Population and Community Dynamics

Part 1. Genetic Diversity in Populations

Pages 676 to 701

Part 2. Population Growth and Interactions

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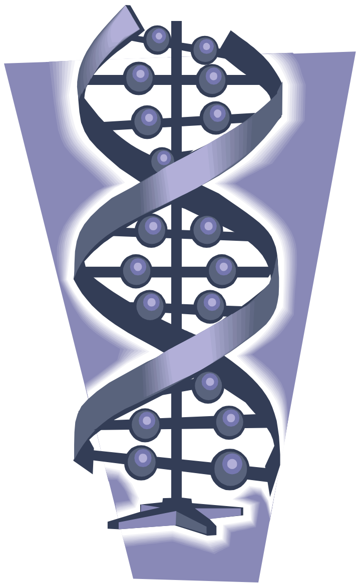


Review

Evolution by Natural Selection

- new variants of a species are continually arising in a population
  - variants can be successful and lead to new species
  - variants can be unsuccessful and die off when faced with environmental pressure
- variations in a population arise from random mutations in the DNA code.
  - evolution depends on:
    - random genetic mutation
    - natural selection (selecting for favorable traits)

Review

Discussing Genetics

- Alleles
  - alternate forms of genes.
  - you get one allele from each parent.
  - are found at certain locus or location on the gene
  - if the alleles at one locus are identical they are said to be homozygous
  - if the alleles at one locus are different they are said to be heterozygous

Review

Discussing Genetics

- Alleles
  - if the alleles inherited from the parents are different, the dominant allele will be expressed in the individuals appearance.
    - this becomes the phenotype.
    - the remaining allele has no affect on the phenotype but remains as part of the individuals genotype (DNA blueprint).

Review

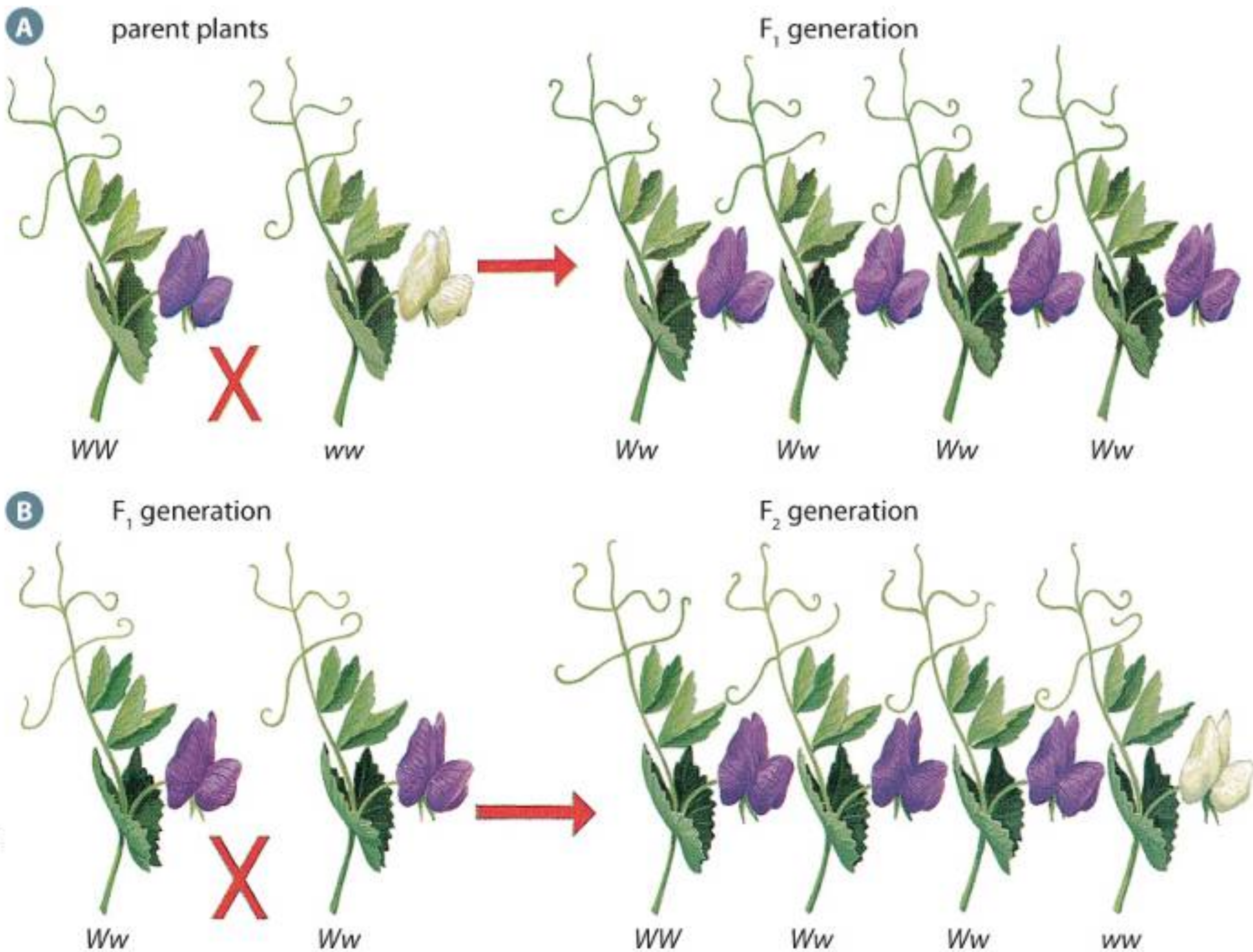


Figure P8.1 Two generations (**A** and **B**) resulting from the cross of a purple-flowered pea plant and a white-flowered pea plant.

Review

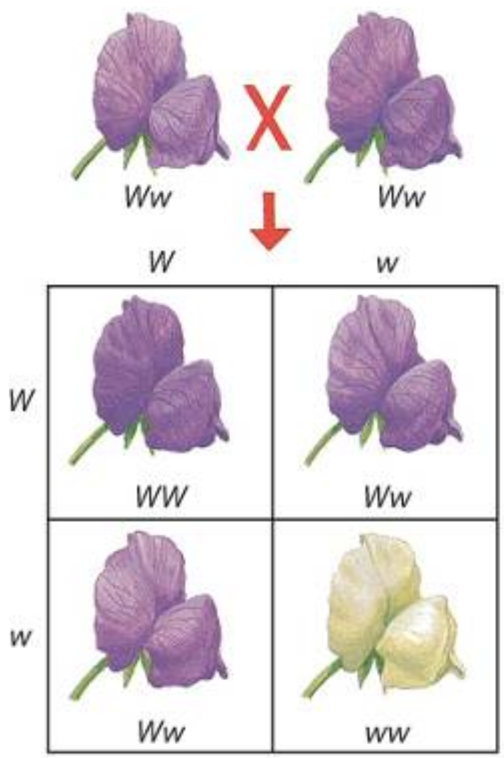


Figure P8.2 This cross between heterozygous pea plants (the same as the $F_1 \times F_1$ cross in Figure P8.1) is shown in a Punnett square.

