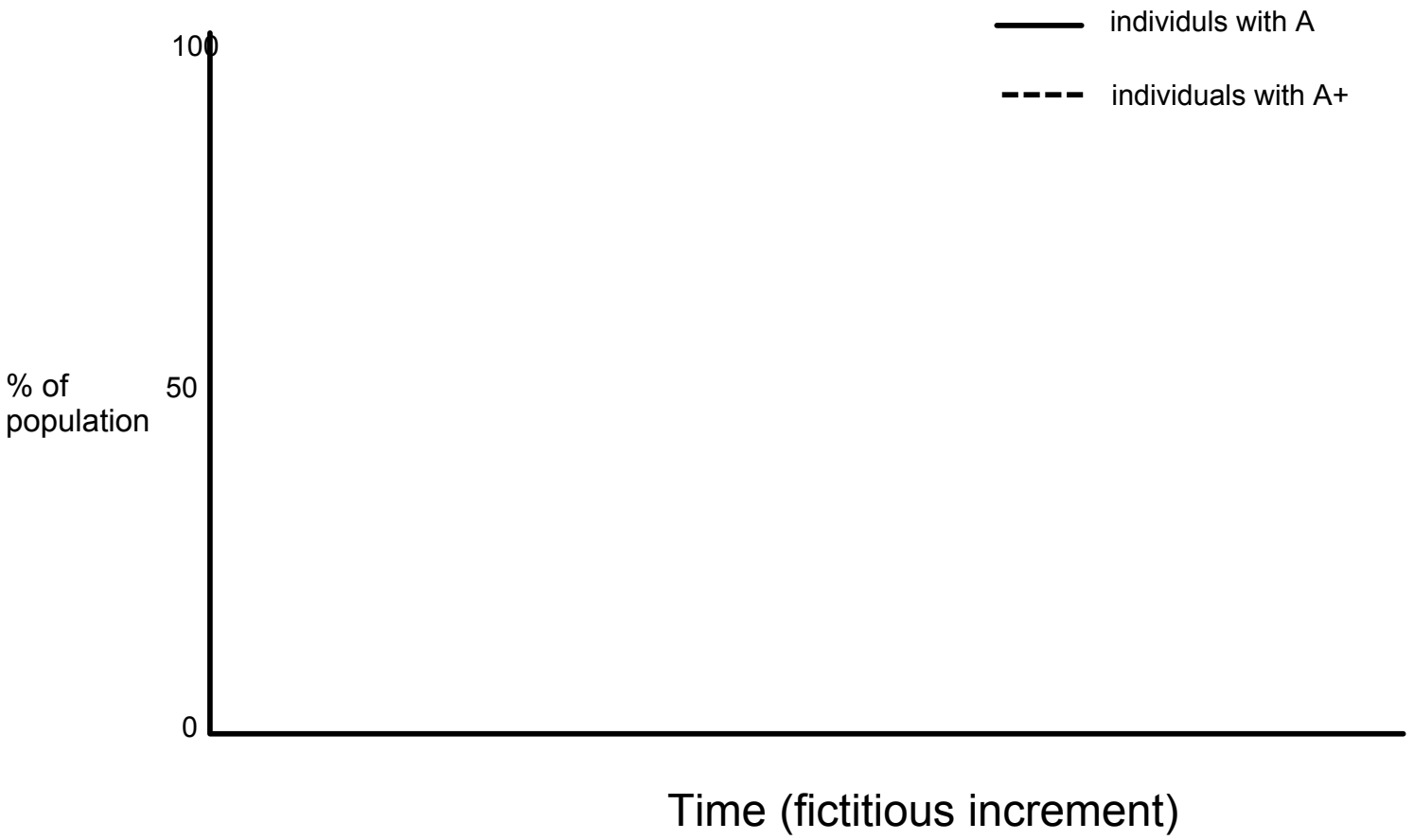
A population of bacteria has a low frequency of allele A, only 2%, in their gene pool. This allele slows the bacterias' reproductive process. Individuals with allele A+ can reproduce faster and dominate the population.

