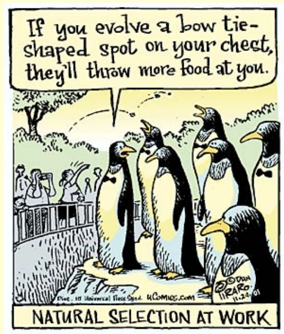
MICROEVOLUTION



On the Origin of Species…
WHAT IS A SPECIES?

- Individuals in one or more populations
- Potential to interbreed
- Produce fertile offspring

WHAT IS A POPULATION?

- Group of interacting individuals belonging to one species and living in the same geographic area

- **A population is the smallest unit that can evolve.**

Figure 23.6

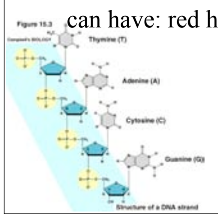
EVOLUTION OF POPULATIONS

The Synthetic Theory of Evolution
- Applying population genetics to the Darwinian model

- *Genetics & Variability*
- Non-Adaptive Evolution
- Fitness & Natural Selection
- Sexual Selection

Genes & Alleles

- Genes code for morphology, physiology, or behavior.
- Gene for hair color or leg length.
- **Alleles** are alternative forms genes can have: red hair, brown hair, etc.



The double helix

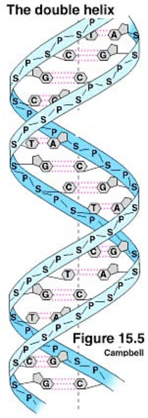
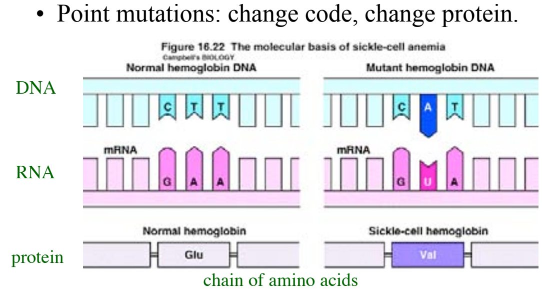


Figure 15.5
Campbell

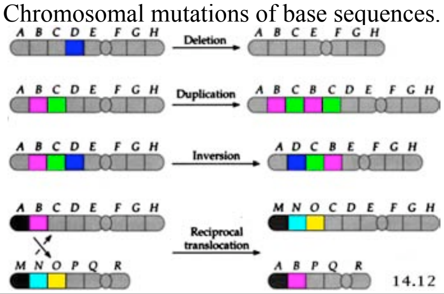
Genetic variation: how do new forms arise?

- Point mutations: change code, change protein.



Genetic variation: how do new forms arise?

- Chromosomal mutations of base sequences.

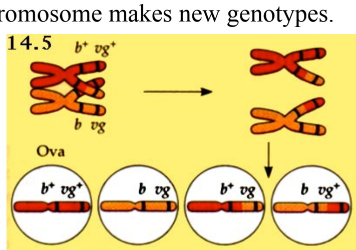


Mutation Events Are Random

- Mutations are destructive alterations to previously existing complex systems.
- Most mutations are neutral or detrimental — *very* few are beneficial.
- The need for a mutation to arise does **not** increase its probability.

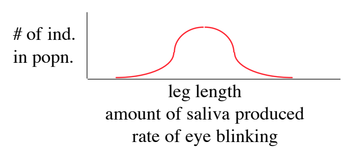
Genetic variation: how do new forms arise?

- Crossing over between maternal & paternal chromosome makes new genotypes.



Individual Variation

- Individuals vary in bell-curve of **phenotypes**
  - phenotype = genotype + environment.
- Due to different environments or genotypes
  - But only gene differences are passed on.