Genotype	Genotype	Phenotype
WW	homozygous dominant	purple flower
Ww	heterozygous	purple flower
ww	homozygous recessive	white flower

<u>Probability of Getting a Purple Flower</u>

Desired trait/Number of possible outcomes

3/4

0.75

<u>Probability of Getting a Homozygous Dominant Offspring</u>

Desired trait/Number of possible outcomes

1/4

0.25

Part 1. Genetic Diversity in Populations
I) Introduction

- Definitions
  - Population:
    - a group of organisms of the same species (can interbreed) and live in the same area and time.
  - Gene pool:
    - sum of all the genes in a certain population
      - the more variation in a gene pool the better the populations chances of surviving environmental pressures.
  - Genotypic ratio
    - the ratio of offspring with each possible allele combination from a particular cross
  - Genotypic frequency
    - the proportion of a population with a particular genotype

Part 1. Genetic Diversity in Populations
I) Introduction

- example:

Figure 19.3 Determining the genotype and allele frequencies in a population sample by counting

Phenotype			
Genotype	*BB*	*Bb*	*bb*
Number of mice (total = 200)	72	96	32

- this is a sample of a mouse population of 200 with 72 homozygous black mice (BB), 96 heterozygous black mice (Bb) and 32 homozygous white mice (bb). Black is dominant over white (black > white)

Part 1. Genetic Diversity in Populations
I) Introduction

The genotypic frequency of the bb genotype is found by: (number with desired genotype)/ (total population) 32/200 0.16 (usually given a decimal) *as a percent 0.16 x 100% =16%*	The genotypic frequency of the Bb genotype is found by: (number with desired genotype)/ (total population) 96/200 0.48 (usually given a decimal) *as a percent 0.48 x 100% =48%*	The genotypic frequency of the BB genotype is found by: (number with desired genotype)/ (total population) 72/200 0.36 (usually given a decimal) *as a percent 0.36 x 100% =36%*

- the sum of all three genotypes will be 1.00 or 100%

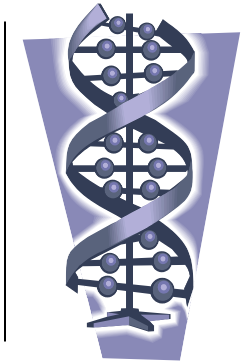
Part 1. Genetic Diversity in Populations
I) Introduction

Figure 19.3 Determining the genotype and allele frequencies in a population sample by counting

Phenotype

Genotype	*BB*	*Bb*	*bb*
Number of mice (total = 200)	72	96	32
Genotype frequency	$\frac{72}{200} = 0.36$	$\frac{96}{200} = 0.48$	$\frac{32}{200} = 0.16$

Part 1. Genetic Diversity in Populations
I) Introduction



- phenotypic ratio
  - the proportion of the population with a particular phenotype.

<u>example</u> *phenotypic Black mice* (genotypes BB and Bb) (72+96)/200 168/200 **0.84** (0.84 x 100% = 84%)	<u>example</u> *phenotypic white mice* (bb only) 32/200 **0.16** (0.16 x 100% = 16%)

Part 1. Genetic Diversity in Populations
I) Introduction

- allele frequency
  - the rate of occurrence of a particular allele in a population.
    - usually expressed as a decimal
  - because diploid organisms have two possible alleles for every gene the total number of alleles in a population is twice the number of the individuals.
  - example:
    - a sample population of 200 mice will have 400 alleles for coat colour.

Part 1. Genetic Diversity in Populations
I) Introduction

- allele frequency for Coat Colour in the Mouse population

Phenotype	Genotype	Alleles	Frequency	Math	Total
Black	*BB*	*B* *B*	72		
Black	*Bb*	*B* *b*	96 96		
White	*bb*	*b* *b*	*32* *32*		
		Total:			

Part 1. Genetic Diversity in Populations
I) Introduction

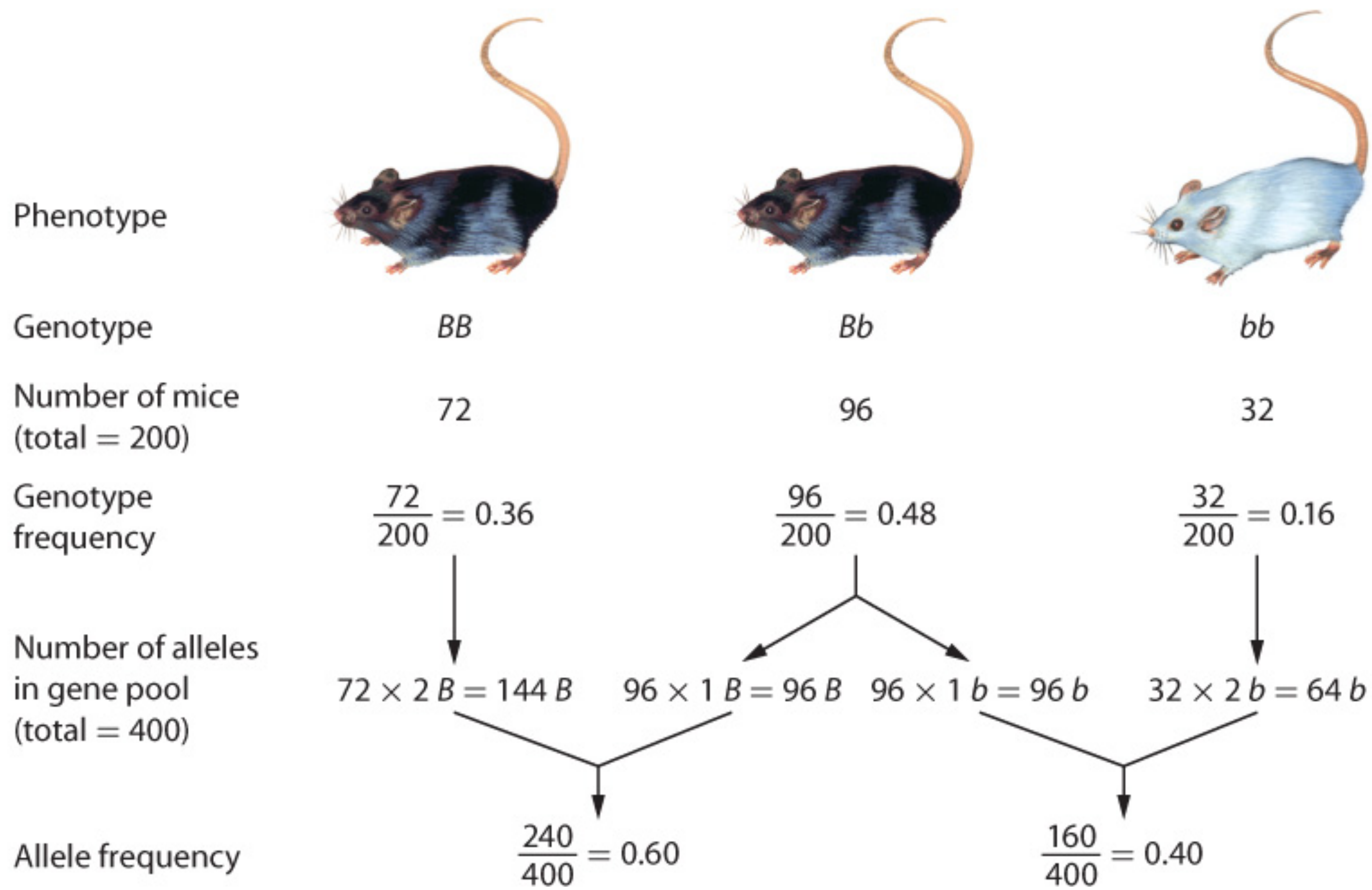
- the frequency of each allele is found by dividing the incidence of the allele by the total number of alleles in the sample

