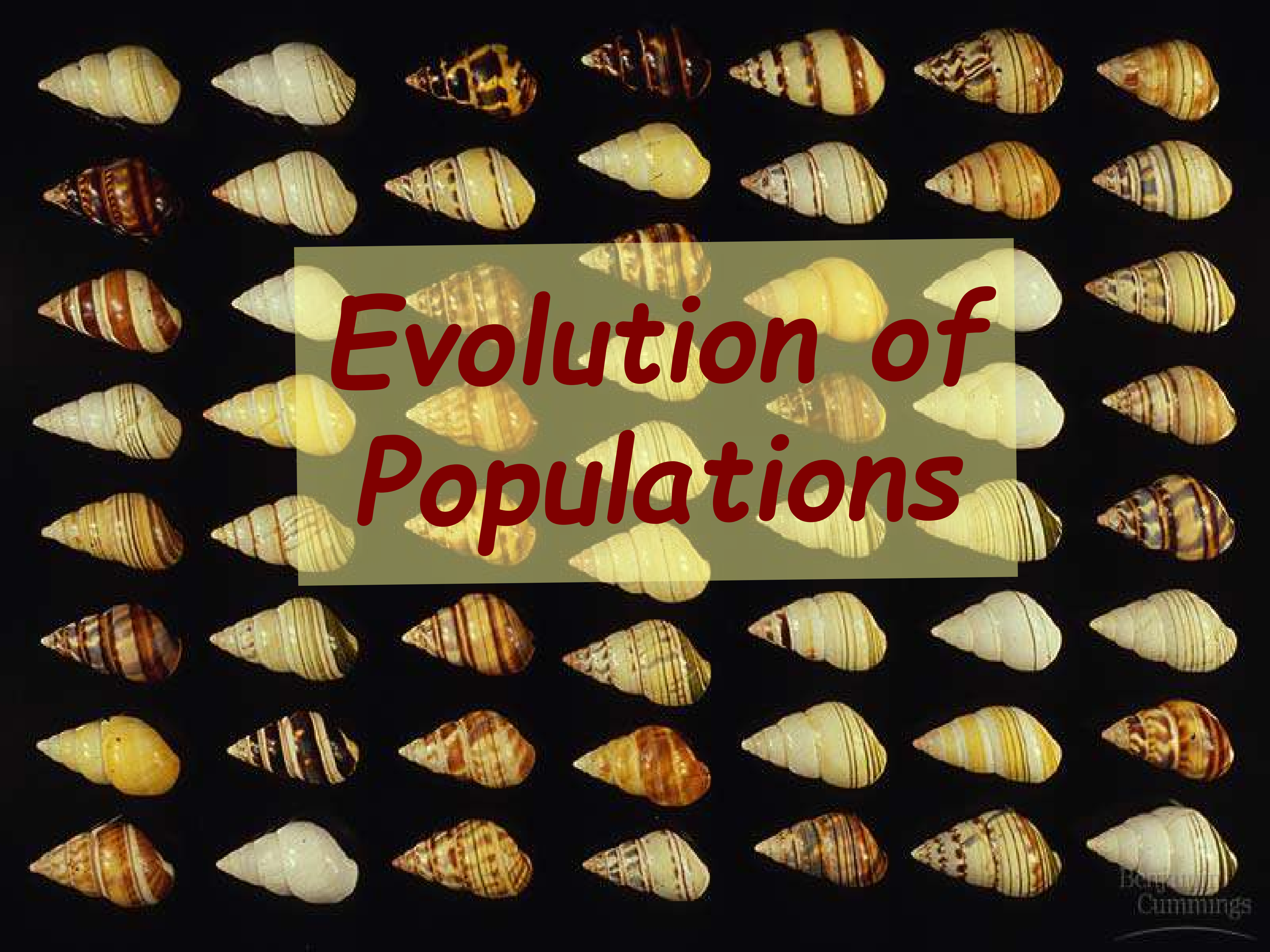
Evolution of Populations



The Gene Pool

- Members of a species can **interbreed** & produce **fertile offspring**
- Species have a **shared gene pool**
- **Gene pool** – all of the combined alleles of every individual in a population

Allele Frequency

Each allele in a gene pool exists at a certain rate, or frequency.

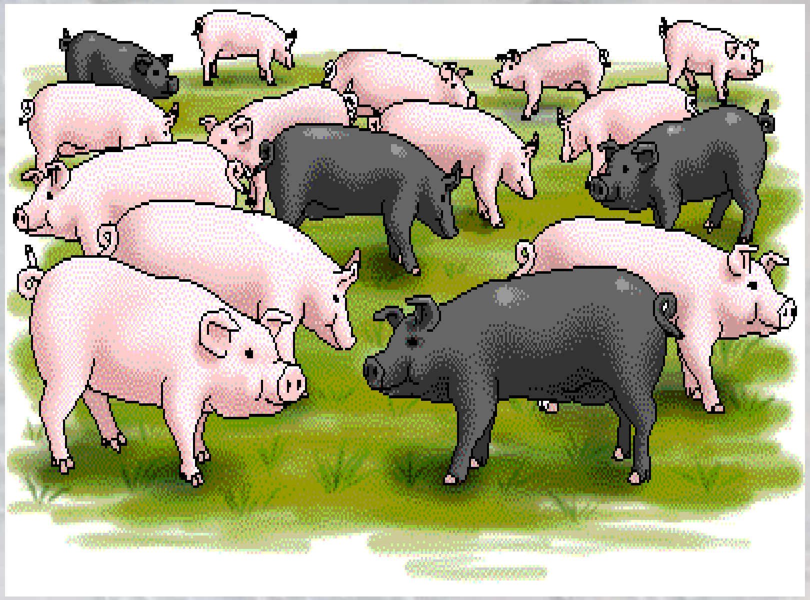
Allele Frequency: is the measure of how common an allele is in a population

What is allele frequency for black pigs? White pigs?

(B=white b=black)

4/16= .25 x 100%= 25% b

12/16= .75 x 100%= 75% B



Genetic Variation: Two main sources

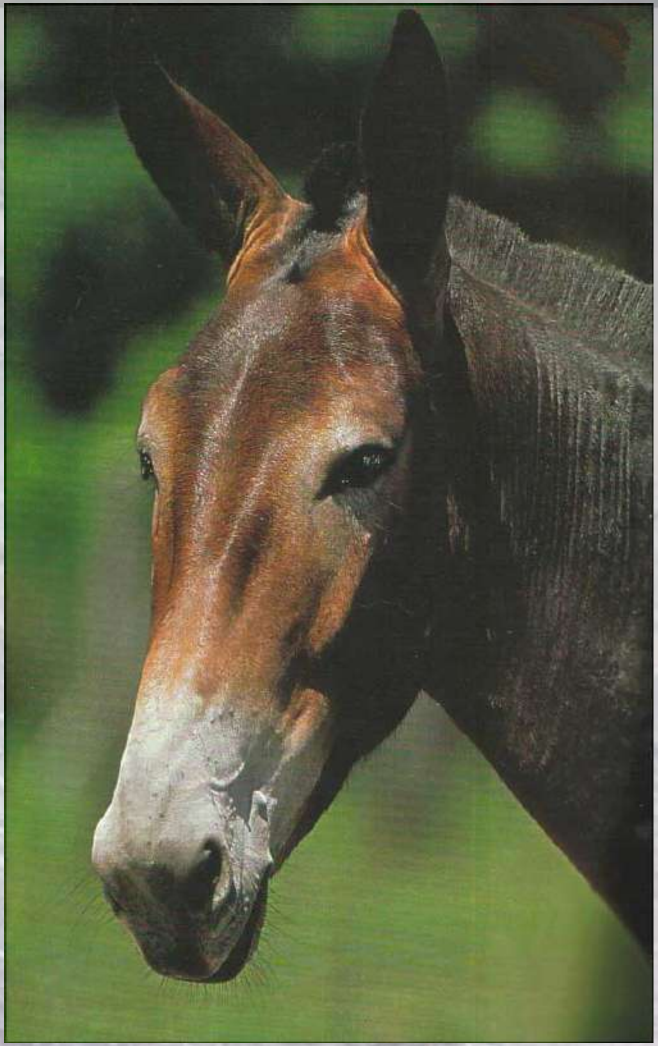
Mutation: random change in DNA of a gene.This change can form a new allele. Mutations in reproductive cells can then be passed to offspring. This increases the genetic variation in the gene pool. Because there are many individuals in a population, new mutations from frequently in gene pools.

Recombination:

New allele combinations from in offspring during recombination. Most recombination occurs during meiosis. When gametes are made, each parent's alleles are arranged in different ways. This creates many different genetic combinations.