Non-genetic Phenotypic Variation

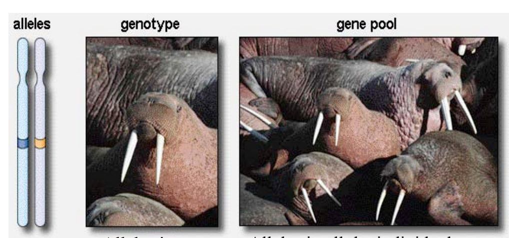
- Environmentally induced phenotypic variations within the same genotype

(a) Map butterflies that emerge in spring: orange and brown

(b) Map butterflies that emerge in late summer: black and white

Figure 23.9

Alleles to Gene Pools

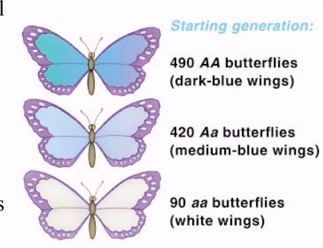


Alleles in an individual

Alleles in all the individuals of the population

GENE POOL & FREQUENCY OF ALLELES IN THE POPULATION

- Gene pool is the total collection of genes and their variations (alleles) in a population
- Reservoir of variations from which the next generation derives its genes
- Polymorphic



Allelic frequency=
49% AA + 42% Aa + 9% aa = 70% A + 30% a

The Hardy-Weinberg Theorem

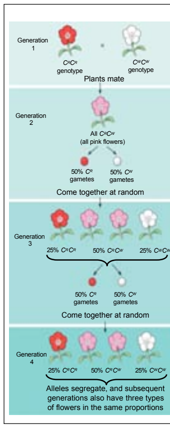


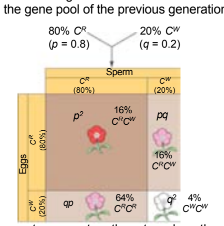
Figure 23.4

- If gametes contribute to the next generation randomly, Mendelian segregation and recombination of alleles preserves genetic variation in a population
  - the frequencies of alleles and genotypes in a population's gene pool ***remain constant from generation to generation***

A population in **Hardy-Weinberg equilibrium**

- p = frequency of occurrence of the C^R allele in the population
- q = frequency of occurrence of the C^W allele in the population

Gametes for each generation are drawn at random from the gene pool of the previous generation:



If the gametes come together at random, the genotype frequencies of this generation are in Hardy-Weinberg equilibrium:
64% C^RC^R, 32% C^RC^W, and 4% C^WC^W

Figure 23.5

A population in **Hardy-Weinberg equilibrium**

- p = frequency of occurrence of the C^R allele in the population
- q = frequency of occurrence of the C^W allele in the population

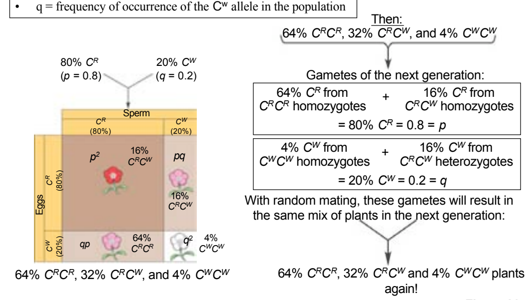


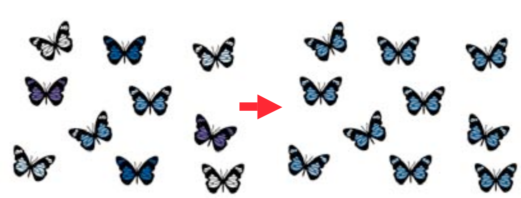
Figure 23.5

A population in **Hardy-Weinberg equilibrium**

- If p and q represent the relative frequencies of the only two possible alleles in a population at a particular locus, then
  - $p^2 + 2pq + q^2 = 1$
    - p^2 = frequency of the genotype homozygous for the first allele
    - q^2 = frequency of the genotype homozygous for the first allele
    - $2pq$ = frequency of the heterozygous genotype

BIOLOGICAL EVOLUTION

- Change in a population's gene pool over time as a result of a change in frequency of an allele