The Frequency of the *B* Allele	The Frequency of the *b* Allele
240/400 = 0.60 (60%)	160/400 = 0.40 (40%)

- the sum of all the phenotypic frequencies will be 1.00 or 100%

Part 1. Genetic Diversity in Populations
I) Introduction

Figure 19.3 Determining the genotype and allele frequencies in a population sample by counting



Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- early thinking by biologist lead to the wrong idea that recessive alleles will eventually be eliminated from the population.
  - example:
    - the most common blood type in Alberta is O which is a recessive genotype (*ii*)
  - Godfrey Hardy and Wilhelm Weinberg showed that allele frequency in a population will remain the same from one generation to the next if five conditions are met.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- the five conditions of the Hardy-Weinberg Principle
    1. The population is large enough that chance events will not alter allele frequencies.
    2. Mates are chosen on a random basis.
    3. There are no net mutations
    4. There is no migration
    5. There is no natural selection against any phenotypes.
- the principle gives us a “snap shot” of a static population (not evolving)

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- consider a trait that is controlled by a dominant and a recessive allele.
  - the letter "*p*" represents the frequency of the dominant allele
  - the letter "*q*" represents the frequency of the recessive allele
  - because there is only two forms of the alleles the frequencies must add up to 1.00

$$p + q = 1.00$$

frequency of dominant allele	frequency of recessive allele	all the alleles (100 percent)

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- the Hardy-Weinberg principle and the Punnett's Square

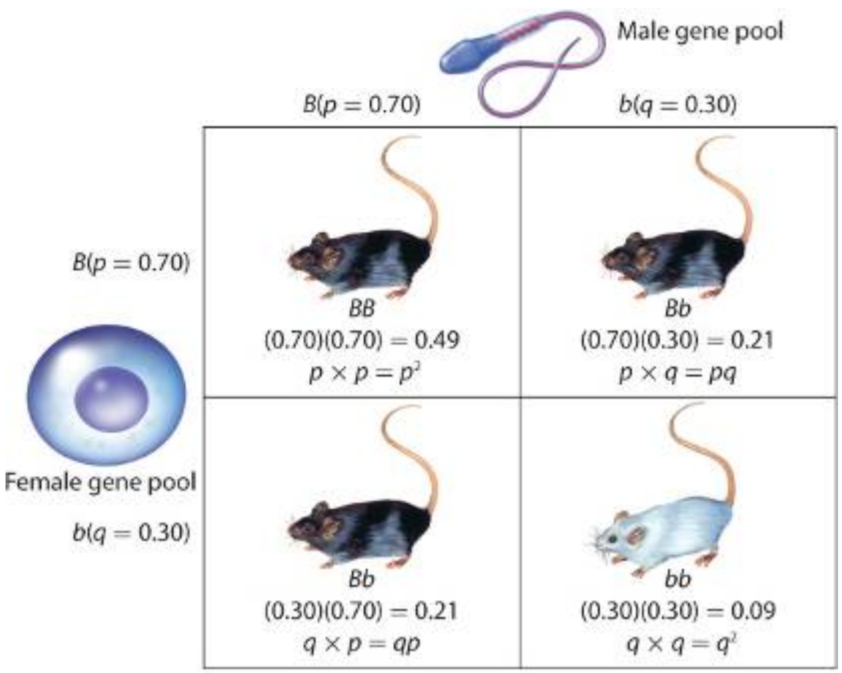


Figure 19.4 A Punnett square can be used to determine the expected genotype frequencies in the next generation. This Punnett square has been scaled up to represent the genotype frequencies for the gametes in an entire gene pool. In generic terms, p^2 represents the homozygous dominant offspring, $2pq$ represents the heterozygous offspring, and q^2 represents the homozygous recessive offspring.

- in this example the dominant allele frequency is 0.70 (p = 0.70) and the recessive allele frequency is 0.30 (q = 0.30)
  - if p represents the frequency of the dominant allele then p^2 represents the frequency of homozygous dominant offspring.
  - if q represents the frequency of the recessive allele then q^2 represents the frequency of homozygous recessive offspring.
  - there are two possible combinations that will result in the heterozygous genotypes

$$pq + qp = \mathbf{2pq}$$

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

The Hardy-Weinberg Principle

$$p^2 + 2pq + q^2 = 1.00$$

- p^2: frequency of homozygous dominant genotype
- $2pq$: frequency of heterozygous genotype
- q^2: frequency of recessive genotype
- 1.00: all the individuals in the population (100%)

- The Hardy-Weinberg Principle can be used to calculate the proportion of individuals with a specific genotype in a population.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- example
  - the dominant allele "*p*" frequency is 0.70 and the recessive allele "*q*" frequency is 0.30 in a mouse population of 200.

$$p^2 + 2pq + q^2 = 1.00$$

$$(0.70)^2 + 2(0.70)(0.30) + (0.30)^2 = 1.00$$

$$0.49 + 0.42 + 0.09 = 1.00$$

  - 49% of the next generation will be homozygous dominant
  - 42% of the next generation will be heterozygous dominant
  - 9% of the next generation will be homozygous recessive

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- example

$$p^2 + 2pq + q^2 = 1.00$$

  - we can modify the equation to predict the frequencies of traits in a population

$$p^2 (N) + 2pq (N) + q^2 (N) = N$$

where "N" is the population size

$$0.49(N) + 0.42(N) + 0.09(N) = N$$

$$0.49(200) + 0.42(200) + 0.09(200) = 200$$

  - 98 individuals will be homozygous dominant
  - 84 individuals will be heterozygous
  - 18 individuals will be homozygous recessive.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Sample Problem 1: Albinism in a Snake Population

- In a randomly mating population of snakes, one out of 100 snakes counted is albino, a recessive trait. Determine the theoretical percentage of each of the genotypes in the population.