A toxin is introduced into this population and it is lethal to any individual who does not posses the A allele.

What will happen to this population over time?

Bottleneck Effect

Draw a graph that shows the population before, during and after this toxic event. Can you see why it is called a bottleneck?

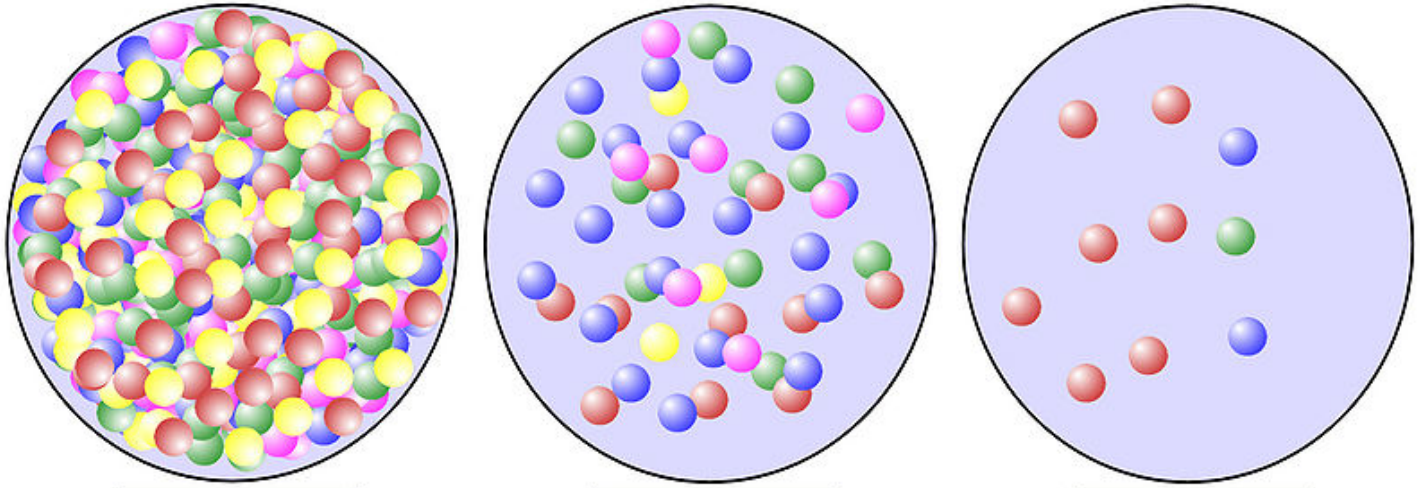


Bottleneck Effect

Bottleneck Effect happens when most of the population is killed off due to natural disaster such as fire, flood, volcano, or earthquake.

As a result, all of the alleles carried by these individuals are lost.

Bottleneck Effect



Initial frequency distribution	
	0.20
	0.20
	0.20
	0.20
	0.20

5th generation frequency distribution	
	0.40
	0.06
	0.20
	0.14
	0.20

10th generation frequency distribution	
	0.20
	0.00
	0.10
	0.00
	0.70

Founder Effect

A large population of fish live in a lake in western Oregon. These fish are usually blue in color, but a mutation causes a new allele (B+) leading to pink color.

Over time B+ is passed to future generations and a small group of these fish are pink.

Founder Effect

A pet supply company finds out about the new kind of fish and is interested in selling them to the public. They take a sample of this population of fish but only take the pink variety.

In an isolated man-made tub, these fish are bred to produce fish that they can sell.