Genetic Variation

- Different species do **NOT exchange genes** by interbreeding
- Different species that interbreed often produce **sterile or less viable** offspring e.g. Mule (Hybridization)



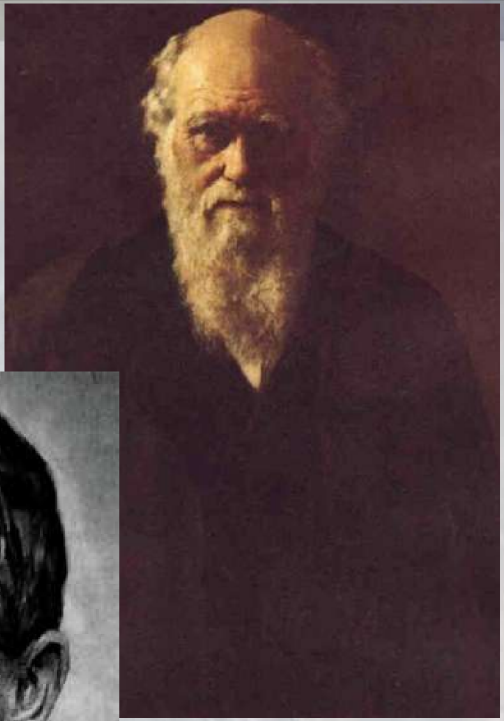
Populations

- A group of the **same species living in an area**
- No two individuals are exactly alike **(variations)**
- More **Fit** individuals survive & pass on their traits

Modern Evolutionary Thought

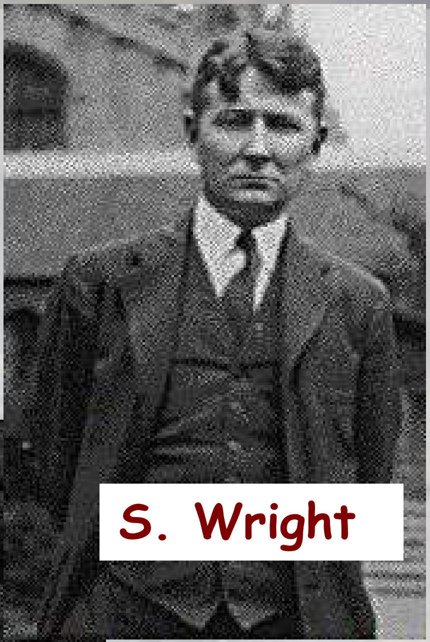
Modern Synthesis Theory

- Combines Darwinian selection and Mendelian inheritance
- Population genetics - study of genetic variation within a population
- Emphasis on quantitative characters

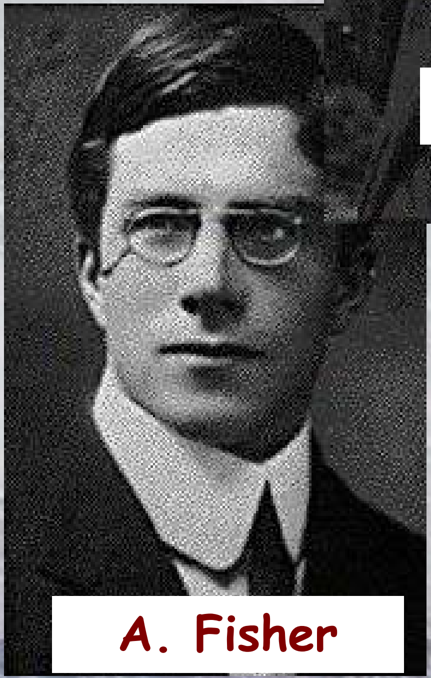


Modern Synthesis Theory

- **1940s – comprehensive theory of evolution (Modern Synthesis Theory)**
- **Introduced by Fisher & Wright**
- **Until then, many did not accept that Darwin's theory of natural selection could drive evolution**



S. Wright



A. Fisher

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Modern Synthesis Theory

- Today's theory on evolution
- Recognizes that GENES are responsible for the inheritance of characteristics
- Recognizes that POPULATIONS, not individuals, evolve due to natural selection & genetic drift
- Recognizes that SPECIATION usually is due to the gradual accumulation of small genetic changes

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Speciation

- Formation of new species
- One species may split into 2 or more species
- A species may evolve into a new species
- Requires very long periods of time

Microevolution

- Changes occur in gene pools due to mutation, natural selection, genetic drift, etc.
- Gene pool changes cause more VARIATION in individuals in the population
- This process is called MICROEVOLUTION
- Example: Bacteria becoming unaffected by antibiotics (resistant)

Natural Selection leads to Microevolution

3 ways that natural selection can change the distribution of a trait: directional, stabilizing, and disruptive selection

Directional: selection that favors a phenotype at one end or extreme (ex. Antibiotic-resistant bacteria)

Stabilizing: selection that favors the middle or intermediate phenotype (ex. Gall fly develops more in the middle size gall because woodpeckers eat large and wasps attack small)

Disruptive : selection that favors both extreme phenotypes instead of the most common

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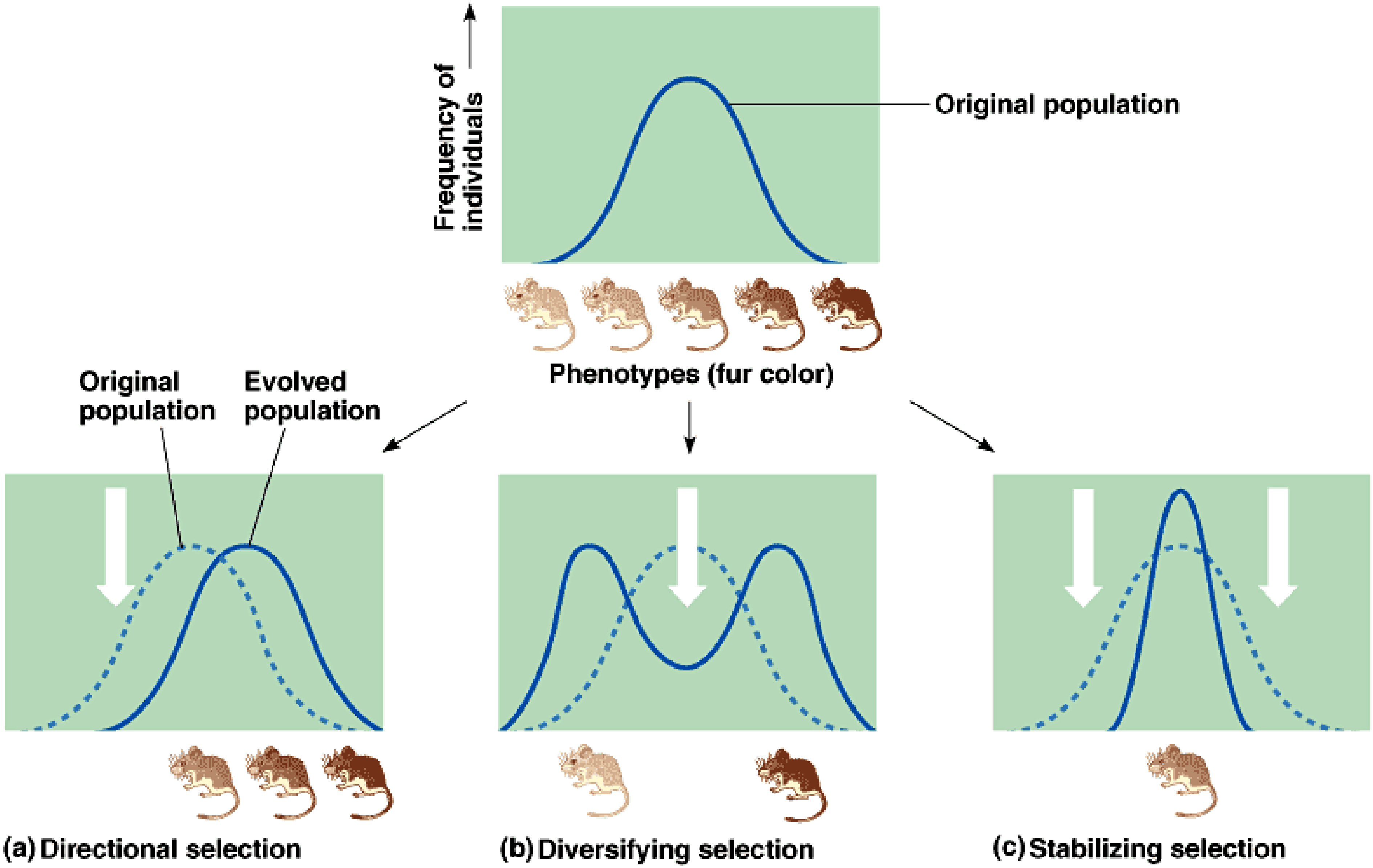

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Species & Populations

- **Population** - a localized group of individuals of the same species.
- **Species** - a group of populations whose individuals have the ability to breed and produce fertile offspring.
- **Individuals near a population center** are, on average, more closely related to one another than to members of other populations.

