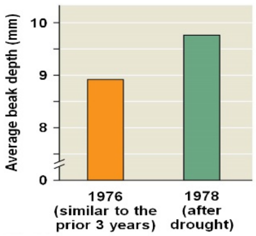
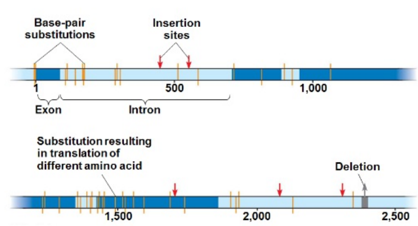
Chapter 21: The Evolution of Populations

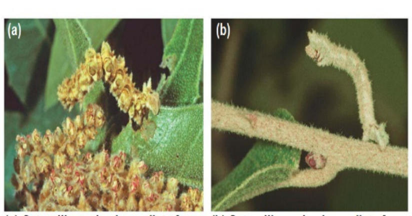
*Individual organisms do not evolve; Populations evolve
Ground Finch Evolution: a change in average beak depth
*1977 Drought left only large, hard seeds as a reliable food source
*only 180 of 1200 birds survived (why?)



*in the course of several generations, the proportion of large beaks increased
Microevoluton: changes in allele frequencies in a population over time
-as the proportion of individuals with large beaks increases, so too does the frequency of alleles that encode large beaks
3 Main Mechanisms tha can cause allele frequency change:
1. natural selection
2. Genetic Drift (chance, founder effect, bottleneck)
3. gene flow(transfer of alleles between populations)

A. Genetic Variation makes Evolution possible
Darwin recognized variation of heritable traits as a keyy for natural selection
Mendel described how heritable traits passed from parents to offspring
1. Genetic Variation (provides raw material for evolutionary change)
a. Variation occurs in phenotypes we can see AND in molecular traits we cannot see
-differences in genes or other DNA sequences
b. either or traits: Mendel's pea flowers (white or purple)
-often determined by a single gene locus with different alleles producing distinct phenotypes
c. polygenic traits: pheotype influenced by many genes
2. gene variability: can lead to phenotypic variation
genetic variability at the whole gene level = avg. % of loci that are heterozygous
ex. *D. melanogaster* is heterozygous for 14% of its 13,700 genes
3. nucleotide variability: may not lead to phenotypic variation
-many variations occur at introns (non-coding part of a gene)
-variations occuring in exons (coding region) often do not alter a.a. sequence
4. Phenotype is often a product of genotype & environment





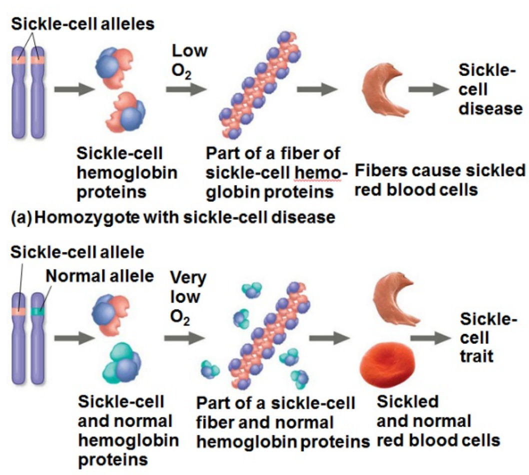
(a) Caterpillars raised on a diet of (b) Caterpillars raised on a diet of

B. Sources of Genetic Variation:
Mutation, Gene Duplication, New genes or Alleles, Sexual Reproduction

1. Formation of new alleles
   a. mutation: only mutations in cell lines that produce gametes can be passed to offspring
      -plants and fungi have many cell lines that produce gametes
      -animals are more restricted (most mutations occur in somatic cells)
   b. most new mutations that alter phenotype are at least slightly harmful
      -natural selection quickly removes harmful alleles
   c. in diploid organisms, recessive harmful alleles can persist (heterozygote protection)
      -maintains a pool of alleles that may benefit if environment changes
2. Neutral Variation: do not confer a selective advantage or disadvantage
3. Altering Gene Number or Position
   a. chromosomal changes that delete, disrupt or rearrange many loci are usually harmful
      -if genes are left intact: may not affect phenotype (rare)
      -some recombinations of genes may be beneficial (even rarer)
   b.duplication of genes during meiosis (unequal crossing-over), DNA replication, or transposable elements (moveable stretches of DNA: jumping genes)
      -if no harm, gene duplications can persist and accumulate mutations resulting in new genes with new functions
      ex. mammals started with a single gene for detecting odor (human 380, mice 1200)