18

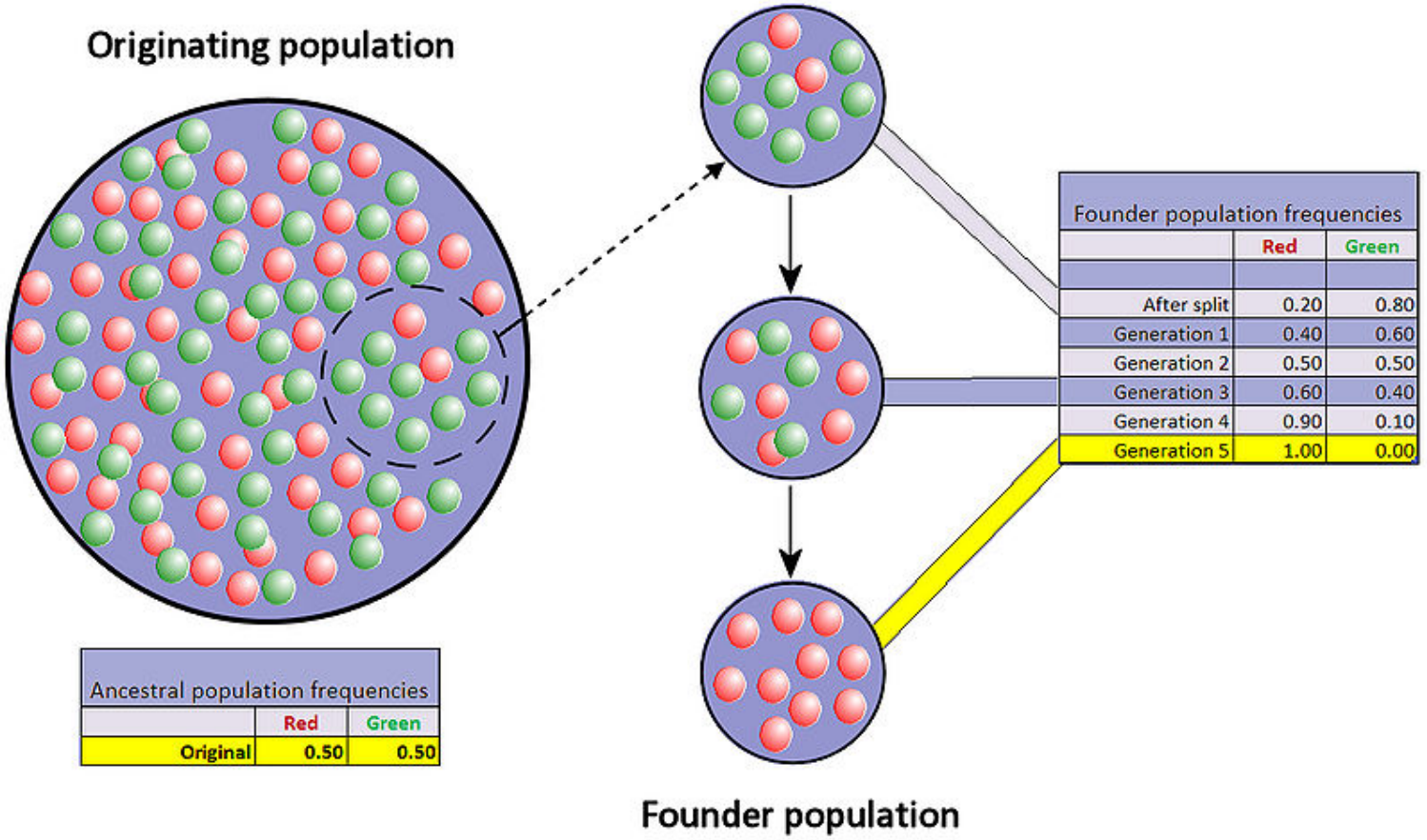
- Yes
- No

Founder Effect

The Founder Effect occurs when a very small group of individuals are a new group (in a new area) and are the "founders" of the new population.

Because there are so few individuals, there is decreased genetic variability. Once alleles are lost in a population, it is extremely difficult to get them back.