What Is Required?

- To determine the values for p^2, $2pq$, and q^2, which represent the frequencies of the *AA*, *Aa*, and *aa* genotypes in the population

What Is Given?

- The value of q^2: The proportion of snakes that are albino and thus have the *aa* genotype is $1.00/100.00$
- $p + q = 1.00$

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Plan Your Strategy

- Change the value of q^2 to a decimal.
- Take the square root of the value of q^2 to find the value of q.
- Subtract q from 1.00 to find the value of p.
- Find the values of p^2 and $2pq$.
- Express p^2 and $2pq$ as percents.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Step 1

$$q^2 = 1.00/100.00$$
$$= 0.0100, \text{ or } 1.00\ \%$$

Step 2

$$\sqrt{q^2} = \sqrt{0.0100}$$
$$q = 0.100$$

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Step 3

$$p + q = 1.00$$
$$p = 1.00 - q$$
$$= 1.00 - 0.100$$
$$= 0.900$$

Step 4

$$p^2 = (0.900)(0.900)$$
$$= 0.810, \text{ or } 81.0\ \%$$
$$2pq = 2(0.900)(0.100)$$
$$= 0.180, \text{ or } 18.0\ \%$$

Homozygous
<u>Dominant (p^2)</u>
0.81 (81%)
<u>Heterozygous(pq)</u>
0.18 (18%)
Homozygous
<u>Recessive (q^2)</u>
0.01 (1%)

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Sample Problem 2: Wing Length in Fruit Flies

- A single pair of alleles codes for one of the genes that controls wing length in fruit flies (*Drosophila melanogaster*). The long wing allele (*L*) is dominant to the short wing allele (*l*). If 40 fruit flies out of 1000 that are counted have short wings, how many fruit flies out of 1000 would be expected to be heterozygotes?

What Is Required?

- To determine the number of fruit flies that are heterozygous (*Ll*) for the wing length gene, given a population sample (*N*) of exactly 1000.

What Is Given?

- The proportion (q^2) of homozygous recessive (*ll*) fruit flies in the sample, $\frac{40}{1000}$

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Plan Your Strategy

- Change the frequency of q^2 to a decimal.
- Take the square root of the value of q^2 to find the value of q.
- Subtract q from 1.00 to find the value of p.
- Find the value of $2pq$.
- Multiply the population size (N) by the frequency of the heterozygous genotype ($2pq$).

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Act on Your Strategy

- **Step 1**

$$q^2 = \frac{40.0}{1000}$$

$$= 0.0400$$

- **Step 2**

$$\sqrt{q^2} = \sqrt{0.0400}$$

$$q = 0.200$$

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- **Step 3**

$$p + q = 1.00$$
$$p = 1.00 - q$$
$$= 1.00 - 0.200$$
$$= 0.800$$

- **Step 4**

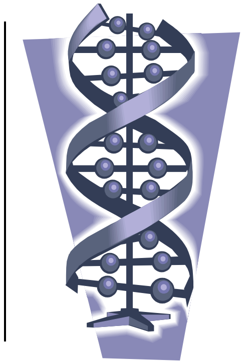
$$2pq = 2(0.800)(0.200)$$
$$= 0.320$$

- **Step 5**

$$\text{number of heterozygotes} = (2pq)(N)$$
$$= (0.320)(1000)$$
$$= 3.2 \times 10^2$$

- The population sample would be expected to contain exactly 320 fruit flies that are heterozygous (*Ll*) for the wing length gene.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle



- the Hardy-Weinberg principle:
  - provides a method to measure the amount of variation within a gene pool.
  - allows geneticists to compare allele frequencies in a population at different times.
    - if there is no change in allele frequency over time then the population is said to be at genetic equilibrium or Hardy-Weinberg equilibrium.
      - a population at genetic equilibrium does not change or evolve over time.
      - populations evolve and change when one of the Hardy-Weinberg principles are not met.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

- the gradual change in allele frequencies of a population is called microevolution

  (microevolution: of a population, any change in allele frequencies resulting from mutation, genetic drift, gene flow, natural selection, or some combination of these)

- the Hardy-Weinberg principle can also be used to study incomplete and co-dominant alleles.
  - population ecologists DNA test populations of interest to find out which alleles individuals carry.