4. Rapid Reproduction
   a. mutation rate among plants and animals avg one in every 100,000 genes per generation
   b. lower rate for prokaryotes but create many more generations per unit of time
      -same for viruses (HIV generation rate is two days)
         -HIV has an RNA genome. RNA mutates faster than DNA
            -drug cocktails have been the best way to compete with mutation
5. Sexual Reproduction
   a. crossing over
   b. independent assortment of chromosomes
   c. fertilization

Figure 11.16



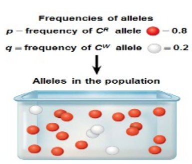
1 in 400 have sickle-cell disease
1 in 10 have sickle-cell trait

II. Using the Hardy-Weinberg Equation to test evolving populations

$$p^2 + 2pq + q^2 = 1$$

A. Gene Pools and Allele Frequencies

1. population: a group of individuals of the same species that live in the same area and interbreed, producing fertile offspring
   a. members of a population typically breed with one another and are then more closely related to each other than to other populations
2. Gene Pools: consists of all copies of every type of allele at every locus in all members of the population
   a. if only one allele is present, the allele is said to be 'fixed'
   b. 500 wildflowers have a single gene for flower color C^R - red C^W-no red (white)
   C^RC^R individuals have red flowers, C^WC^W individuals have white flowers and C^RC^W individuals have pink flowers
   in our population of flowers, 320 have red flowers, 160 have pink & 20 white
   # of total alleles for this gene = 500 x 2 = 1000 alleles
   # of C^R alleles in the population = (320 x 2) + (160 x 1) + (0 x 20) = 800
   frequency of the red allele = 800/1000 = 0.8 or 80% = p
   frequency of C^W allele = (160 x 1) + (20 x 2) = 200; 200/1000 = 0.2 or 20% = q

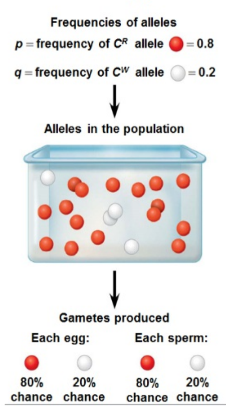


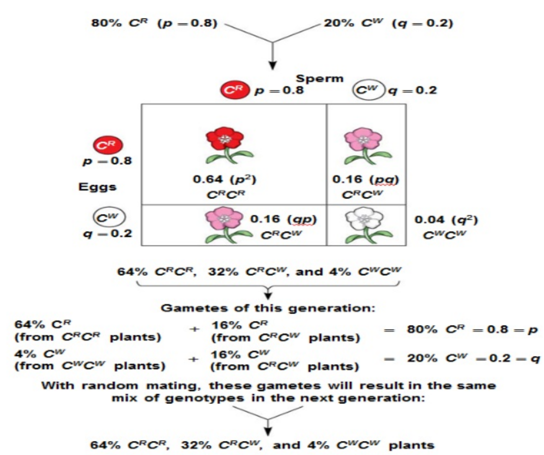
B. The Hardy-Weinberg Equation

*helps to determine the genetic make-up of a pop. if it is NOT evolving

*compare H-W results with the observed results in a live pop.

1. in a pop. that is not evolving: allele frequencies remain constant (H-W Equilibrium)
2. Considering the combination of alleles in ALL of the crosses in a pop.





3. If a pop. is not evolving at the studied locus,
   then the observed frequency of one homozygote must be p^2, the observed frequency of the other homozygote must be q^2 and the observed frequency of the Heterozygote must be 2pq.

