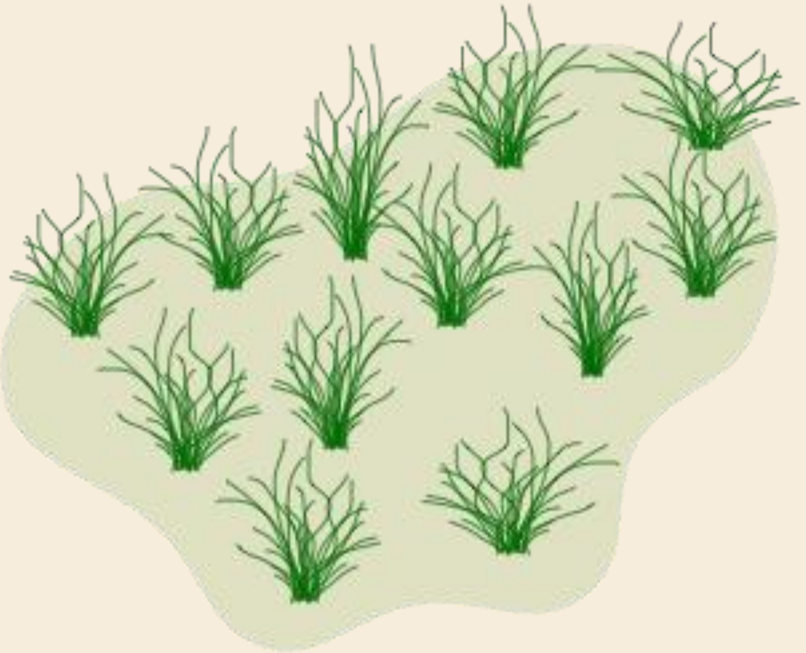
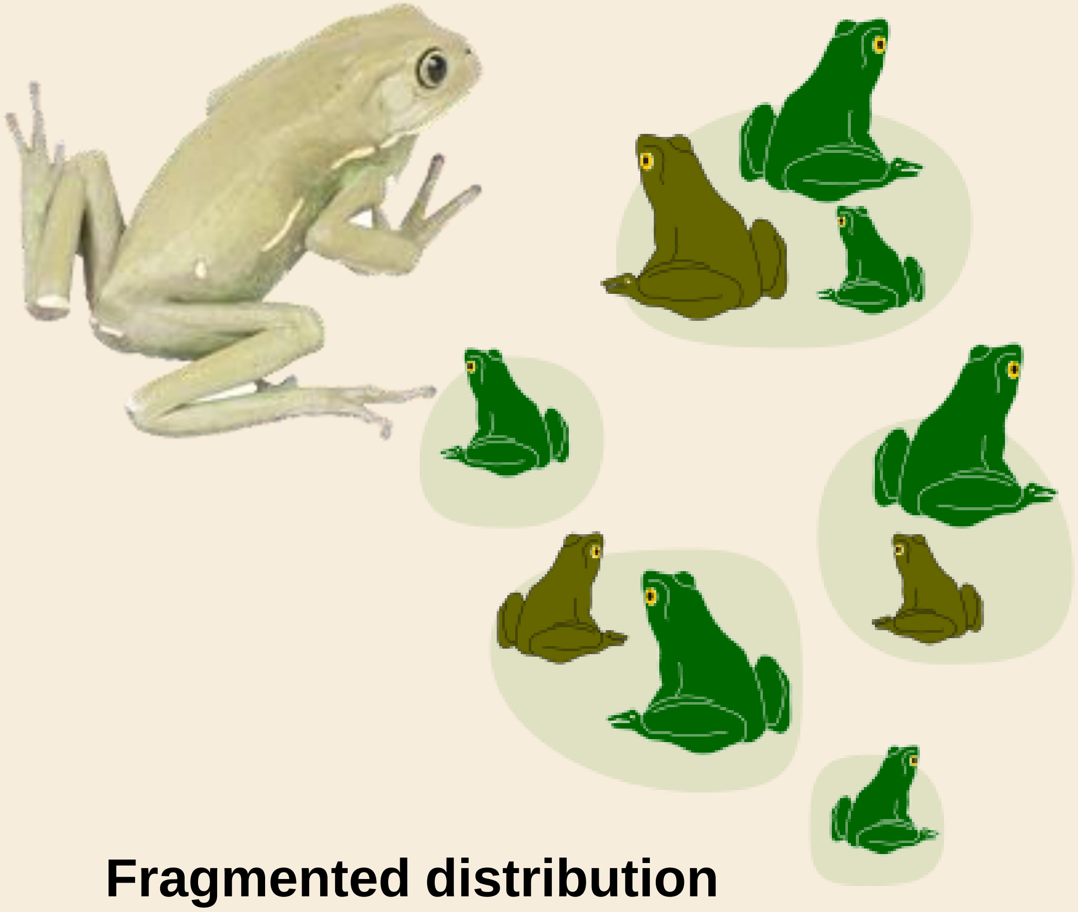
Populations