Part 1. Genetic Diversity in Populations
II) The Hardy-Weinberg Principle

Change in allele frequencies in a collared pika population 1998–2005

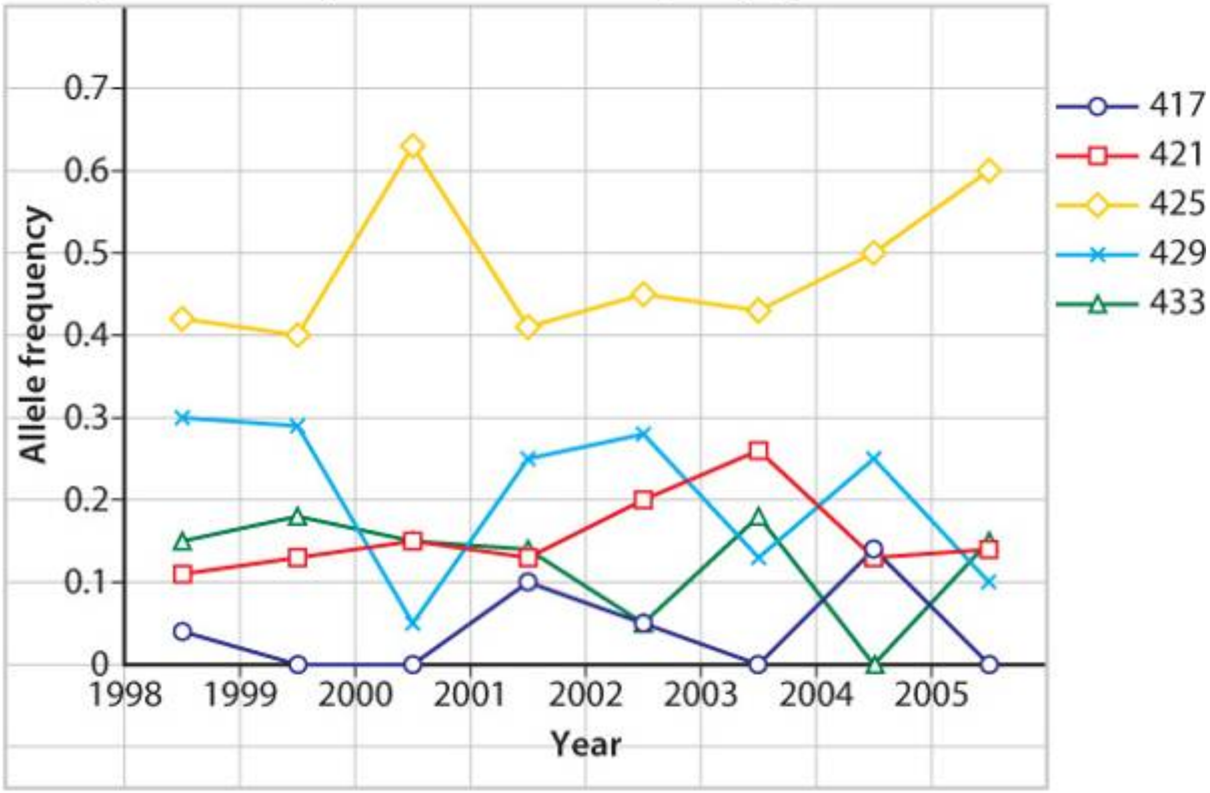


Figure 19.5 The change in frequencies of five alleles (identified by different numbers in the legend) in a collared pika population over eight years. This population, which has been declining in size, appears to be undergoing microevolution. The sum of the allele frequencies estimated for each year of the study is 1.00 (or very close to 1.00 due to rounding and estimation). (Data provided by Jessie Zgurski, University of Alberta.)

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- Genetic diversity
  - the degree of genetic variation within a species or population.
  - the key to a species surviving changing environmental pressures.
- Changes in the gene pool come about from:
  - genetic mutations
  - gene flow
  - non-random mating
  - genetic drift
  - natural selection

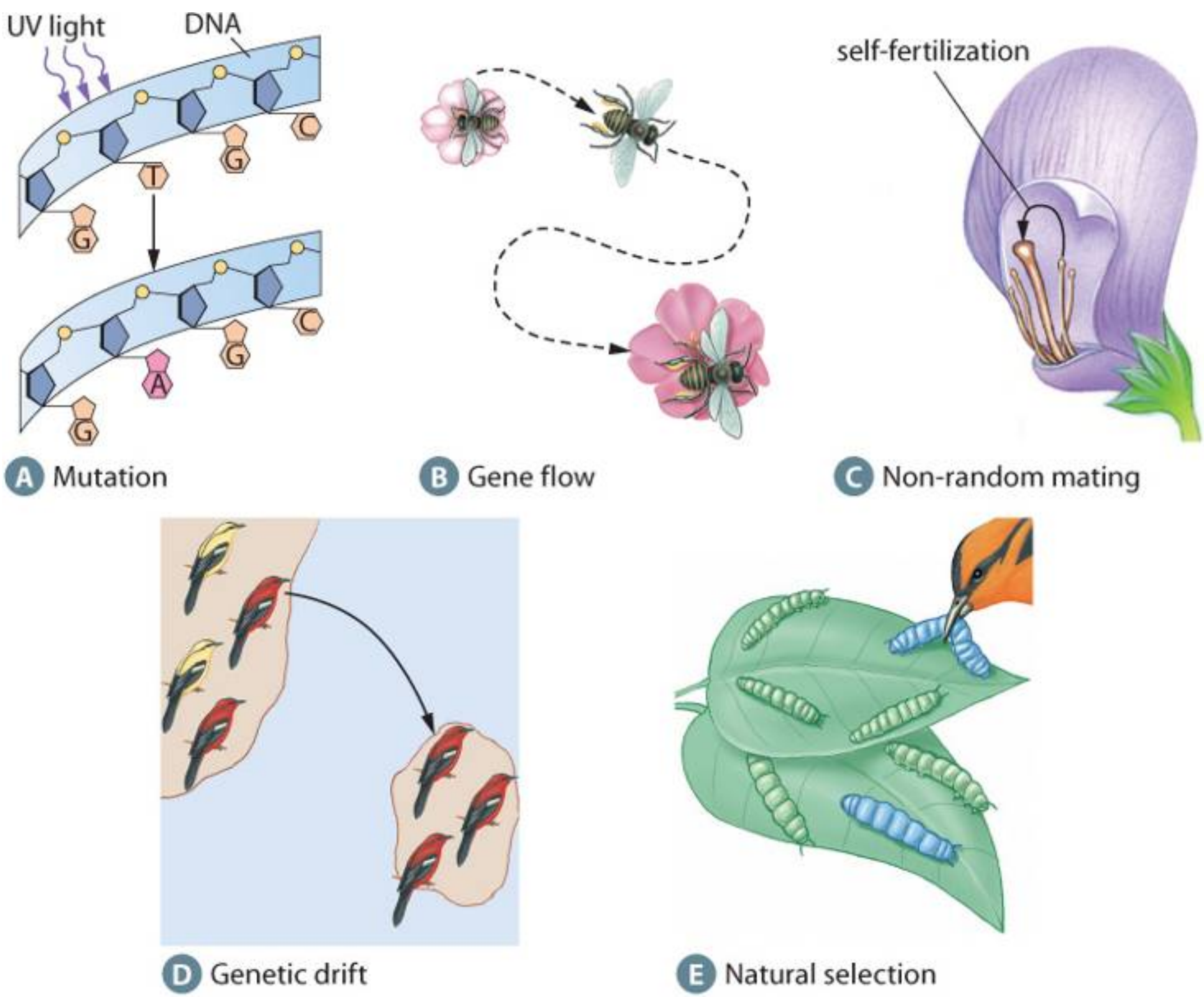


Figure 19.7 The five agents of evolutionary change are **(A)** mutation, a change in DNA; **(B)** gene flow, the migration of alleles from one population to another; **(C)** non-random mating, such as self-fertilization in flowers; **(D)** genetic drift, a change in allele frequencies in a small population due to a chance event; and **(E)** natural selection for favourable variations.

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- mutation
  - a change in DNA of an individual
    - an inheritable mutation has the potential to affect an entire gene pool.
  - most mutations are neutral (no effect)
    - some are harmful (usually does not promote reproduction so it is not spread in the gene pool (death before sex))
    - some are beneficial (may lead to a better fit of an organism to the environment).