Founder Effect



Ancestral population frequencies		
	Red	Green
Original	0.50	0.50

Founder population frequencies		
	Red	Green
After split	0.20	0.80
Generation 1	0.40	0.60
Generation 2	0.50	0.50
Generation 3	0.60	0.40
Generation 4	0.90	0.10
Generation 5	1.00	0.00

Gene Flow Gets Interrupted

If gene flow of a population is interrupted for some reason and 2 or more new populations form in its place, it can lead to **speciation**. This is the beginning of a new **species**.

Species

According to the biological species concept definition...

A species is defined as a group of organisms capable of interbreeding and producing fertile offspring.

In other words, a group of organisms must have the ability to pass their gene pool on to future generations and individuals in the group must not be reproductively isolated from other individuals.

Reproductive Isolation

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Reproductive Isolation

Reproductive isolation is caused by the existence of biological barriers that prevent members of two different species from producing viable, fertile hybrids.

The following slides are examples of isolations that will lead to reduced gene flow and, ultimately, a new species forming. See if you can point out the problem and the distinct new gene pools that will form.

Iguana Castaways

In the summer of 1995, at least 15 iguanas survived Hurricane Marilyn on a raft of uprooted trees. They rode the high seas for a month before colonizing the Caribbean island, Anguilla. These few individuals were perhaps the first of their species, *Iguana iguana*, to reach the island.

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.

There Is A Season

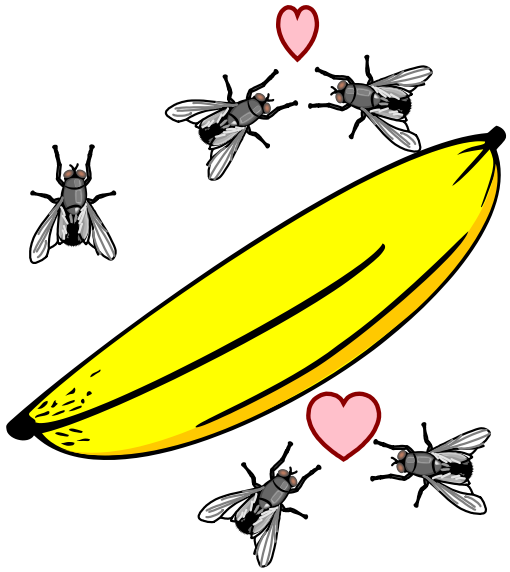
In a mutation event, a few members of a flowering plant population begin to bloom a month after the rest of the population. Flowers are responsible for producing the sexual cells of plants.

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.

Flies on an Island

A population of fruit flies on an island has three food sources: mangos, oranges and bananas. Each fly shows a preference to one of the three foods. Because of this, flies that like bananas spend most of their time with other flies that have that preference. The same could be said for each of the other fruits.

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.



Puppy Love

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.

Clammy

Giant clams reproduce by ejecting sperm and eggs into the open water in hopes that they will find each other. A mutation causes the sperm of some to reduce its ability to couple with some eggs.

Try to put a name to this type of reproductive isolation and explain how this will eventually lead to new species.

Summary

1. **Habitat Isolation/Geographic Isolation** - Different species occupy different habitats in the same area and may never encounter each other.

2. **Temporal Isolation** - Different species breed at different times of the day or year so they would never mate with each other. e.g. Two plants that live in the same area produce pollen at different times of the year.

3. **Behavioral Isolation** - Different species have different mating rituals, dances, behavior. Females from one species will not respond to mating behavior of a male from another species.

4. **Mechanical Isolation** - Differences in structures of sex organs of different species make it impossible for fertilization to take place.

5. **Gametic Isolation -** Sperm from one species cannot survive in the female reproductive tract of another. Also, different species' eggs have different receptors on them so that sperm from another species cannot enter the egg.