The total number of one species in a particular area at the same time.



Continuous distribution

Example: human population, Arctic tundra plant species

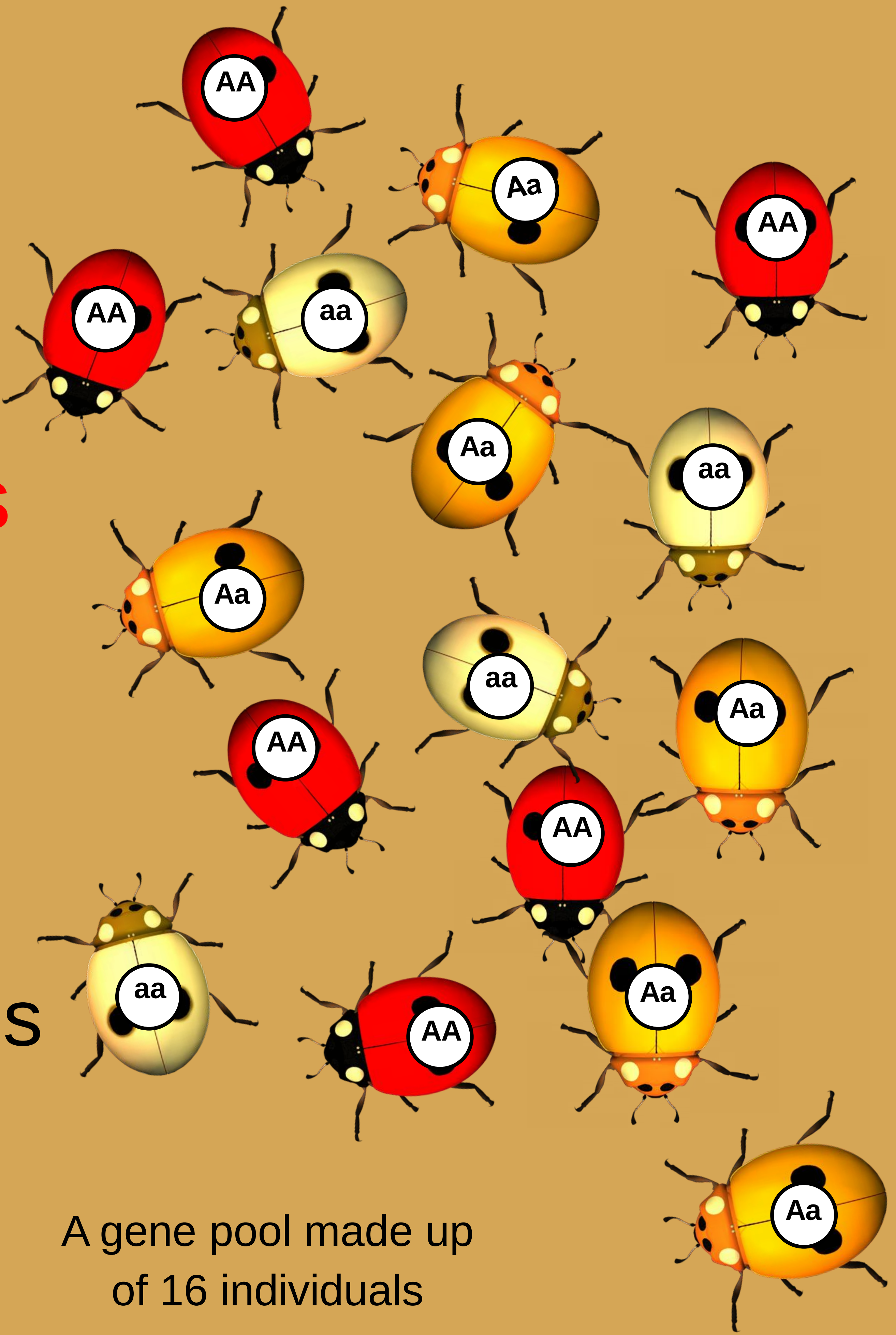


Fragmented distribution