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- an example of a beneficial mutation is one that encodes for receptor protein on white blood cells.
  - if you are homozygous for the mutation you lack a functioning receptor and have resistance to HIV (this can be called a selective advantage)

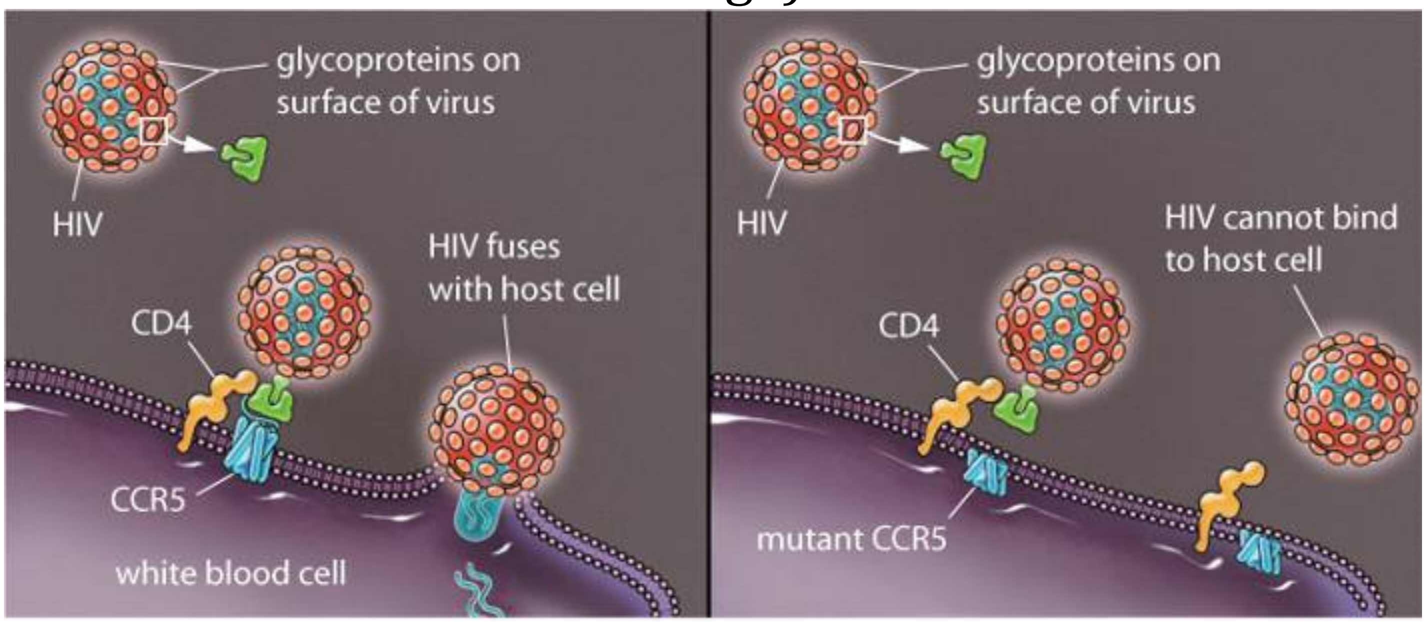


Figure 19.8 In healthy white blood cells, CCR5 is a receptor for chemical messages of the immune system. Along with the receptor CD4, CCR5 acts as a receptor for HIV. Some people who are homozygous for a mutation in the CCR5 gene are resistant to HIV infection.

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- Gene Flow
  - describes the net movement of alleles from one population to another due to the migration of individuals.
    - when mating occurs genetic diversity of the populations increase.

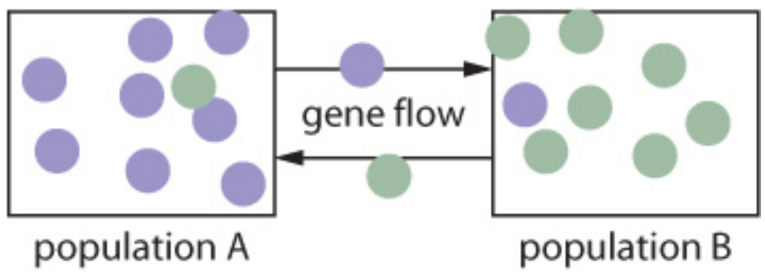


Figure 19.9 Gene flow between nearby populations

    - gene flow can also decrease diversity when there is a net migration out of a population.


SPECIAL ISSUE
TIME
Take a good look at this woman. She was created by a computer from a mix of several races. What you see is a remarkable preview of . . .
THE NEW FACE OF AMERICA
How Immigrants Are Shaping the World's First Multicultural Society

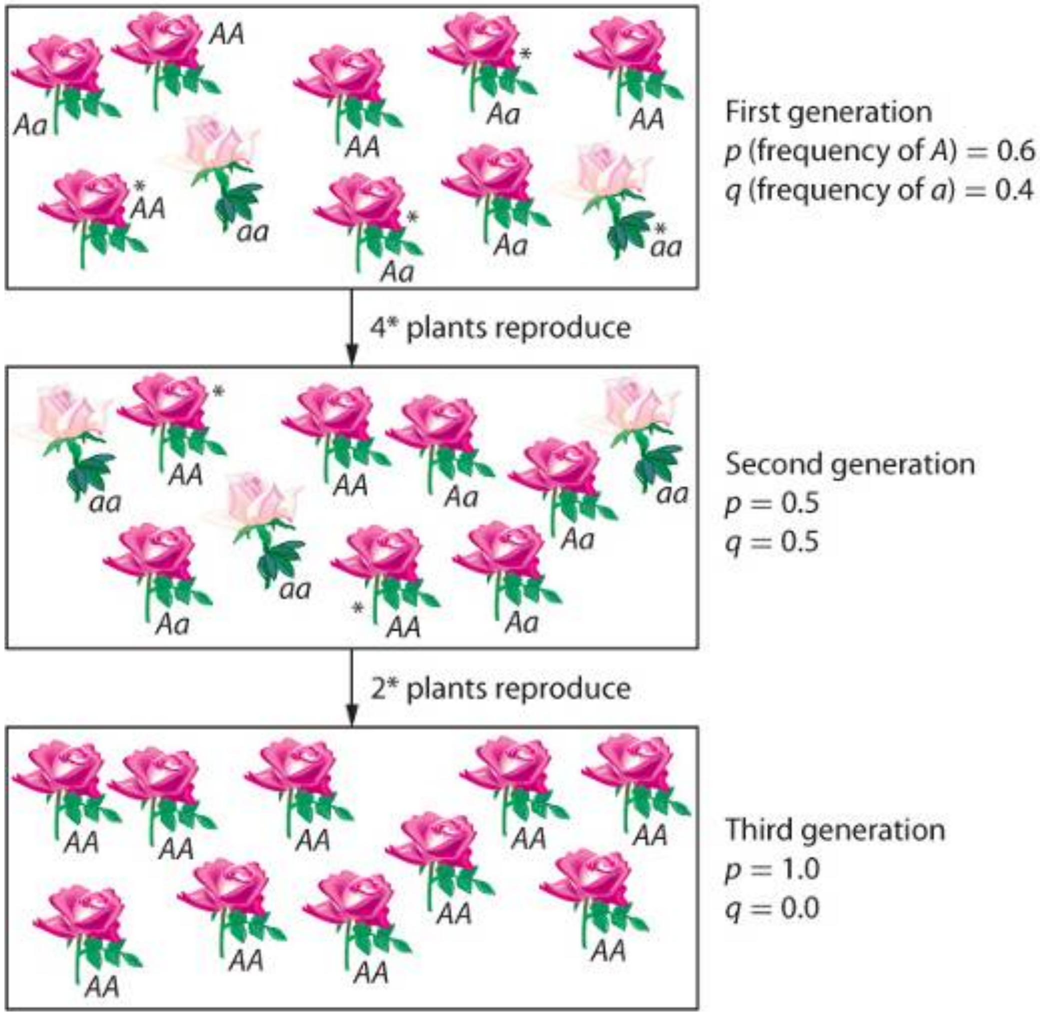
Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- Non-Random Mating
  - unrestricted random mating in animals is uncommon because of preferred phenotypes and interbreeding.
    - in animal populations mates are chosen based on physical and behavioural traits.
  - non-random mating prevents individuals with particular phenotypes from breeding.