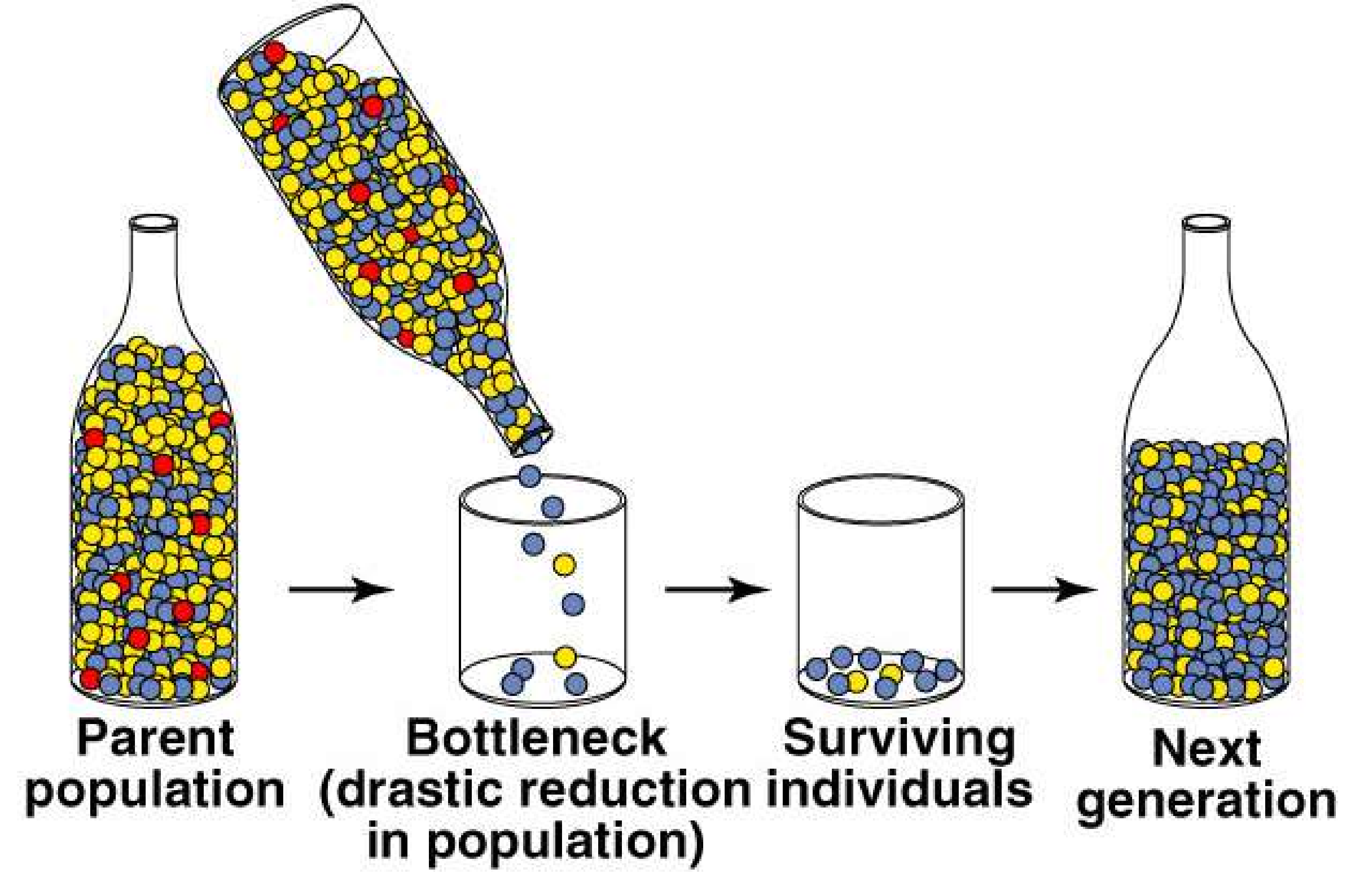
Gene Pools and Gene Flow

- A population's **gene pool** is the total of all genes in the population at any one time.
- If all members of a population are homozygous for a particular allele, then the allele is **fixed in the gene pool.**
- When an organism joins a new population and reproduces, its alleles become part of the gene pool and removes its alleles from the old gene pool of its former population. The movement of these alleles is called **gene flow.**

Genetic Drift

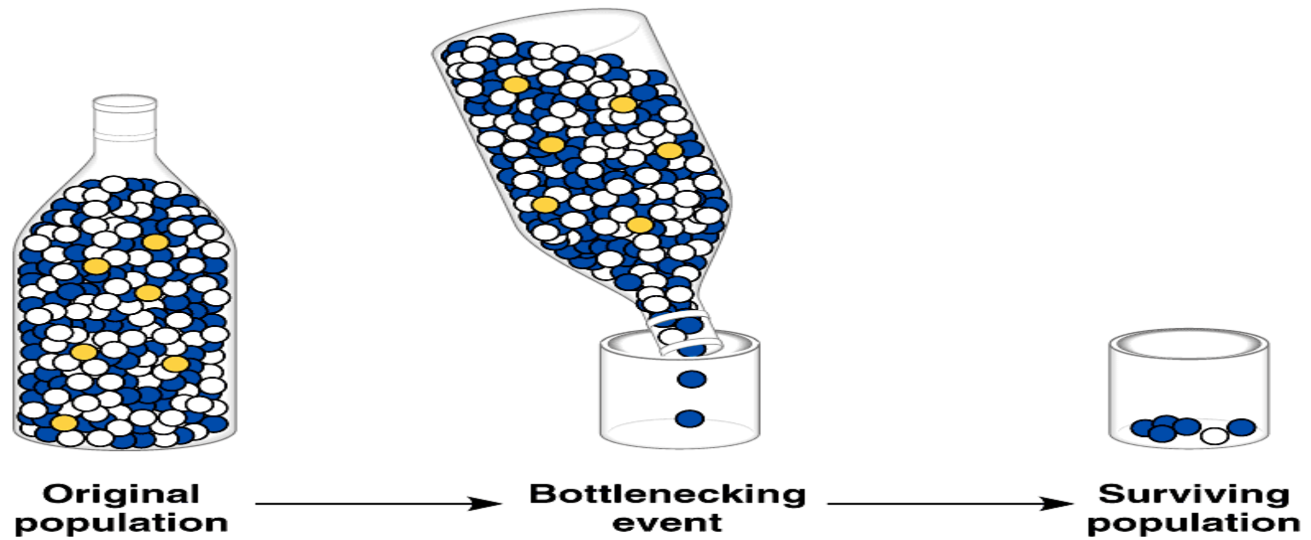
- Changes in allele frequencies that are due to chance are called genetic drift.
- Genetic drift causes a loss of genetic diversity in a population.
- Two processes commonly cause populations to become small enough for genetic drift to occur.

Genetic Drift - Bottleneck Effect



Bottleneck Effect

Bottleneck Effect: occurs after an event greatly reduces the size of the population. Ex. Overhunting led to the decline of seals and only left 20, those 20 did not represent the genetic diversity of the original population so only their alleles provided genetic variation so therefore genetic diversity was limited. Through genetic drift, certain alleles have become fixed while others have been lost completely from the gene pool.



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Founder Effect

Genetic drift that occurs after a small number of individuals colonize a new area.

- Gene pools of these populations are very different from those of a larger populations so therefore you will see an increased percentage of individuals with the allele.
- Genetic Drift can cause several problems for populations.
- Loss of genetic variation so they cannot adapt to changing environment.
- Alleles that are lethal can be in homozygous can now be carried by heterozygous and become more common in gene pool.

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Sexual Selection

Occurs when certain traits increase mating success

Males: Produce sperm continuously , making the value of each sperm relatively small. So therefore, their investment is at little cost.

Females: Limited in number of offspring so they make more investment in the selection of mates."Choosy"

Intrasexual selection: competition among males whoever wins mates.

Intersexual selection:males display certain traits used to attract the female: ex. Peacock

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Five Agents of Evolutionary Change

Selection – Only agent that produces adaptive evolutionary change

- artificial - breeders exert selection
- natural - nature exerts selection
  - variation must exist among individuals
  - variation must result in differences in numbers of viable offspring produced
  - variation must be genetically inherited
    - natural selection is a process, and evolution is an outcome

Five Agents of Evolutionary Change

Selection pressures:

- avoiding predators
- matching climatic condition
- pesticide resistance

Measuring Fitness

Fitness is defined by evolutionary biologists as the number of surviving offspring left in the next generation.

- relative measure
  - Selection favors phenotypes with the greatest fitness.

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Interactions Among Evolutionary Forces

Levels of variation retained in a population may be determined by the relative strength of different evolutionary processes.

Gene flow versus natural selection

- Gene flow can be either a constructive or a constraining force.
  - Allelic frequencies reflect a balance between gene flow and natural selection.

Natural Selection Can Maintain Variation

Frequency-dependent selection

- Phenotype fitness depends on its frequency within the population.
  - Negative frequency-dependent selection favors rare phenotypes.
  - Positive frequency-dependent selection eliminates variation.

Oscillating selection

- Selection favors different phenotypes at different times.