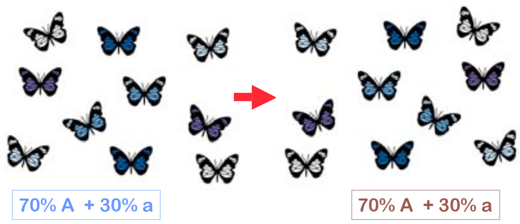


70% A + 30% a

50% A + 50% a

BIOLOGICAL EVOLUTION

- Change in a population's gene pool over time as a result of a **change** in frequency of an allele
- But according to Hardy-Weinburg Equilibrium: if mating is random, the frequency of alleles in a population remains **constant** over time.



BIOLOGICAL EVOLUTION

- Change in a population's gene pool over time as a result of a **change** in frequency of an allele
- But according to Hardy-Weinburg Equilibrium: if mating is random, the frequency of alleles in a population remains **constant** over time.
- Therefore, population evolution is a product of **non-random mating**.

A population in **Hardy-Weinberg equilibrium**

- The five conditions for **Hardy-Weinberg equilibrium:**
  - ✓ Large population size
  - ✓ No significant gene flow
  - ✓ Mutation rate is trivial compared to recombination
  - ✓ Random mating
  - ✓ No significant natural selection
- If any/several of these conditions are not met, changes in allele frequency may occur
  - ➢ non-equilibrium = evolution

BIOLOGICAL EVOLUTION

Remember! —

- **Natural selection works on phenotype**
  - **But only genotype is inherited**
- **Natural selection works on individuals**
  - **But only populations evolve**

EVOLUTION OF POPULATIONS

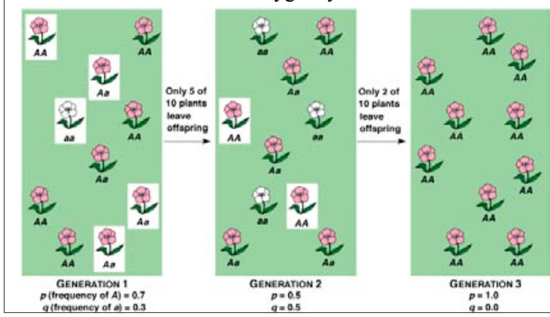
- Genetics & Variability
- *Non-Adaptive Evolution*
- Fitness & Natural Selection
- Sexual Selection

Non-Adaptive Evolution: Most Likely in Small Populations

- Genetic Drift
- Genetic Bottleneck
- Founder Effect
- Gene Flow
- Assortative Mating

Genetic Drift

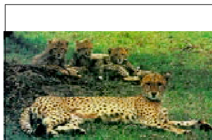
- Random changes in gene frequencies.
  - it can lead to homozygosity.



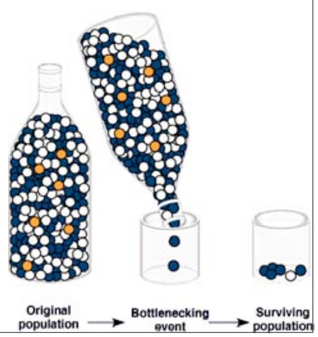
Non-Adaptive Evolution

- Genetic Drift
- *Genetic Bottleneck*
- Founder Effect
- Gene Flow
- Assortative Mating

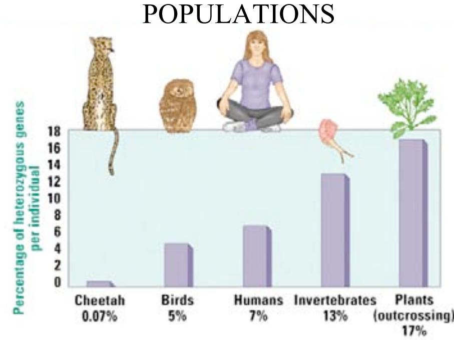
Genetic Bottleneck



- Few survive a population crash
  - cheetahs
  - elephant seals (~20)