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- Genetic Drift
  - a change in allele frequencies due to chance events in a small breeding populations.
    - in general large populations do not experience genetic drift because chance events are unlikely to affect overall allele frequencies.

Figure 19.12 In every generation, only some of the plants in this population reproduce. When the light pink and heterozygous roses in the second generation did not reproduce, the allele for light pink petals was quickly lost from the gene pool.

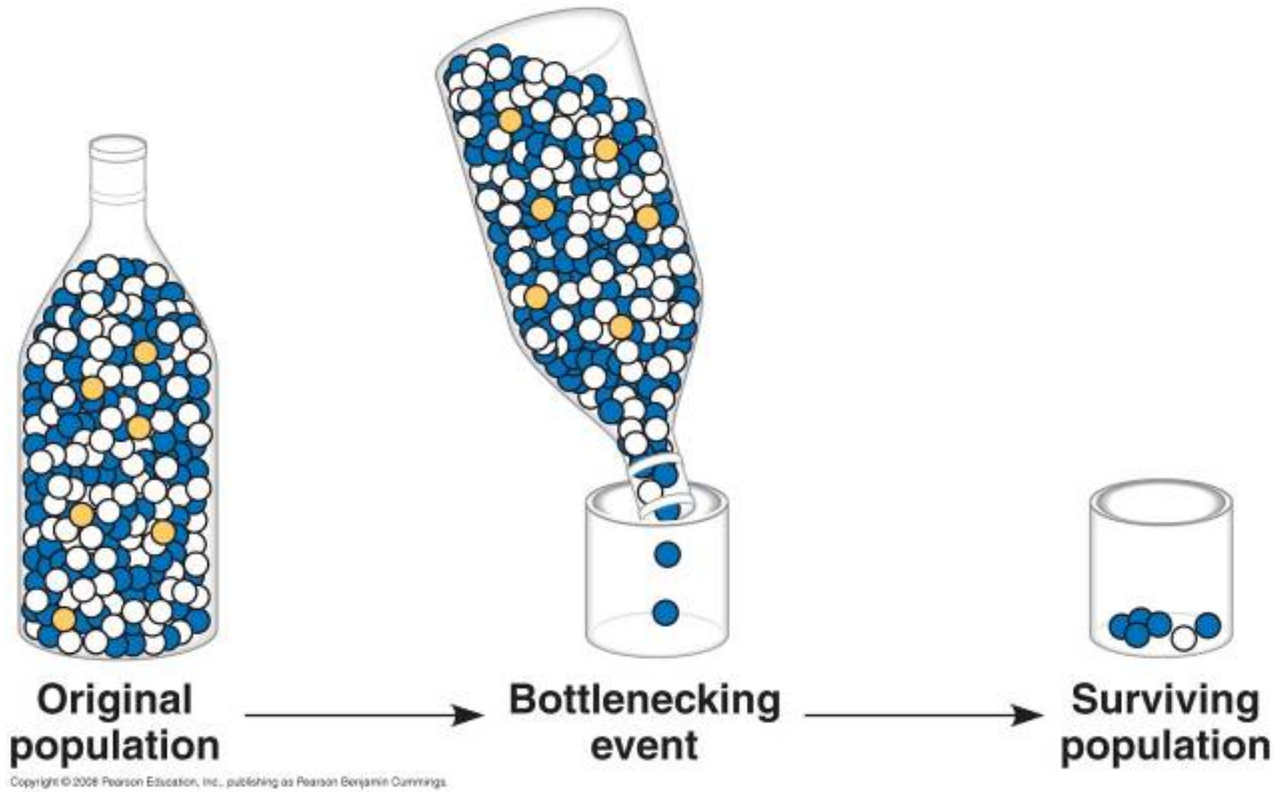


Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- The Founder Effect
  - the gene pool changes that occur when a few individuals start new, isolated populations.
    - occurs frequently on Islands

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- The Bottleneck Effect
  - gene pool change that results from a rapid decrease in population size.



Part 1. Genetic Diversity in Populations
III) Gene Pool Change

Mirounga angustirostris

(Northern Elephant Seal)

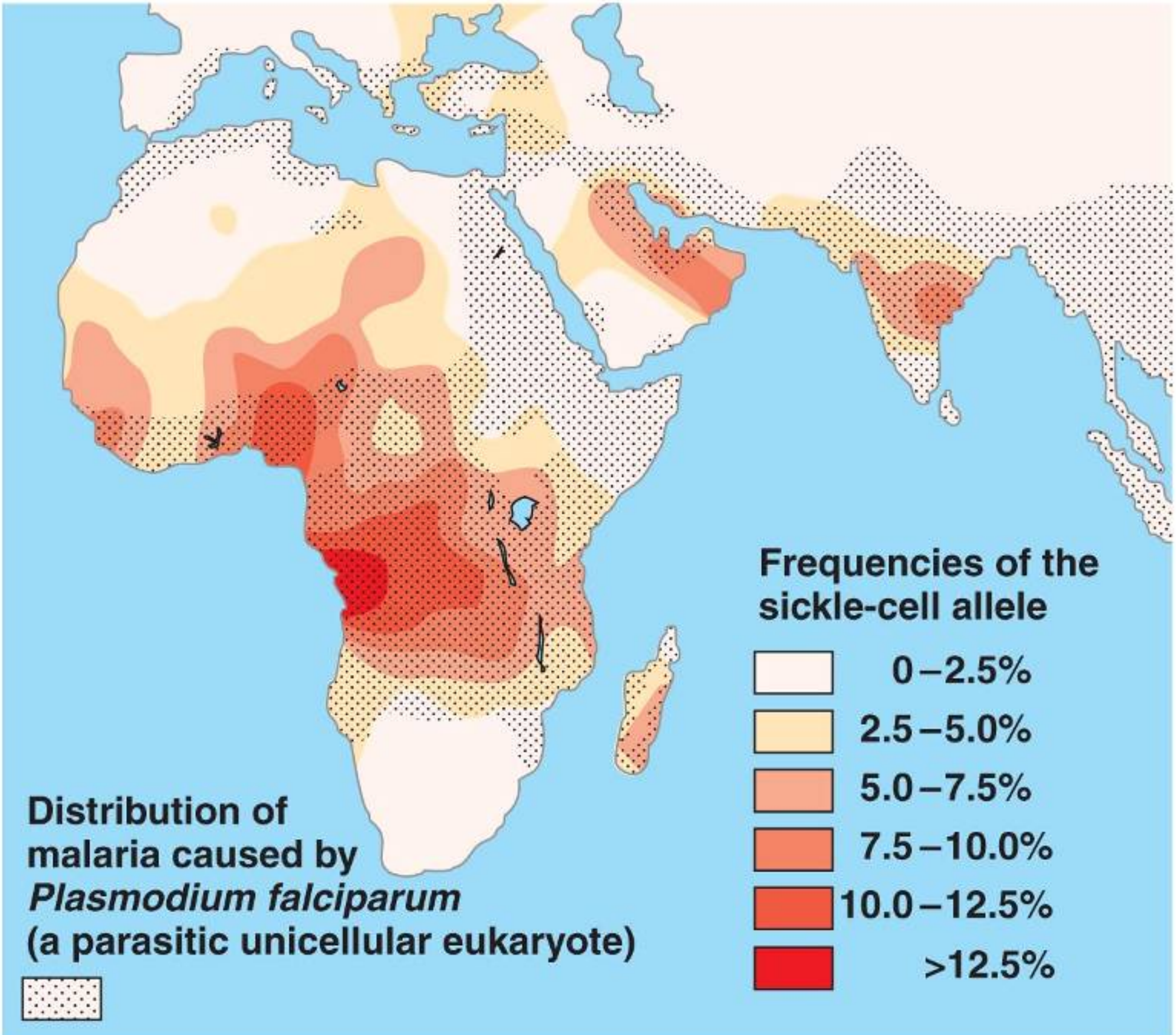
- hunted to as few as 20 individuals by the 1890s.
- today there is tens of thousands of individuals that all came from that small surviving population
  - due to the bottleneck effect there is now a large population of Elephant seals with very low genetic diversity.