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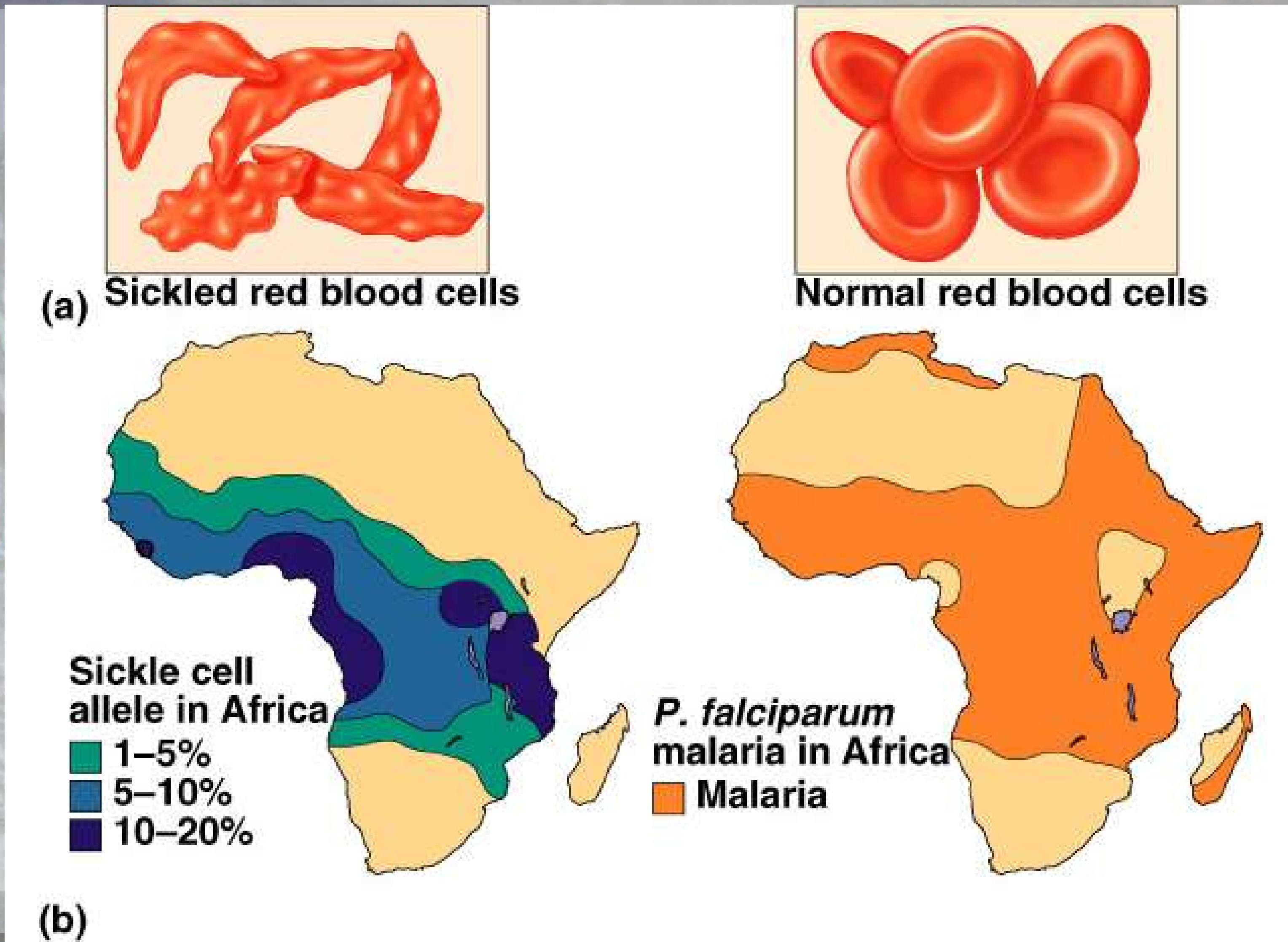
Heterozygote Advantage

Heterozygote advantage will favor heterozygotes, and maintain both alleles instead of removing less successful alleles from a population.

- Sickle cell anemia
  - Homozygotes exhibit severe anemia, have abnormal blood cells, and usually die before reproductive age.
  - Heterozygotes are less susceptible to malaria.

Sickle Cell and Malaria



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Forms of Selection

Disruptive selection

- Selection eliminates intermediate types.

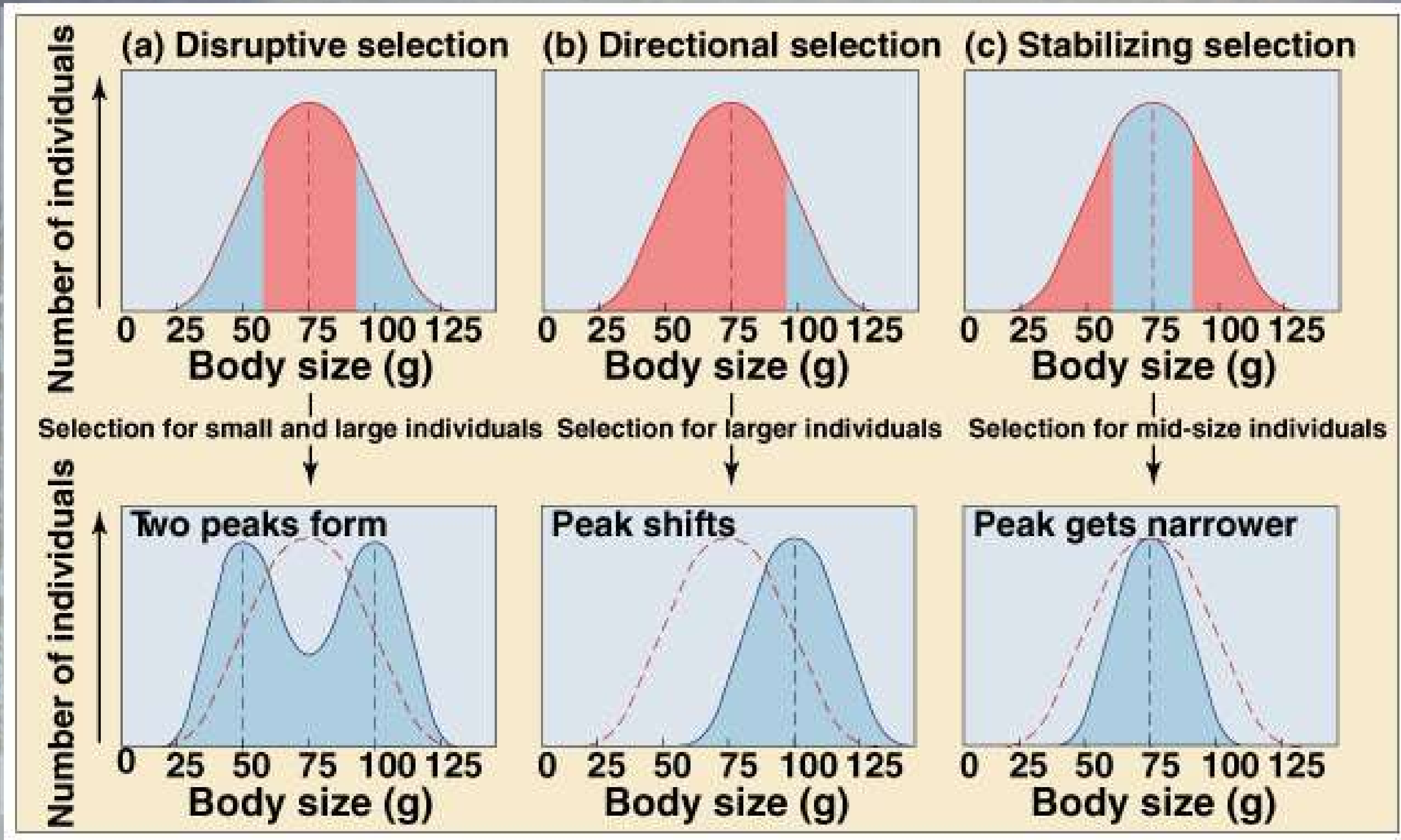
Directional selection

- **Selection eliminates one extreme from a phenotypic array.**

Stabilizing selection

- **Selection acts to eliminate both extremes from an array of phenotypes.**

Kinds of Selection



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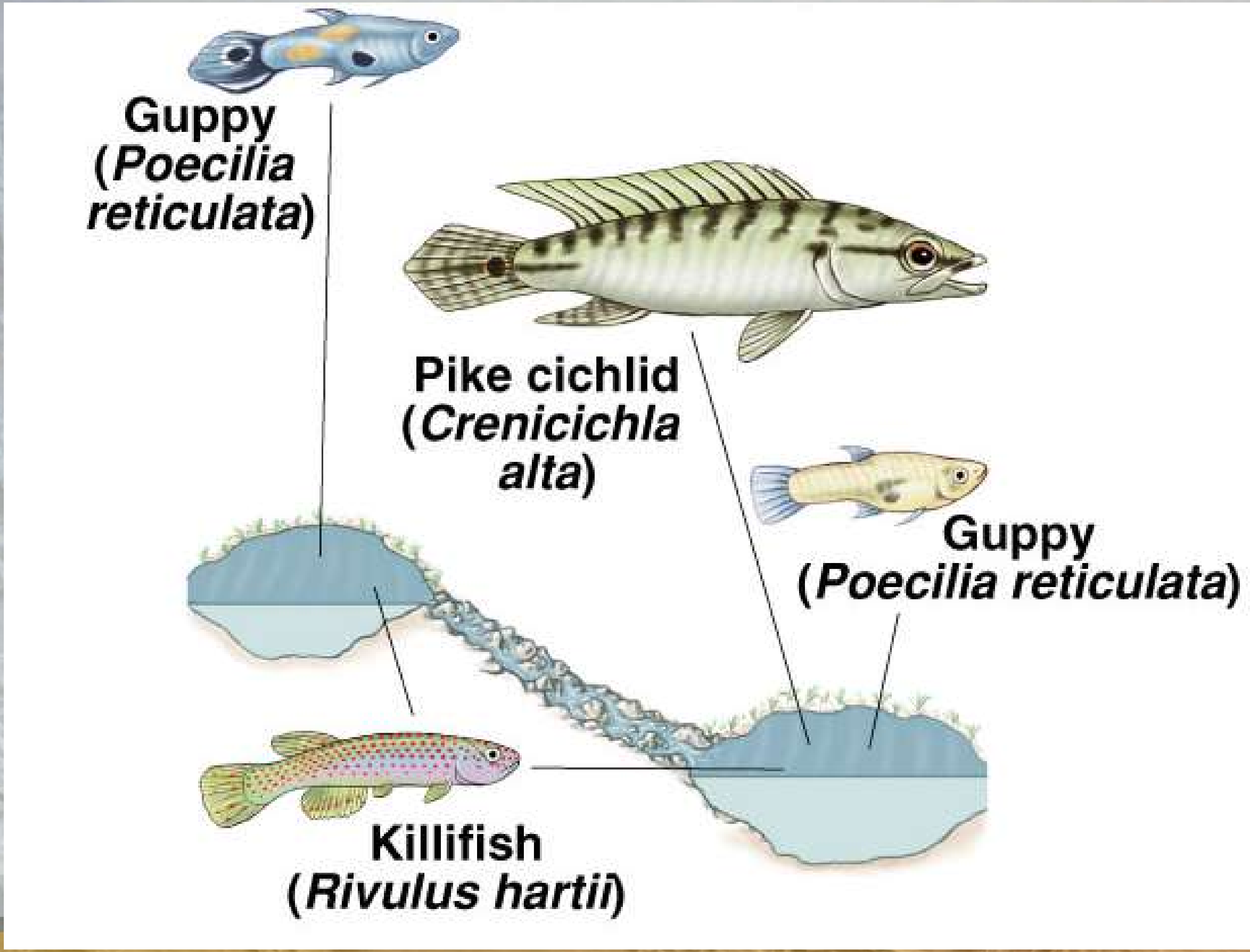
Selection on Color in Guppies

Guppies are found in small northeastern streams in South America and in nearby mountainous streams in Trinidad.