Example: Some frog species

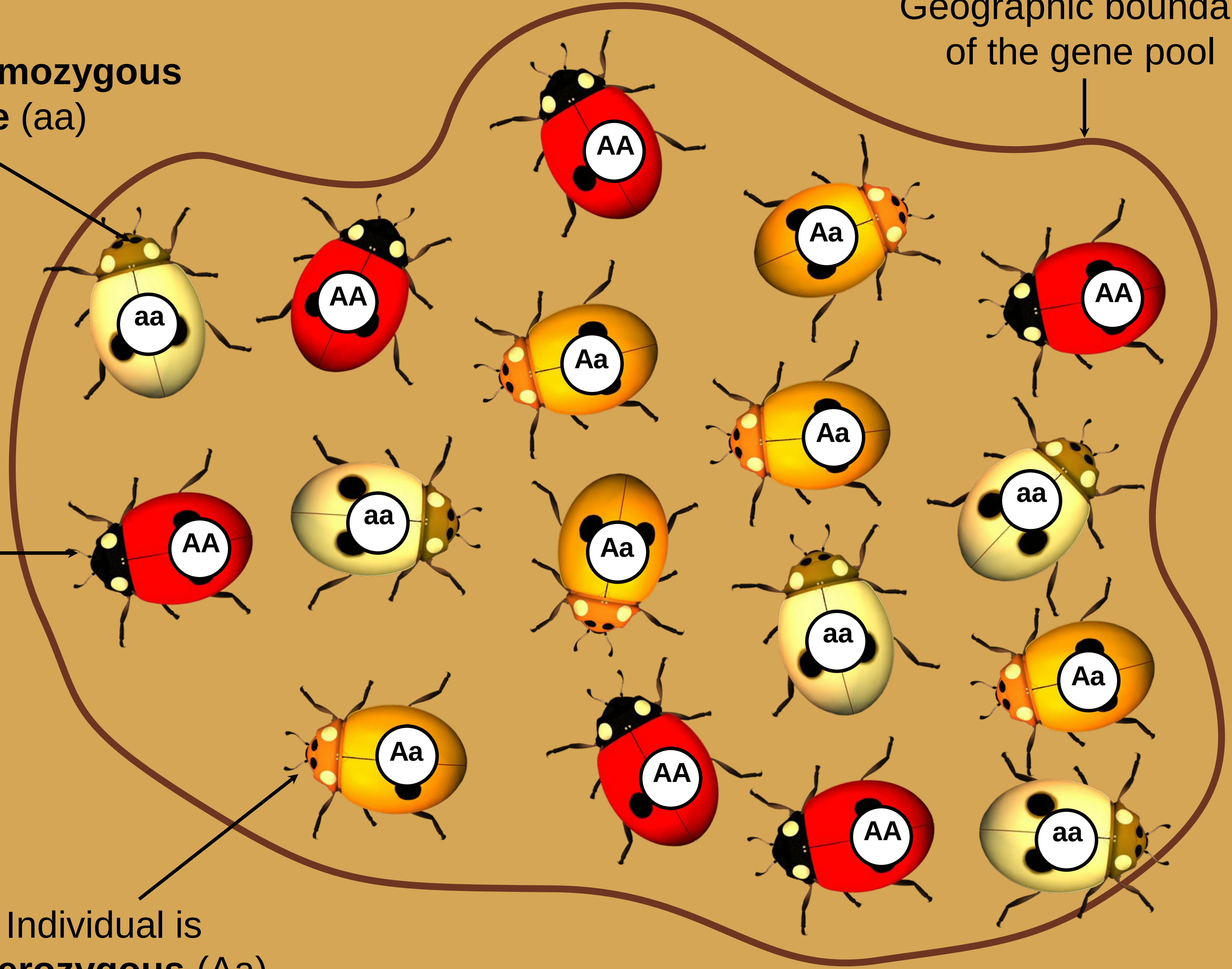
Gene Pool

- A **gene pool** is defined as the sum total of all the genes present in a population at any one time.
- Not all the individuals will be breeding at a given time.