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

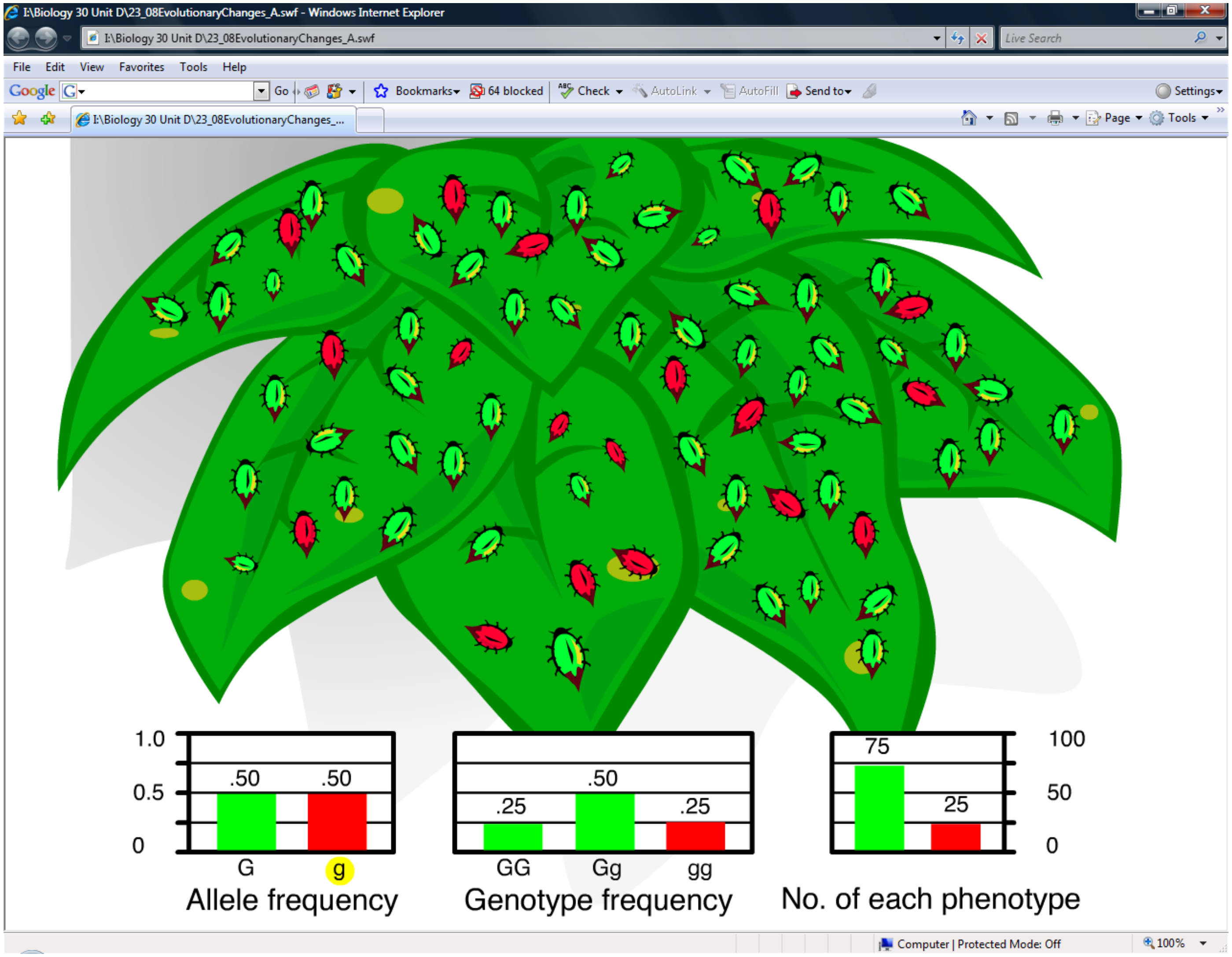
- Natural Selection
  - the only process that leads directly to evolutionary adaptations.
    - individuals best fit to the environment will breed and pass on their favourable variations to the next generation.
      - the environment is what makes mutations beneficial, harmful or neutral.
  - influenced by sexual reproduction (increase diversity) and sexual selection (selecting the best fit)

Part 1. Genetic Diversity in Populations
III) Gene Pool Change

- ***Heterozygote Advantage***
  - *occurs when heterozygotes have a higher fitness than do both homozygotes*
  - *Natural selection will tend to maintain two or more alleles at that locus*
  - *The sickle-cell allele causes mutations in hemoglobin but also confers malaria resistance*


Frequencies of the sickle-cell allele
0–2.5%
2.5–5.0%
5.0–7.5%
7.5–10.0%
10.0–12.5%
>12.5%
Distribution of malaria caused by *Plasmodium falciparum* (a parasitic unicellular eukaryote)

Part 1. Genetic Diversity in Populations
III) Gene Pool Change



Part 1. Genetic Diversity in Populations
III) Gene Pool Change