- Due to dispersal barriers, guppies can be found in pools below waterfalls with high predation risk, or pools above waterfalls with low predation risk.

Evolution of Coloration in Guppies



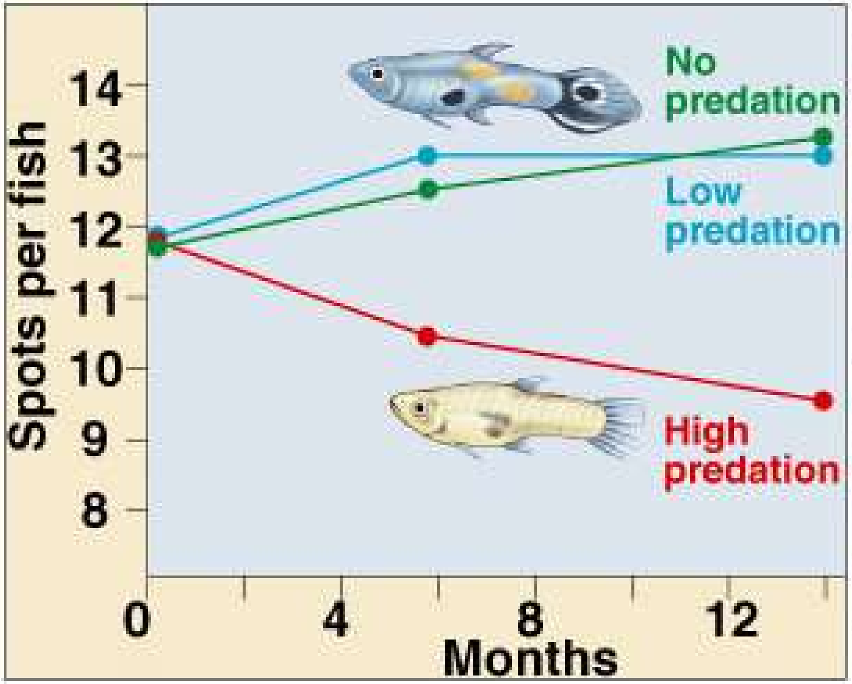
Selection on Color in Guppies

High predation environment - Males exhibit drab coloration and tend to be relatively small and reproduce at a younger age.

Low predation environment - Males display bright coloration, a larger number of spots, and tend to be more successful at defending territories.

- In the absence of predators, larger, more colorful fish may produce more offspring.

Evolutionary Change in Spot Number



Limits to Selection

Genes have multiple effects

- pleiotropy

Evolution requires genetic variation

- **Intense selection may remove variation from a population at a rate greater than mutation can replenish.**
  - **thoroughbred horses**

Gene interactions affect allelic fitness

- **epistatic interactions**

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Population genetics

- **genetic structure** **of a population**
  - alleles
  - genotypes

group of individuals of the same species that can interbreed

Patterns of genetic variation in populations

Changes in genetic structure through time

Describing genetic structure

- **genotype frequencies**
- **allele frequencies**

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Describing genetic structure

- **genotype frequencies**
- **allele frequencies**

genotype frequencies:

200/1000 = 0.2 rr

500/1000 = 0.5 Rr

300/1000 = 0.3 RR

total = 1000 flowers

Describing genetic structure

- genotype frequencies

- allele frequencies

= 400 r

= 500 r
500 R

= 600 R

allele frequencies:
900/2000 = 0.45 r

1100/2000 = 0.55 R

total = 2000 alleles

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for a population with genotypes:

100 GG

160 Gg

140 gg

calculate:

Genotype frequencies

Phenotype frequencies

Allele frequencies

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for a population with genotypes:

100 GG

160 Gg

140 gg

calculate:

Genotype frequencies

260 { 100/400 = 0.25 GG
160/400 = 0.40 Gg } 0.65
140/400 = 0.35 gg

Phenotype frequencies

260/400 = 0.65 green
140/400 = 0.35 brown

Allele frequencies

360/800 = 0.45 G
440/800 = 0.55 g

another way to calculate allele frequencies:

100 GG

160 Gg

140 gg

Genotype frequencies

0.25 GG → G 0.25

0.40 Gg → G 0.40/2 = 0.20

0.40 Gg → g 0.40/2 = 0.20

0.35 gg → g 0.35

Allele frequencies

360/800 = 0.45 G

440/800 = 0.55 g

OR [0.25 + (0.40)/2] = 0.45

[0.35 + (0.40)/2] = 0.65

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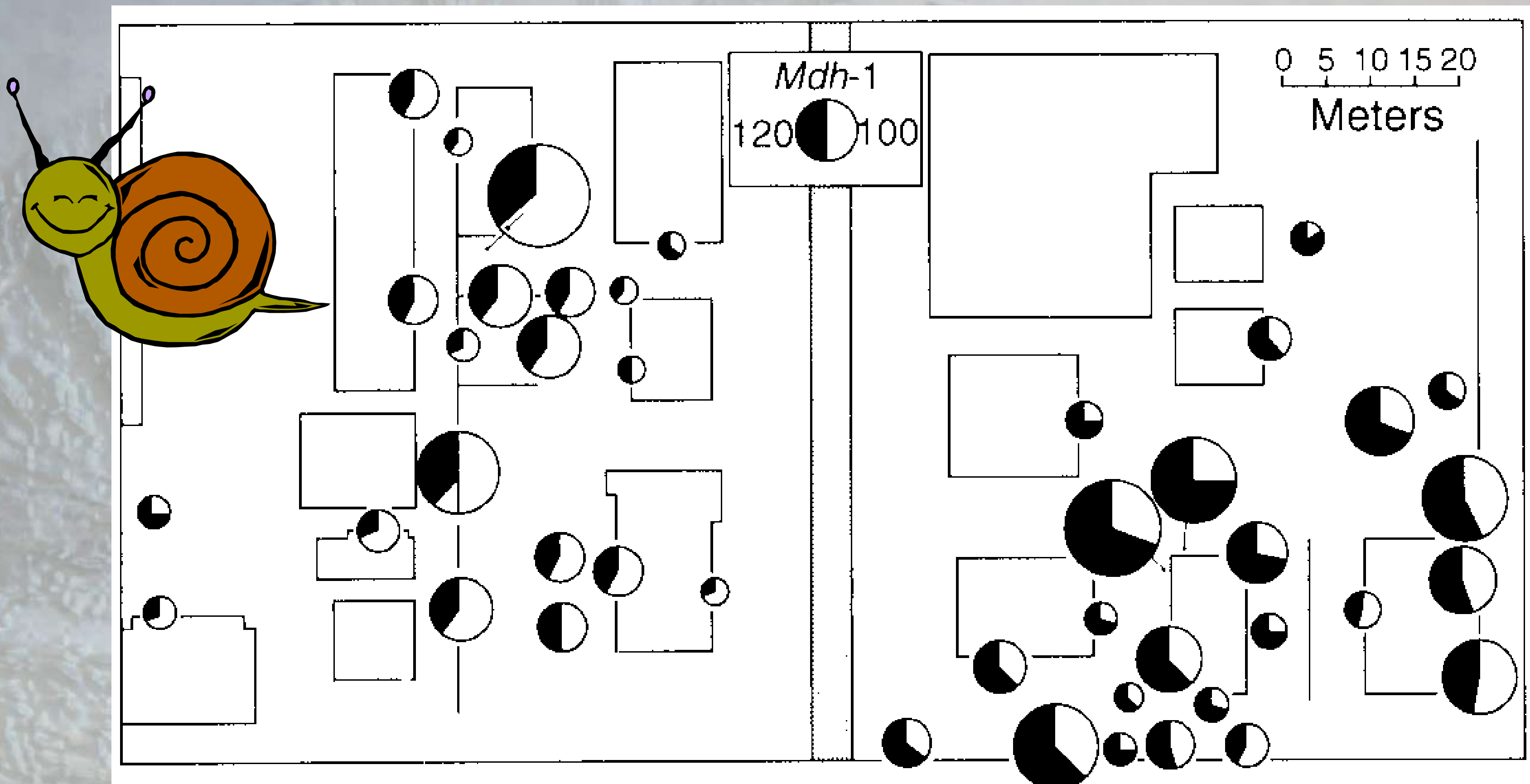
Population genetics – Outline

- ✓ What is population genetics?
- ✓ Calculate - genotype frequencies
  - allele frequencies

Why is genetic variation important?