19

- A Habitat
- B Temporal
- C Behavioral
- D Mechanical
- E Gametic

answer

20

A Habitat
B Temporal
C Behavioral
D Mechanical
E Gametic

answer

21

- A Habitat
- B Temporal
- C Behavioral
- D Mechanical
- E Gametic

answer

22

A Habitat
B Temporal
C Behavioral
D Mechanical
E Gametic

answer

Pre-Zygotic Barriers

The previous slides explained barriers that would be considered **pre-zygotic**. This is because they prevent a **zygote** from forming. A zygote is the term for the cell that is produced from the combining of sperm and egg. In other words, no fertilized egg can be produced because of the barrier.

Post-Zygotic Barriers

Post-Zygotic Barriers occur after fertilization. A zygote has been formed, however the offspring is infertile or unviable.

These barriers are the final stages of gene pool isolations. The genetic makeup of the isolated groups becomes so different that if an attempt at breeding is made, the genetics prevent a viable offspring from being produced.

Post-Zygotic Barriers

Reduced viability of zygote

The gene of the different parent species may interact and impair development of the hybrid offspring. Most of the hybrids do not complete development but those that do are very frail.

Post-Zygotic Barriers

Reduced fertility of offspring

Even if a strong offspring is produced, it may be sterile. If the parental chromosome number is different in the two parents, the offspring will not produce normal gametes and they cannot mate with either of the parental species and genes cannot flow freely between the species.

Horse

X

Donkey

A mule is a sterile animal
it cannot produce offspring. So horse and donkey are separate species.

Post-Zygotic Barriers

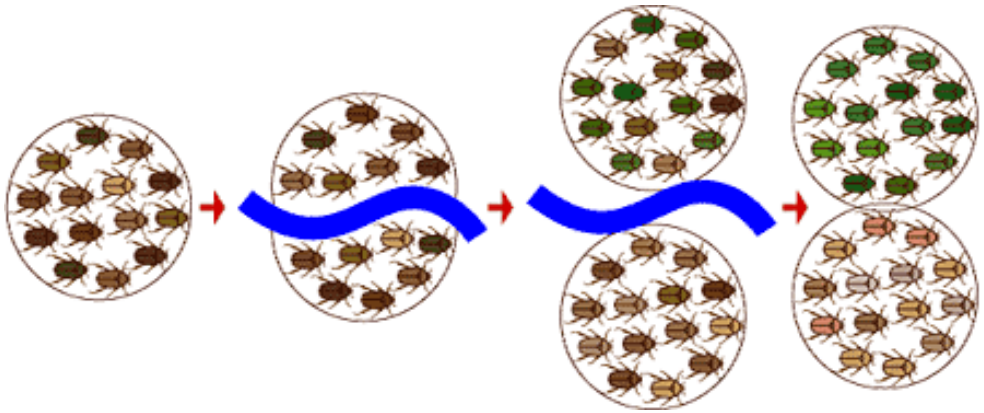
Offspring Breakdown

These offspring are fertile, but when they try to mate with the parental species or with one another, their offspring are feeble or sterile.

Allopatric Speciation

If a population becomes split into two separate populations due to some type of geographic barrier, this can lead to allopatric speciation. Since the two groups of the original population have become isolated from one another, gene flow between the two is interrupted.

Name some examples of how this can occur.



Allopatric Speciation

Once a geographic barrier has divided a population into two distinct populations and gene flow does not take place between the two, what has actually happened is that the original gene pool has been divided into two separate gene pools now.

These two gene pools can each change independently of each other due to all the different mechanisms that we have already spoken about and over time, each population becomes a new species.

Speciation due to geographic separation is referred to as **vicariance**.

Speciation due to a vicariance event

Sympatric Speciation

In sympatric speciation, there is no geographic barrier that separated a population; therefore, the members of a population remain in contact with one another.

If the members of the population remain in contact with one another, how do they evolve into different species? What mechanisms can play a role in this occurring?

Darwin's Tree

Life has progressed this way for billions of years. New species coming into existence, other species going extinct. Each contributing to the diversity of organisms on Earth that Darwin termed the **Tree of Life.**