A gene pool made up of 16 individuals

Gene Pool



Geographic boundary
of the gene pool

Individual is **homozygous**
recessive (aa)

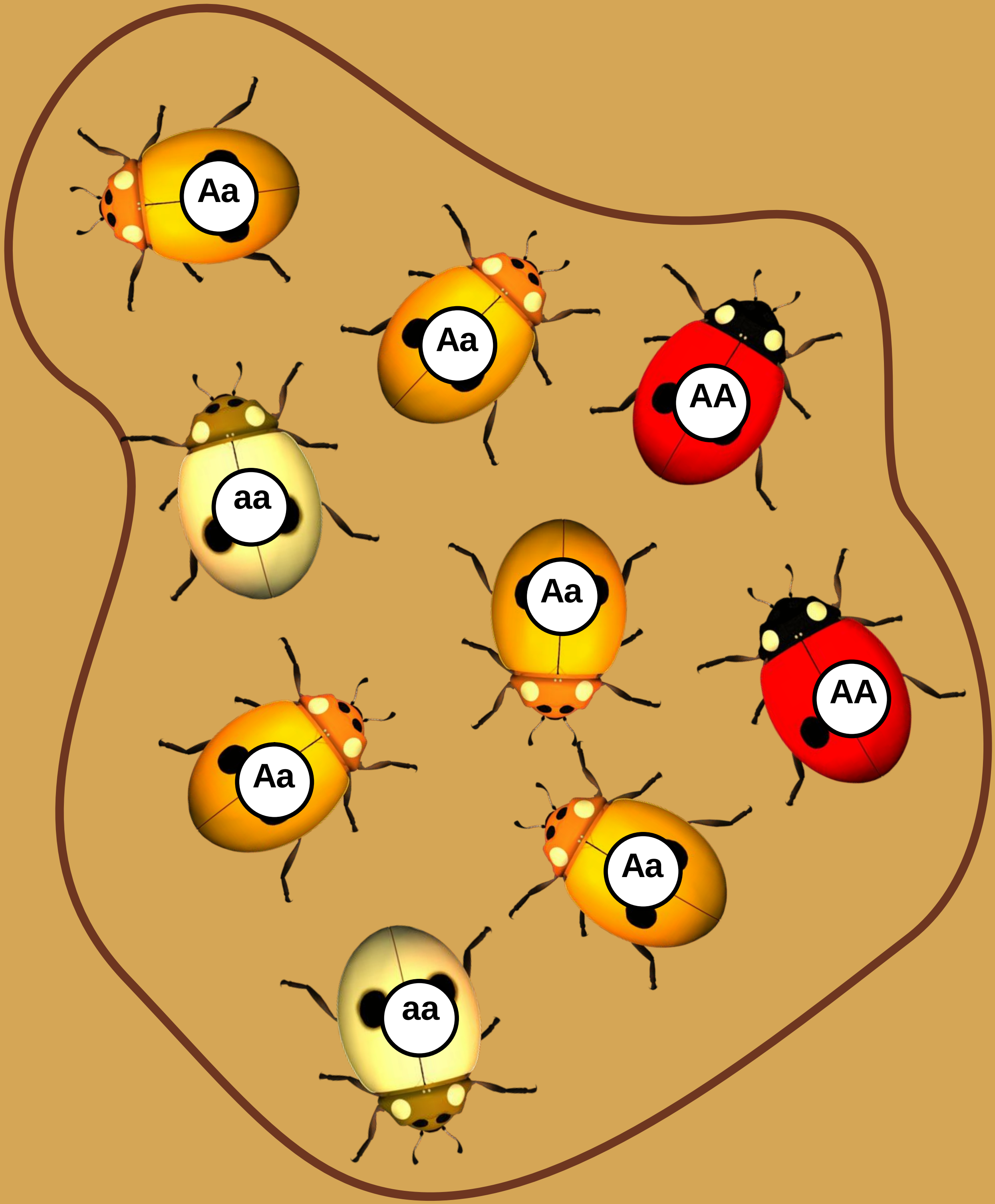
Individual is
homozygous
dominant (AA)