How does genetic structure change?

Genetic variation in space and time



Frequency of *Mdh-1* alleles in snail colonies in two city blocks

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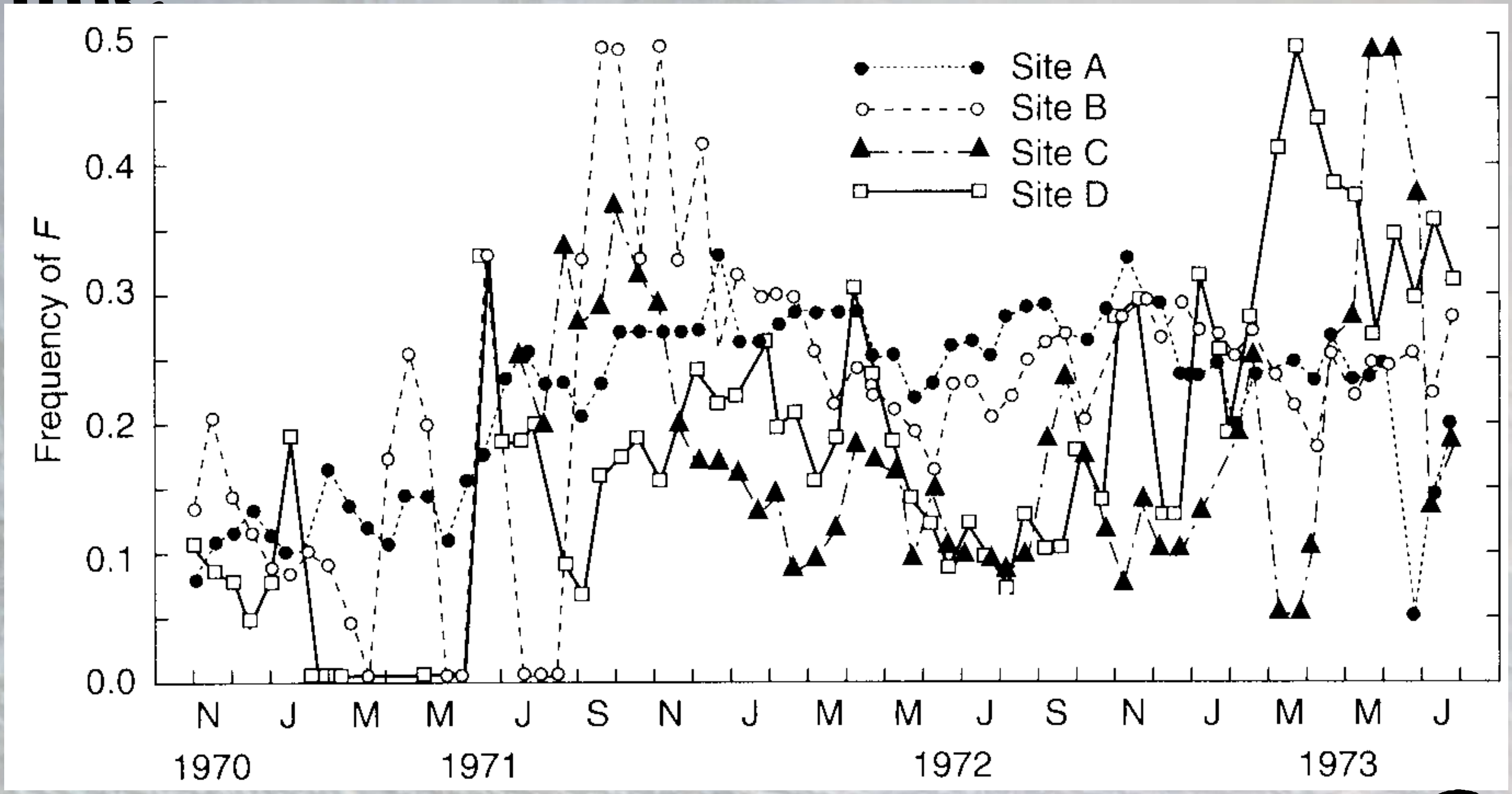
Genetic variation in space and time



Changes in frequency of allele *F* at the *Lap* locus in prairie vole populations over 20 generations

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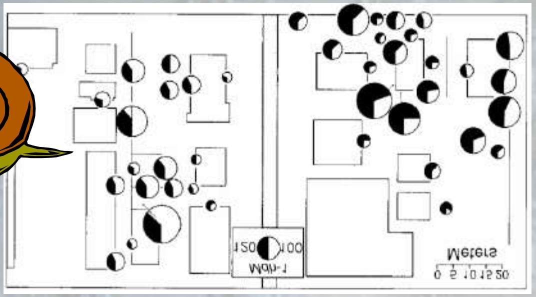
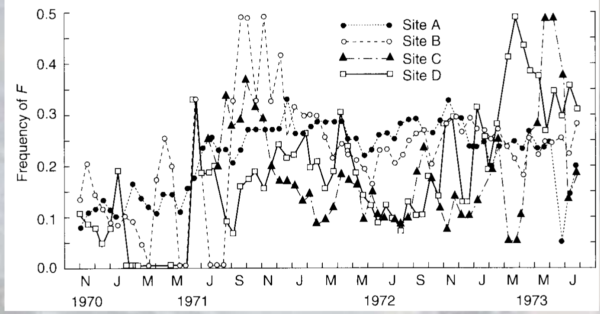
Genetic variation in space and time



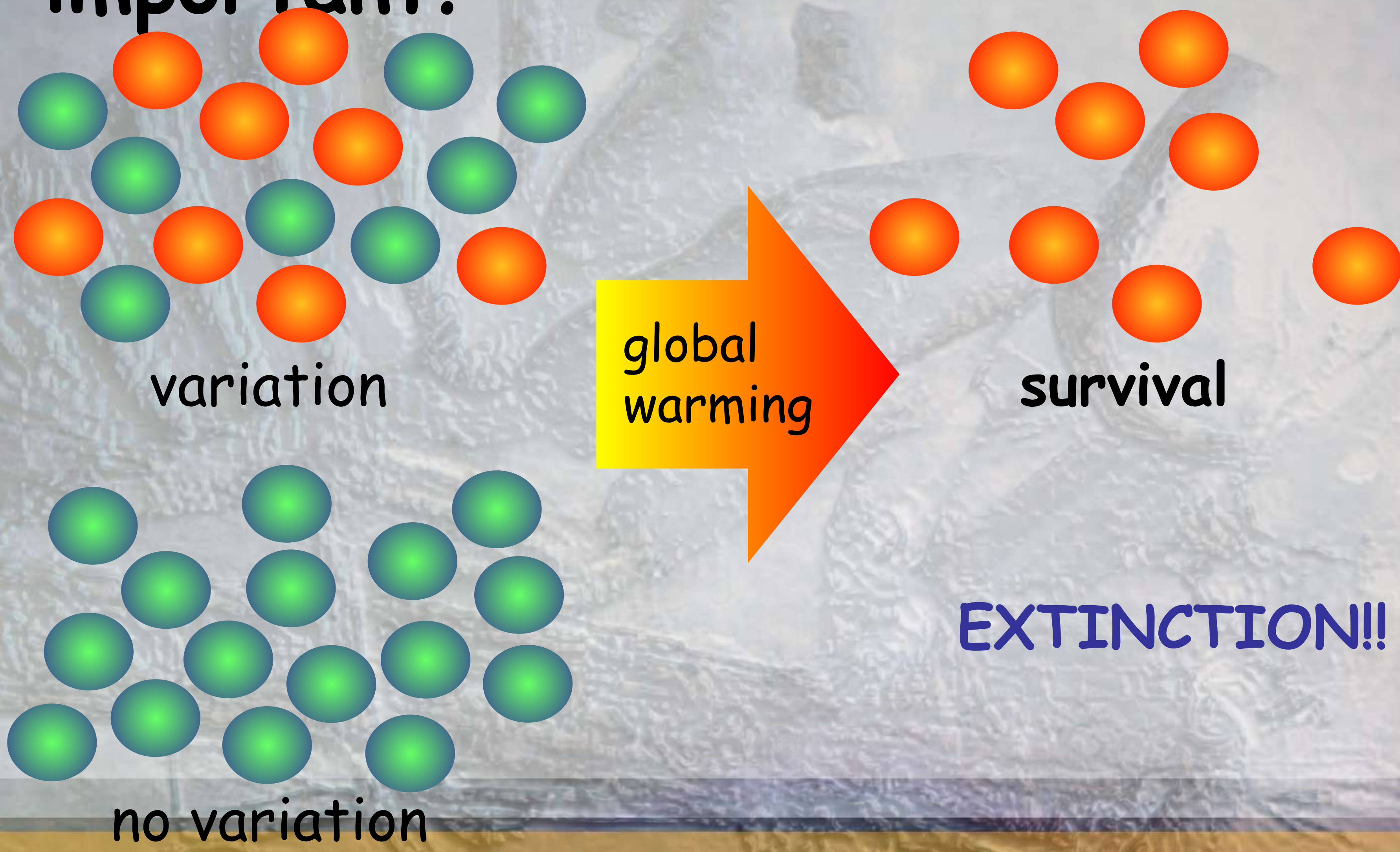


Why is genetic variation important

potential for change in genetic struc

- adaptation to environmental change
- conservation
- divergence of populations
- biodiversity

Why is genetic variation important?