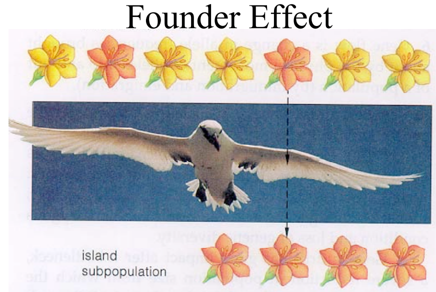
VARIATION IN CHEETAH POPULATIONS



Non-Adaptive Evolution

- Genetic Drift
- Genetic Bottleneck
- *Founder Effect*
- Gene Flow
- Assortative Mating

Founder Effect



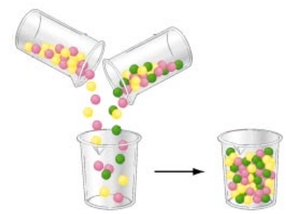
- A few individuals disperse to new place
  - ABO frequencies of Dunkers in PA vs. Germany.

Non-Adaptive Evolution

- Genetic Drift
- Genetic Bottleneck
- Founder Effect
- *Gene Flow*
- Assortative Mating

Gene Flow

- Breeding w/ outsiders
  - Spaniards in Central America



Non-Adaptive Evolution: Significant *only* in small populations.

* **Genetic Drift**: random changes in gene freq.
* **Genetic Bottleneck**: few survive pop. crash
- ➢ cheetahs & elephant seals

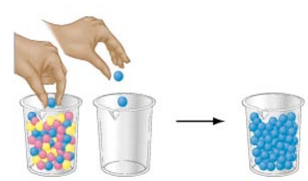
* **Founder Effect**: few disperse to new place
- ➢ ABO frequencies of Dunkers in PA vs. Germany.

* **Gene Flow**: breeding w/ outsiders
- ➢ Spaniards in Central America

* □ ↑ **homozygosity.**
* □ □ **homozygosity.**

Non-adaptive Evolution: Nonrandom mating

- **Assortative Mating**: with those who look most like you.
- **Sexual Selection**: coming soon!



EVOLUTION OF POPULATIONS

- Genetics & Variability
- Non-Adaptive Evolution
- Fitness & Natural Selection
  - *Modes of Selection*
- Sexual Selection

Terms used in Natural Selection

- **Fitness**: measure of how many genes you pass on to future generations.
- Differential representation of genes in future generations due to differential survival to reproductive maturity.
  - Requires heritable (genetic) variation among individuals.
- If differential survival is based upon **expressed** genotypic differences
  - it **may** lead to changes in population gene frequency.

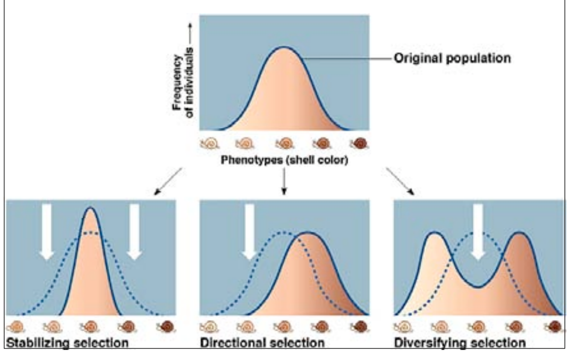
"Survival of the fittest"

"Reproduction of the fittest"

Fitness and Selection

- **Darwinian fitness** is a *relative* measure
  - how many offspring does one individual leave relative to others in the population.
- Inheritance acts upon genotype
- Selection acts upon phenotype
  - morphology, physiology, or behavior
- Agents of selection
  - physical environment
  - biological environment
    - con- or hetero-specifics.