Individual is
heterozygous (Aa)

A gene pool made up of 16 individual organisms
with gene A, and where gene A has two alleles

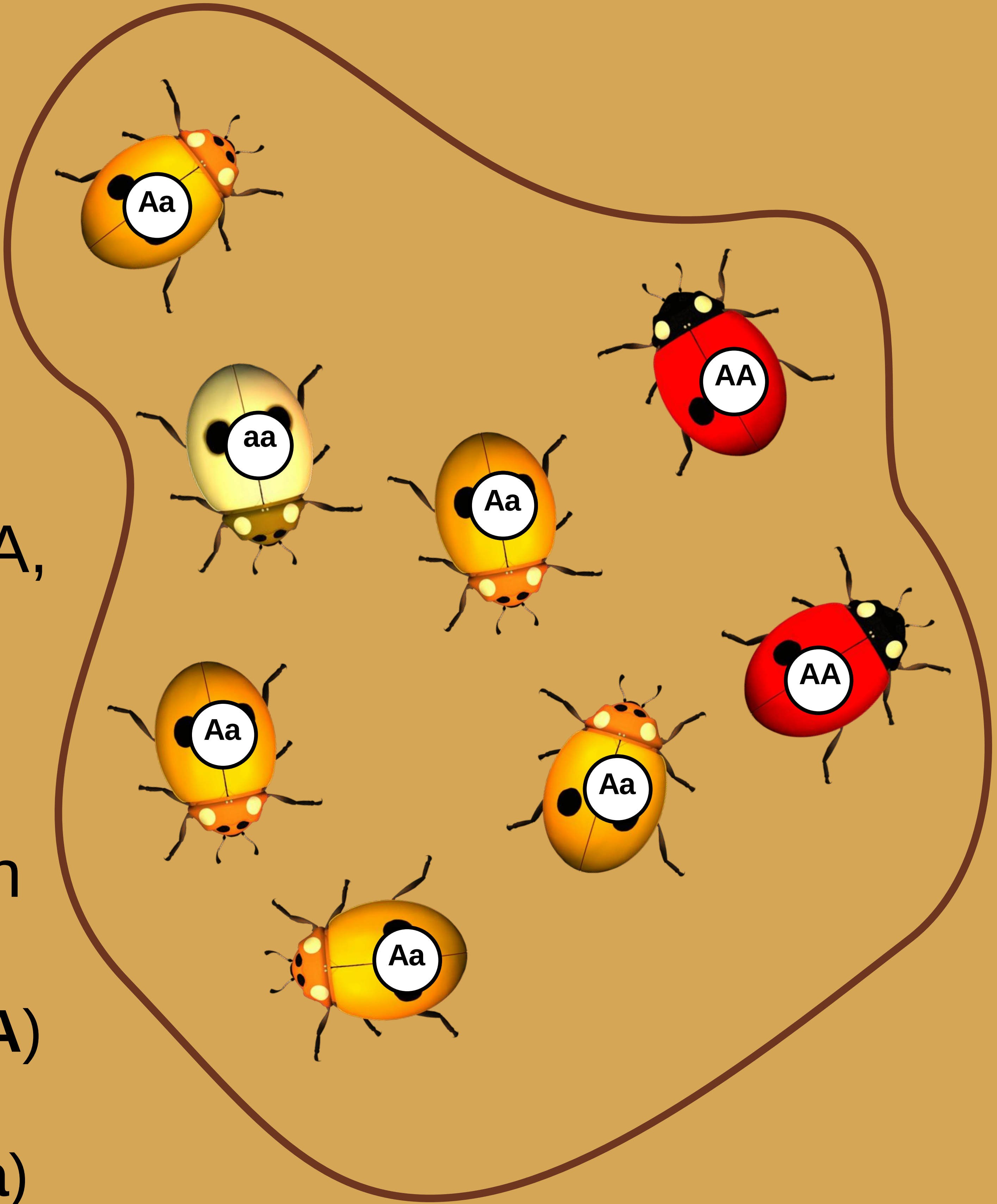
Analyzing a Gene Pool

- By determining the frequency of **allele types** (e.g. A and a) and **genotypes** (e.g. AA, Aa, and aa) it is possible to determine the state of the gene pool.
- The state of the gene pool will indicate if it is **stable** or **undergoing change**. Genetic change is an important indicator of evolutionary events.