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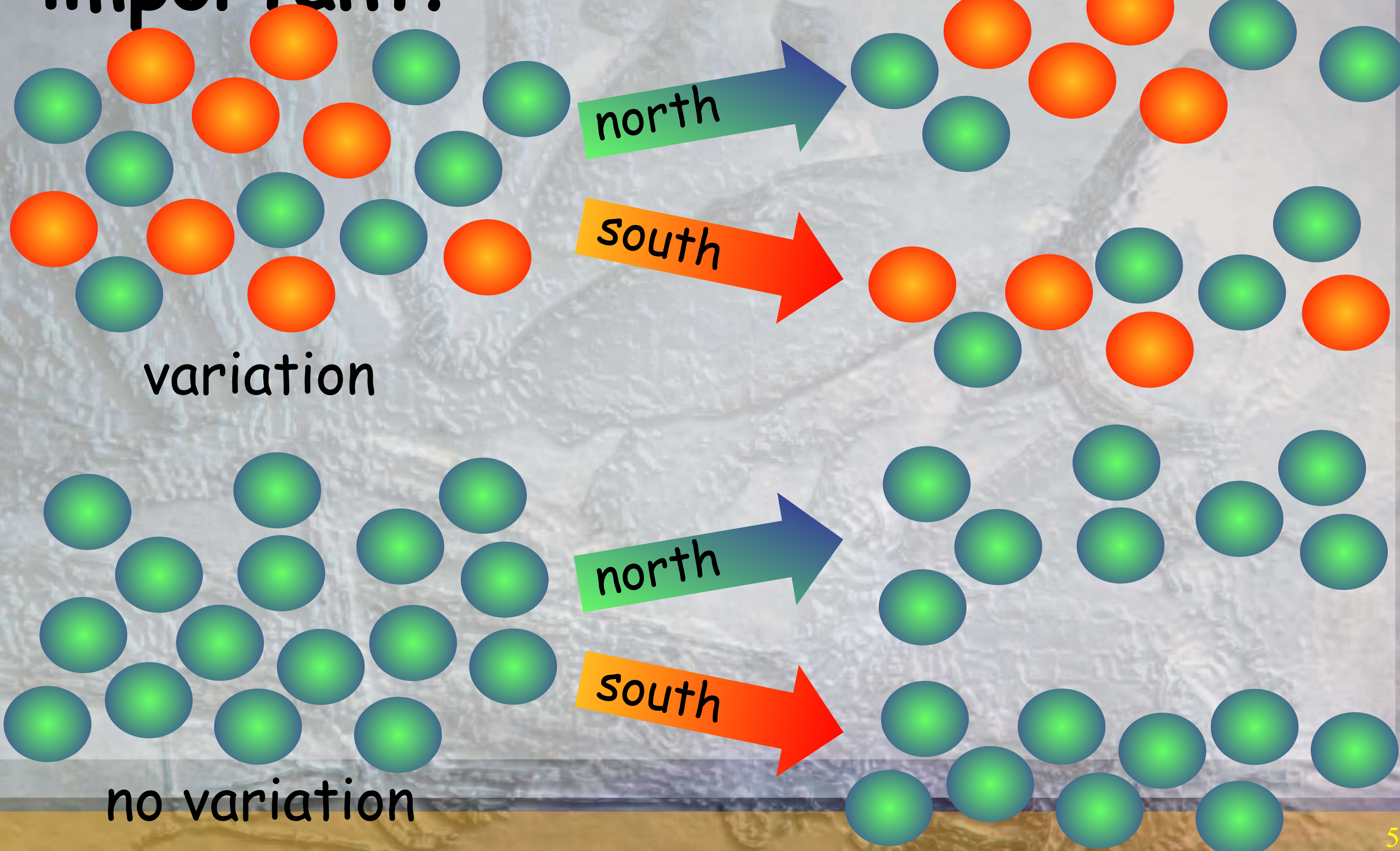
Why is genetic variation important?



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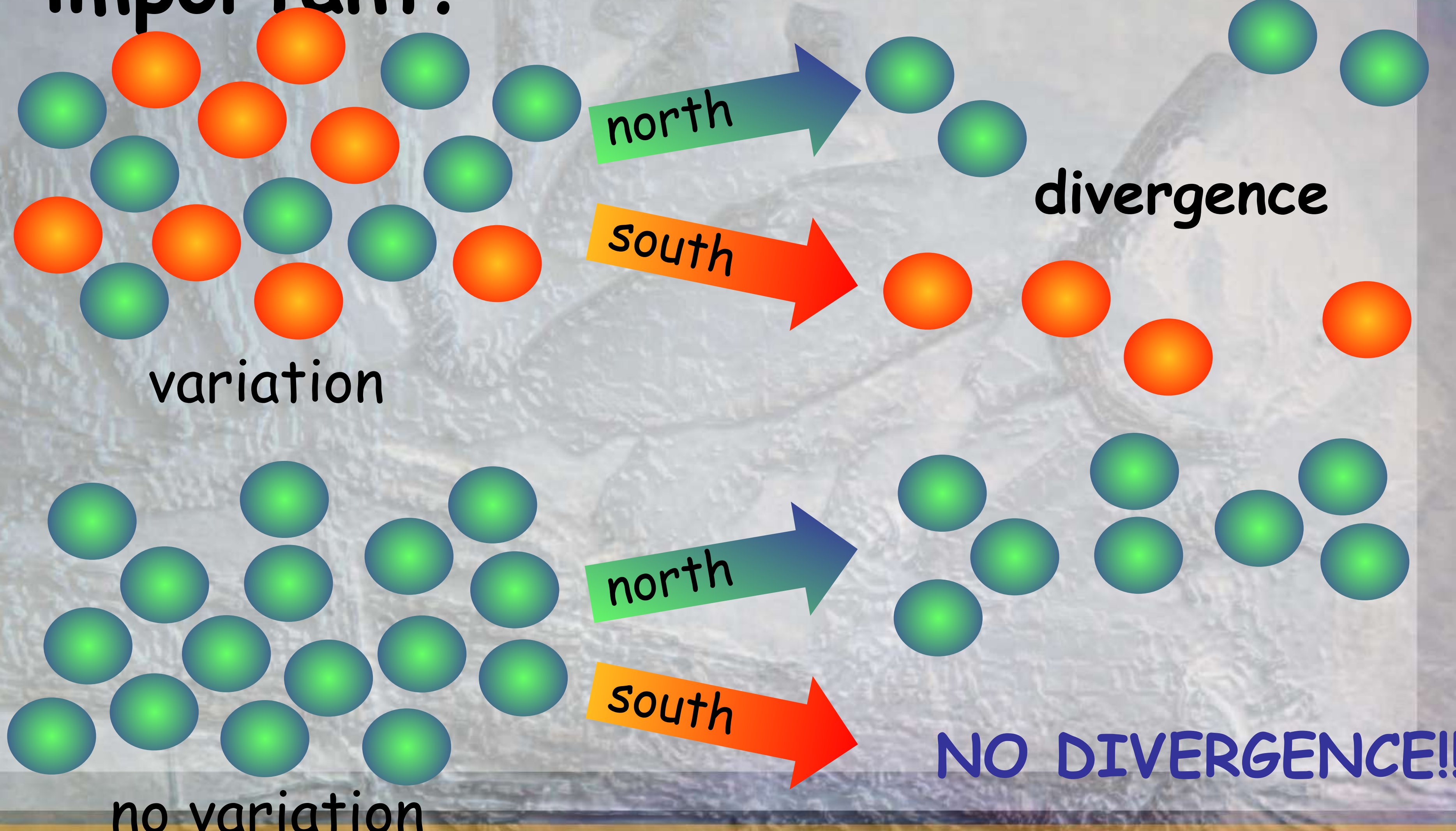
Why is genetic variation important?

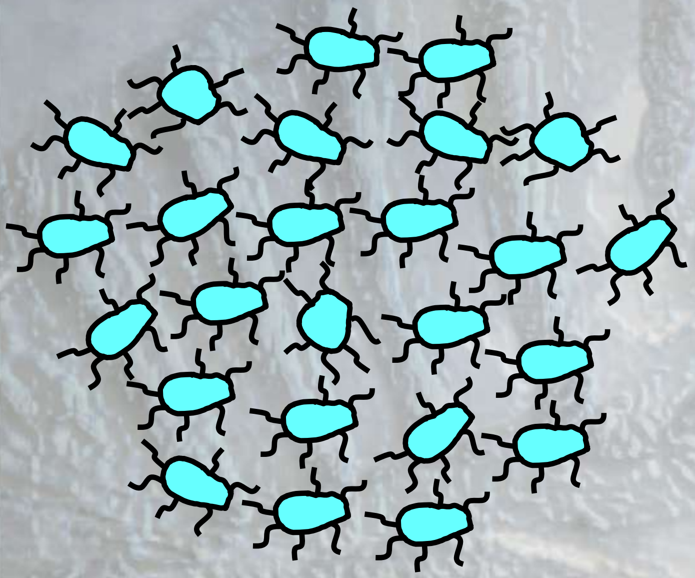


Natural selection

Resistance to antibacterial soap

Generation 1: 1.00 not resistant
0.00 resistant

Natural selection



Resistance to antibacterial soap

Generation 1: 1.00 not resistant

0.00 resistant

Natural selection

mutation!