4. Conditions for H-W Equilibrium
   a. No Mutations can happen at the studied locus
   b. Random Mating: assume all male-female matings are equally likely
   c. No Natural Selection: all combinations of alleles have equal success rates
   d. Extremely large population size: less likely to have chance fluctuation in allele freq.
   e. No Gene Flow: no movement of alleles into or out of the pop

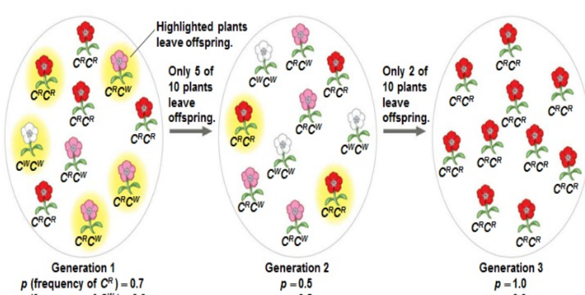
Departure from these conditions usually lead to evolutionary change

5. Applying H-W Equation
   a. PKU (phenylketonuria) is a recessive genetic disorder
   b. PKU occurs in 1 of every 10,000 babies born in the US each year
   c. if all assumptions hold true then:
   d. since allele is recessive (q) we must estimate the number of heterozygotes (2pq)
      - since 1 PKU in 10,000 births then q2 = 1/10000 = 0.0001; q = 0.01
      - since p + q = 1; then p = 0.99
      - the frequency of heterozygotes (carriers) is 2 x 0.99 x 0.01 = 0.0198 or 2% of pop.

III. Natural Selection, Genetic Drift and Gene Flow can alter Allele Freq.

A. Natural selection
   1. variations in heritable traits that influence survival or reproduction are selected for or against
      a. pre 1930's mosquitos have a 'DDT resistant allele' freq =0%
         post 1960's (after DDT exposure) have a 'DDT resistant allele" frequency = 37%. WHY?
      b. adaptive evolution: a process in which traits that enhance survival or reproduction tend to increase in frequency over time.

B. Genetic Drift
   1. Chance events can cause allele frequencies to change in unpredictable ways
      a. especially in small populations



2. The Founder Effect

a. occurs when a few individuals become isolated from a larger pop and establish a new pop with a gene pool that differs from the original pop

ex. 1814 settlement of Tristan da Cunha, 15 colonists founded a settlement. By 1960, 4 members of the population had retinitis pigmentosa (a recessive genetic disorder that causes blindness) out of a population that has grown to 240 individuals. The population in 1814 from which the founders had come, had the recessive allele in a frequency of 0.013. How has the founder effect impacted the new population?

3. The Bottleneck Effect

a. a severe reduction in population size over a short period of time can cause a significant change in allele frequencies

*alleles may be overrepresented, underrepresented or may disappear in the "new" population

b. Populations may eventually increase in size but the effect of a reduced gene pool can cause a low level of genetic variability for a long time

c. Prairie Chickens in Illinois. Population in 1930's was 25,000. By 1960's -1,000 by 1993 it was less than 50. 1930-1960 93% of eggs hatched, 1993 <50%

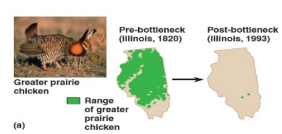
4. Effects of Genetic Drift

a. Chance events have a significant effect in small populations.

b. Causes allele frequencies to change at random in unpredictable ways

c. Can lead to a loss of genetic variation in a population

d. Can cause harmful alleles to become 'fixed'



Location	Population size	Number of alleles per locus	Percentage of eggs hatched
Illinois			
1930–1960s	1,000–25,000	5.2	93
1993	<50	3.7	<50
Kansas, 1998 (no bottleneck)	750,000	5.8	99
Nebraska, 1998 (no bottleneck)	75,000–200,000	5.8	96

(b)

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(b)

C. Gene Flow: the transfer of alleles into or out of a population due to the movement of fertile individuals or their gametes

1. gene flow tends to reduce the genetic difference between populations

*can become a single population with a common gene pool

2. Gene flow can also affect how well populations are adapted to local environmental conditions

ex. songbird (*Parus major*): two populations:one island: survival rate seems to depend on where the females are born. Eastern born survives better than Central born regardless of where the females settle and raise offspring.