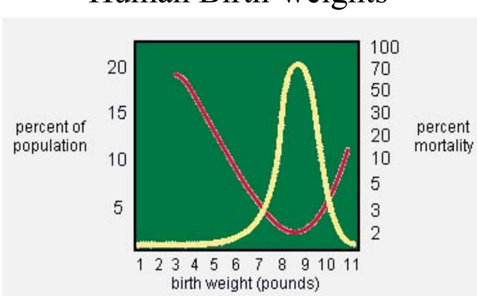
Modes of Selection

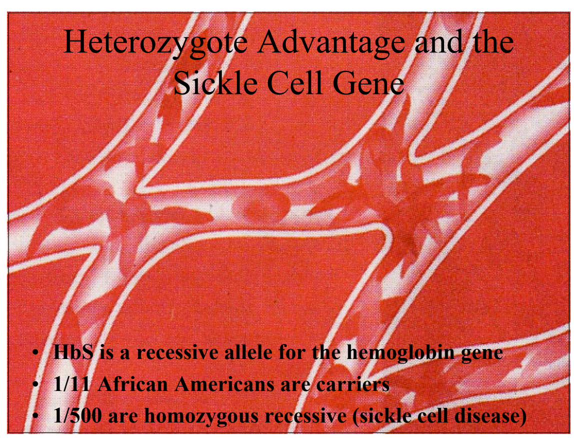


Modes of Selection

- Fitness and Selection
- Stabilizing Selection
- Directional Selection
- Diversifying Selection

Stabilizing Selection: Human Birth-weights

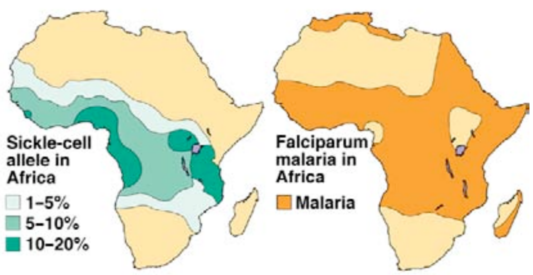




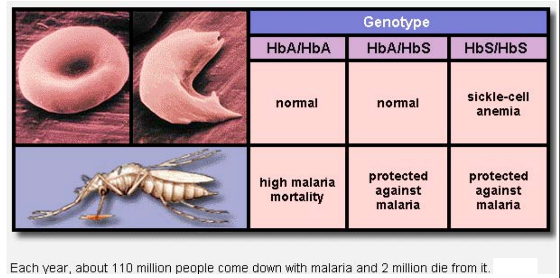
Heterozygote Advantage and the Sickle Cell Gene

- **HbS is a recessive allele for the hemoglobin gene**
- **1/11 African Americans are carriers**
- **1/500 are homozygous recessive (sickle cell disease)**

MALARIA AND SICKLE CELL DISEASE



Heterozygote Advantage: Malaria and Sickle Cell Anemia



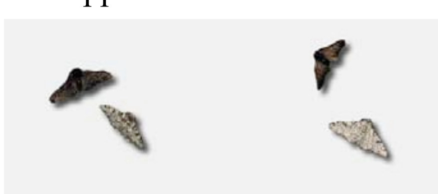
Modes of Selection

- Fitness and Selection
- Stabilizing Selection
- Directional Selection
- Diversifying Selection

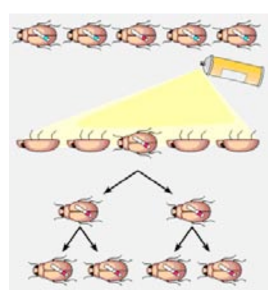
Directional Selection: The Pepper Moth *Biston betularia*

Industrial melanism in early 1900's

Directional Selection: The Pepper Moth *Biston betularia*



EVOLUTION OF PEST RESISTANCE

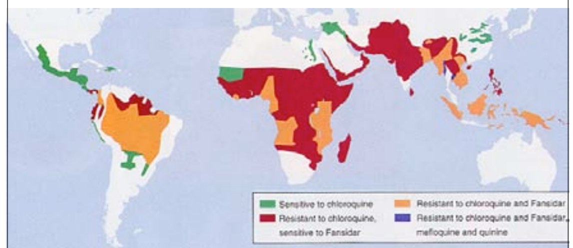


- Red gene confers resistance to pesticide
- Insecticide application
- Only individuals carrying red gene survive
- Red gene increases in population