Resistance to antibacterial soap

Generation 1: 1.00 not resistant
0.00 resistant

Generation 2: 0.96 not resistant
0.04 resistant

55

Natural selection

Resistance to antibacterial soap

Generation 1: 1.00 not resistant
0.00 resistant

Generation 2: 0.96 not resistant
0.04 resistant

Generation 3: 0.76 not resistant
0.24 resistant

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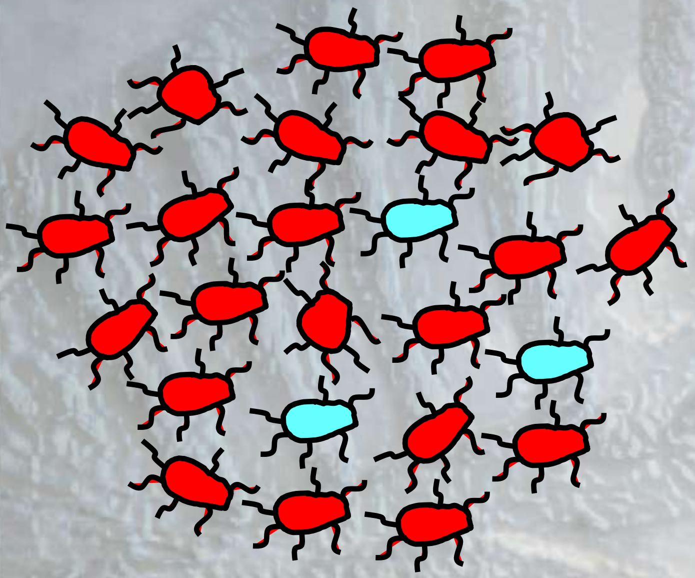
Natural selection



Resistance to antibacterial soap

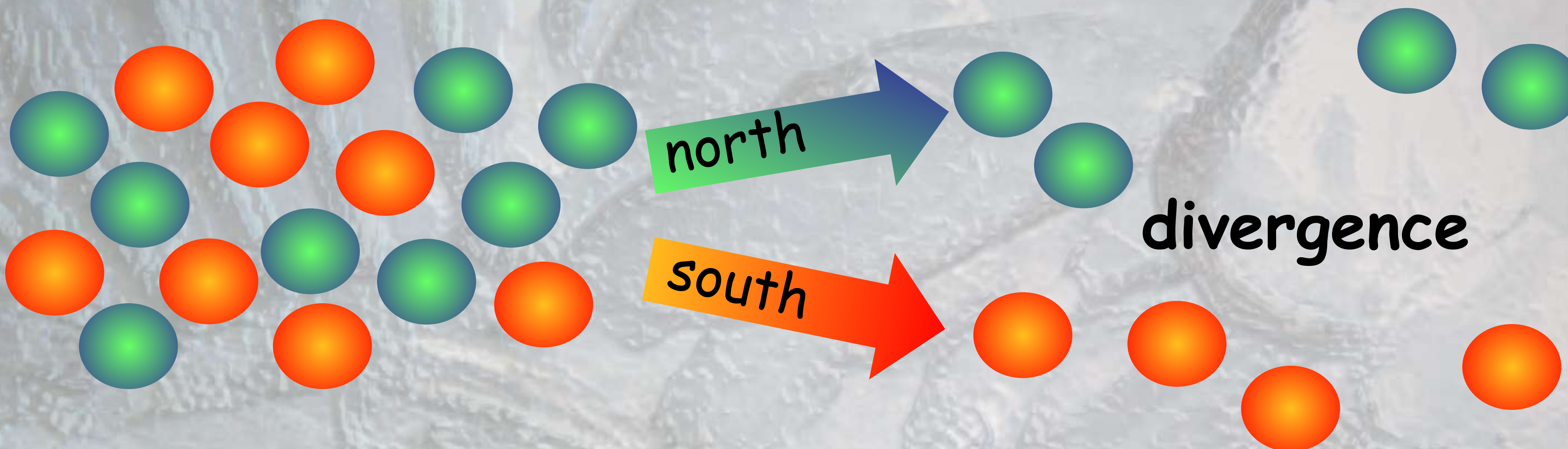
Generation 1: 1.00 not resistant
0.00 resistant

Generation 2: 0.96 not resistant
0.04 resistant

Generation 3: 0.76 not resistant
0.24 resistant

Generation 4: 0.12 not resistant
0.88 resistant

Natural selection can cause populations to diverge



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Selection on sickle-cell allele

aa – abnormal ß hemoglobin sickle-cell anemia — **very low fitness**

AA – normal ß hemoglobin vulnerable to malaria — **intermed. fitness**

Aa – both ß hemoglobins resistant to malaria — **high fitness**

Selection favors heterozygotes (Aa).

Both alleles maintained in population (a at low level)

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How does genetic structure change?

- mutation
- migration
- natural selection
- **genetic drift**

genetic change by chance alon

- sampling error
  - misrepresentation
  - small populations

- non-random mating

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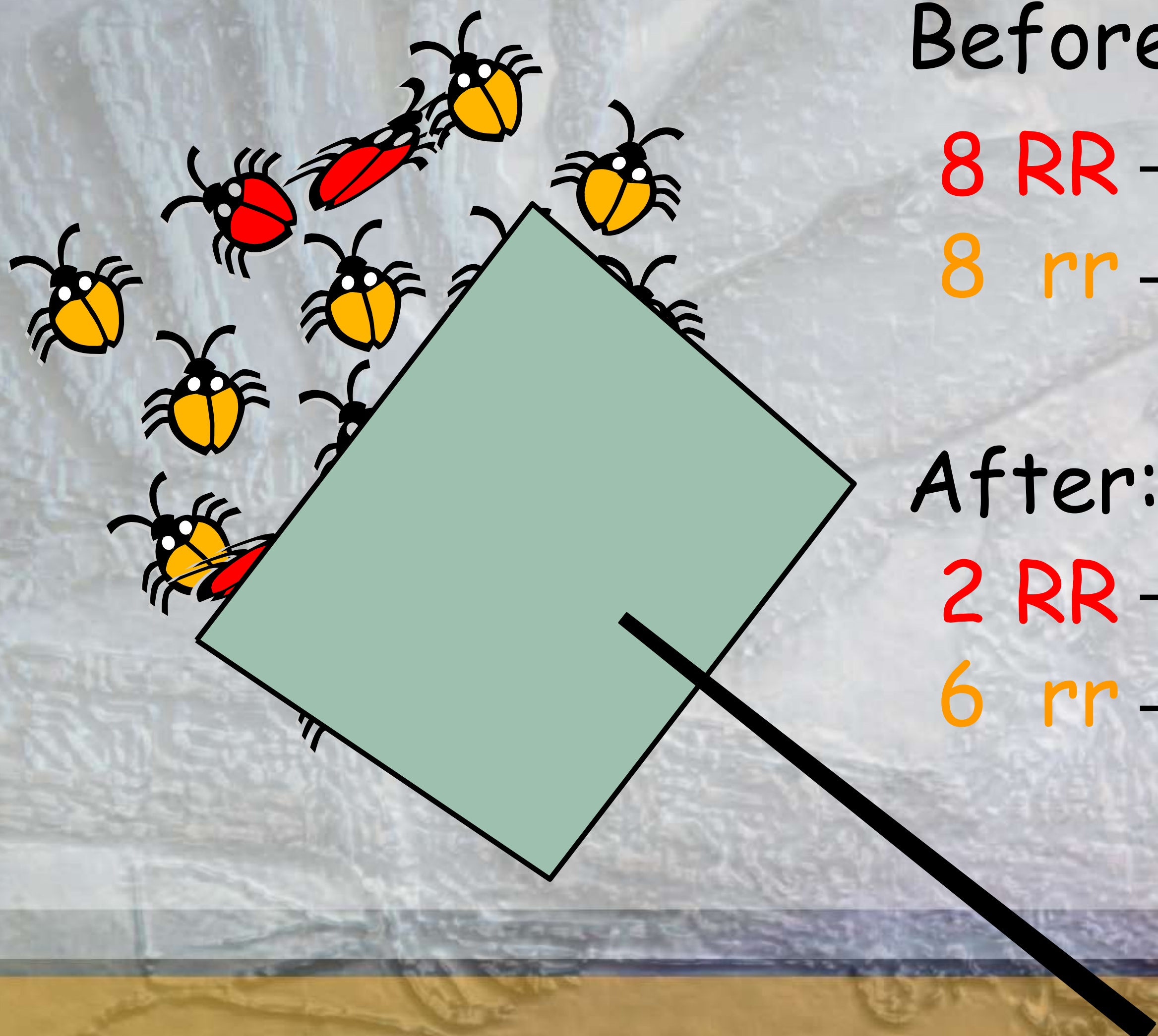
Genetic drift



Before:

8 RR → 0.50 R
8 rr → 0.50 r

After:

2 RR → 0.25 R
6 rr → 0.75 r

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How does genetic structure change?

- mutation
- migration
- natural selection
- genetic drift
- non-random mating

} cause changes in allele frequencies

How does genetic structure change?

- mutation
- migration
- natural selection
- genetic drift
- **non-random mating**

mating combines alleles into genotypes

- non-random mating

⇓

non-random allele combinations