Analyzing a Gene Pool

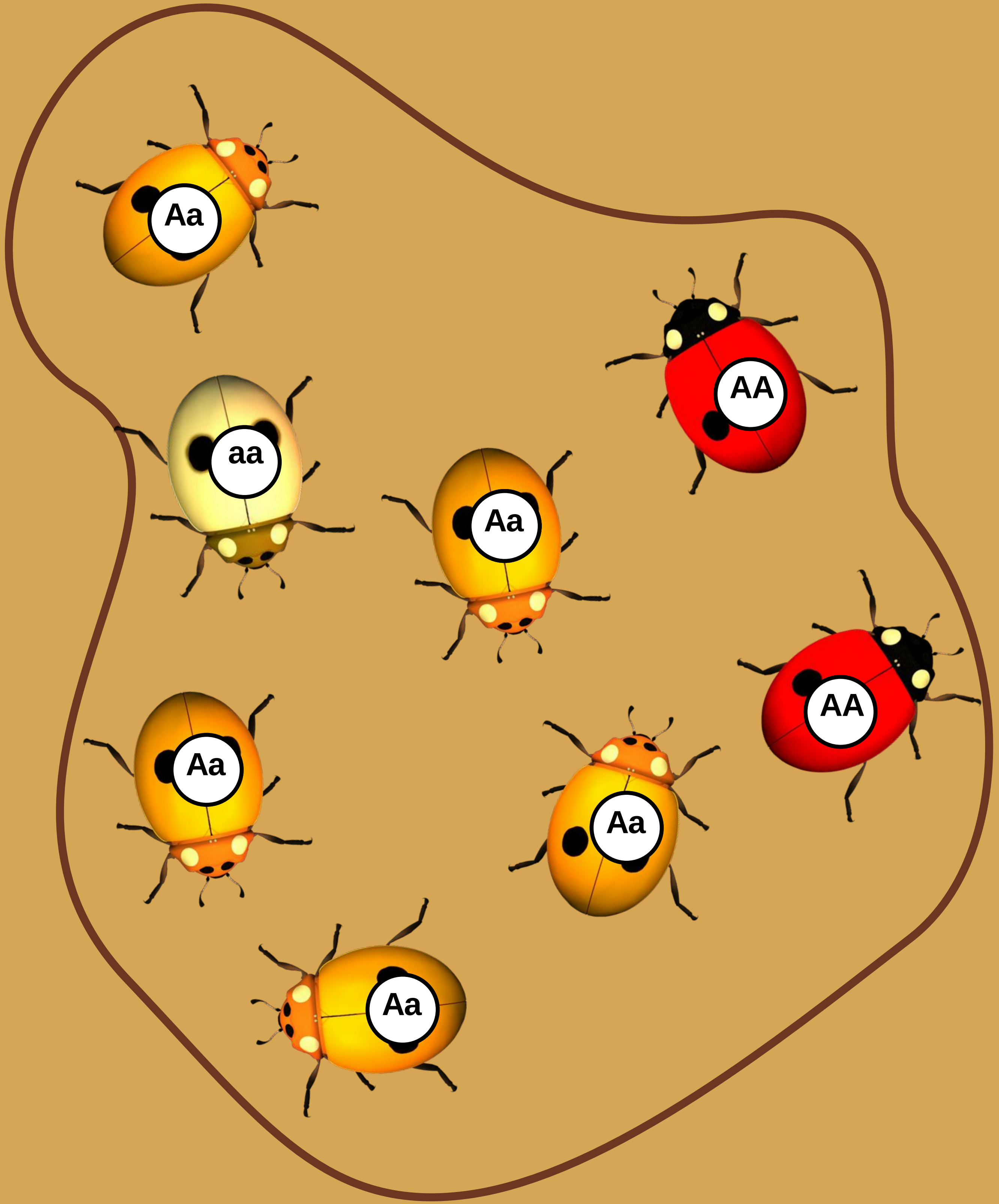
- **EXAMPLE**
  - The small gene pool comprises 8 individuals.
  - Each individual has 2 alleles for a single gene A, so there are a total of 16 alleles in the population.
  - There are individuals with the following genotypes:
    - homozygous dominant (**AA**)
    - heterozygous (**Aa**)
    - homozygous recessive (**aa**)