3. Gene flow can also transfer alleles that improve the ability of populations to adapt to local conditions

ex. worldwide spread of several insecticide-resistant alleles in the mosquito (*Culex pipiens*) a vector of West Nile virus

4. Gene flow has become a important agent of evolutionary change in humans leading to fewer genetic differences among populations

IV. Natural Selection is the only mechanism that consistantly causes adaptive evolution

*Natural Selection is a blend of chance and "sorting"

*Chance in the creation of new variations and sorting favorable alleles

* Natural selection is NOT random

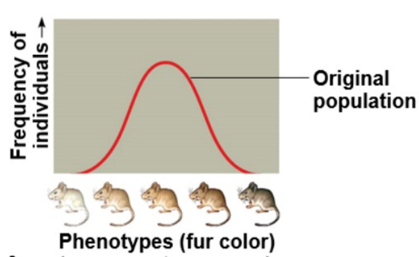
A. Relative Fitness: the contribution an individual makes to the gene pool of the next generation relative to the contribution of other individuals

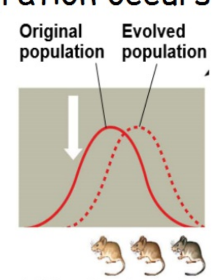
1. typically refers to genotypes but selection acts more directly on phenotype

2. Directional selection: occurs when conditions favor individuals exhibiting one extreme of a phenotypic range

a. causes a shift in the populations frequency curve for that phenotype

b. common when environment changes or migration occurs to a different habitat

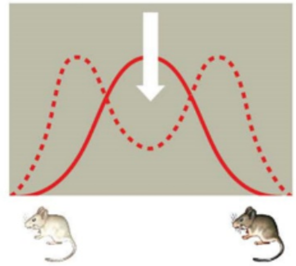




(a) Directional selection

3. Disruptive Selection occurs when conditions favor individuals at both extremes of a phemotypic range over individuals with intermediate phenotypes

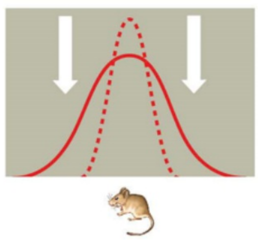
ex. black-bellied seedcracker finches



(b) Disruptive selection

4. Stabilizing Selection: favors intermediate phenotypes over extremes

ex. human birth weight: lower mortality for intermediate weight newborns (6.6-8.8lbs)



(c) Stabilizing selection

B. The Key Role of Natural Selection in Adaptive Evolution

1. A Continuous Dynamic Process: as environments change, so does the selection for advantageous traits

a. gene flow and genetic drift play a lesser role since their effects are unpredictable

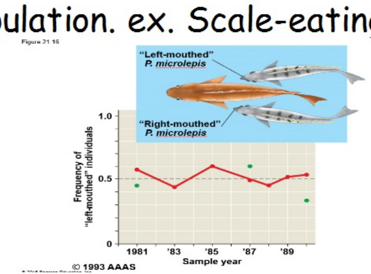
b. Natural Selection is the only mechanism that consistantly leads to adaptive evolution

2. Balancing Selection: What prevents Selection from eliminating all unfavorable alleles?

a. Heterozygote Advantage: idividuals who are heterozygous at a particular locus have greater fitness than do both homozygotes

*defined through genotype and not phenotype: if the Hz phenotype is intermediate, this may lead to stabilizing selection (ex. sickle cell)

b. Frequenct-dependent Selection: the fitness of a phenotype depends on how common it is in a population. ex. Scale-eating fish (*Perissodus microlepis*)



3. Sexual Selection: individuals with certain inherited traits are more likely than other individuals of the same sex to obtain mates

a. can result in sexual dimorphism (a difference in secondary sexual characteristics between males and females of the same species

b. intrasexual selection: within the same sex; usually males

c. intersexual selection (mate choice): one sex chooses a mate from the other sex

*traits associated with "good genes"