MALARIA TODAY

- Mostly under control in 1947
- Common today in tropical countries
- Kills 2.7 million per year
- Mostly children

MALARIAL RESISTANCE



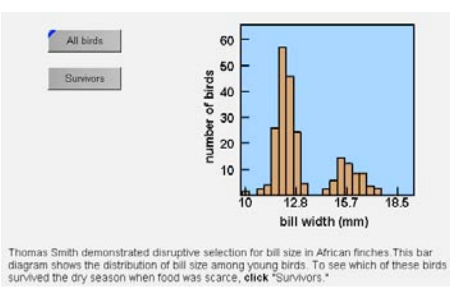
Modes of Selection

- Fitness and Selection
- Stabilizing Selection
- Directional Selection
- *Diversifying Selection*
  - a.k.a. ***disruptive selection***

Diversifying Selection: African Seedcrackers

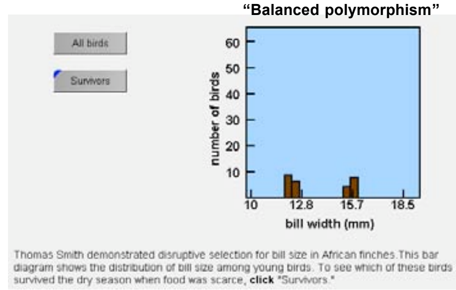
These birds feed on seeds of two sedge species.

Diversifying Selection: African Seedcrackers



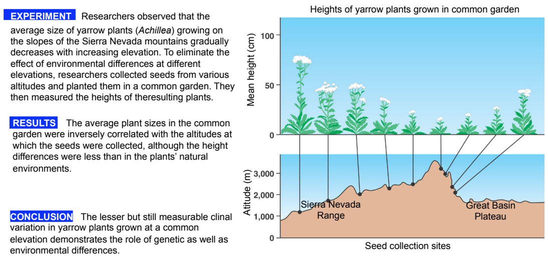
Diversifying Selection: African Seedcrackers

"Balanced polymorphism"



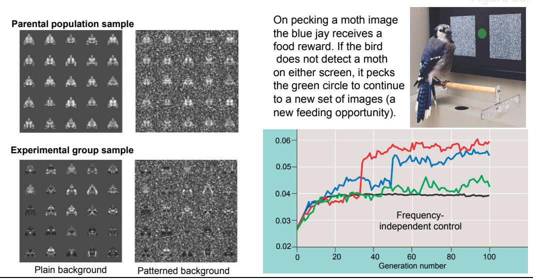
Diversifying Selection:

- Different phenotypes favored in different parts of the population's range
- E.g., a **cline:** graded change in a trait along a geographic axis



Diversifying Selection

- Frequency-dependent selection
  - Predators learn to focus on most common phenotype
  - Minor alternate phenotypes escape notice



EVOLUTION OF POPULATIONS

- Genetics & Variability
- Non-Adaptive Evolution
- Adaptive Evolution: Natural Selection
  - Modes of Selection
- *Sexual Selection*

Sexual Selection

- **Natural Selection** (NS): differential reproduction due to differential survival.
- **Sexual Selection** (SS): differential reproduction due to *increased* Reproductive Success (RS) despite possible *decreased* survival.

Sexual Selection

- Even though some variations may *increase* survival, health, competitive success, etc., …
- they will **not** increase in frequency in the gene pool **if** they are **not also** associated with increased reproductive success!

Sexual Selection

- Even though some variations may *decrease* survival, health, competitive success, etc., …
- they **will** increase in frequency in the gene pool **if** they **are also** associated with increased reproductive success!

TO BE DISCUSSED FURTHER IN NEXT LECTURE