Determining Allele Frequencies

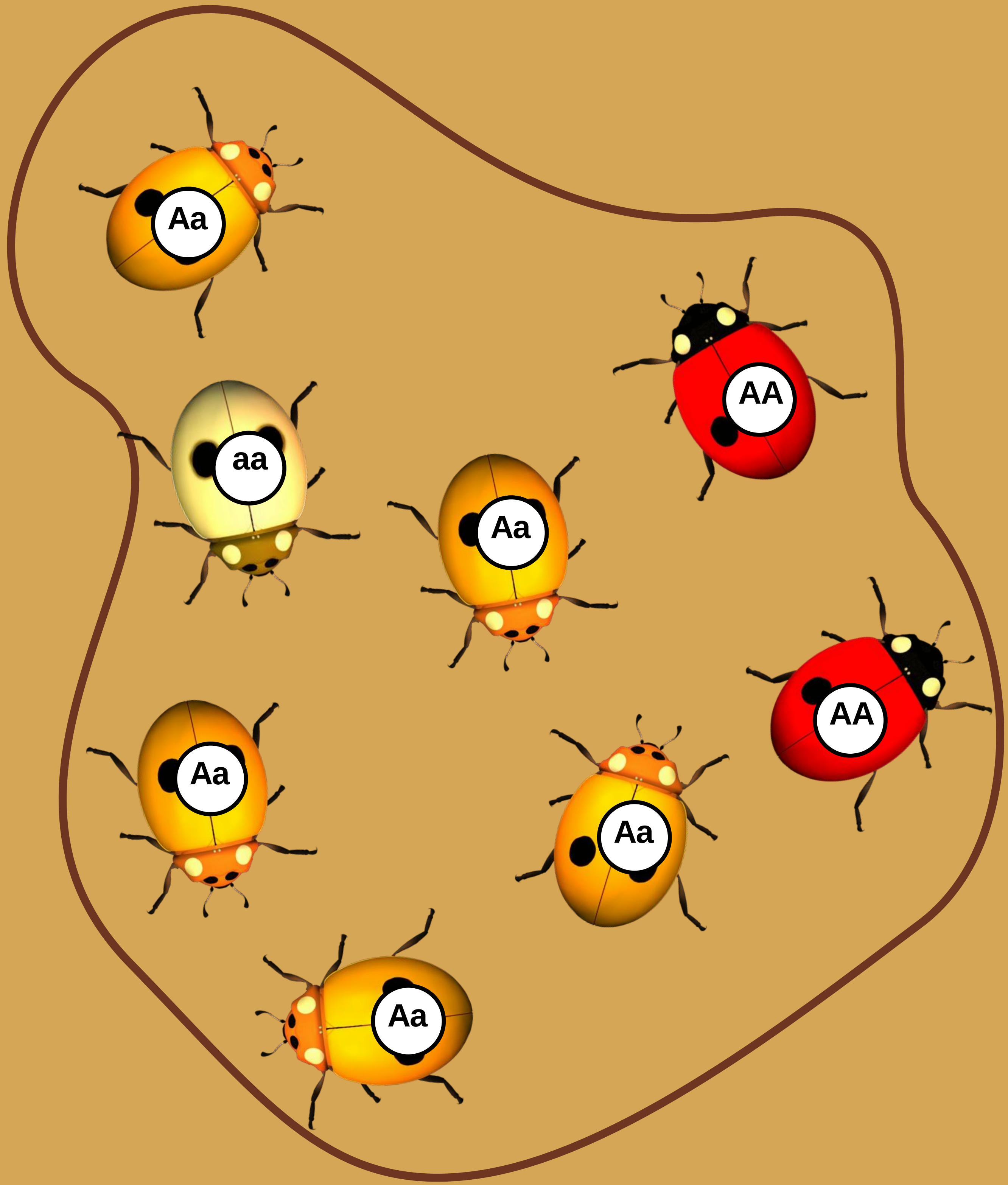
- To determine the frequencies of alleles in the population, count up the numbers of dominant and recessive alleles, regardless of the combinations in which they occur.

$$\frac{\text{No. of dominant alleles}}{\text{Total no. of alleles}}$$



Determining Genotype Frequencies

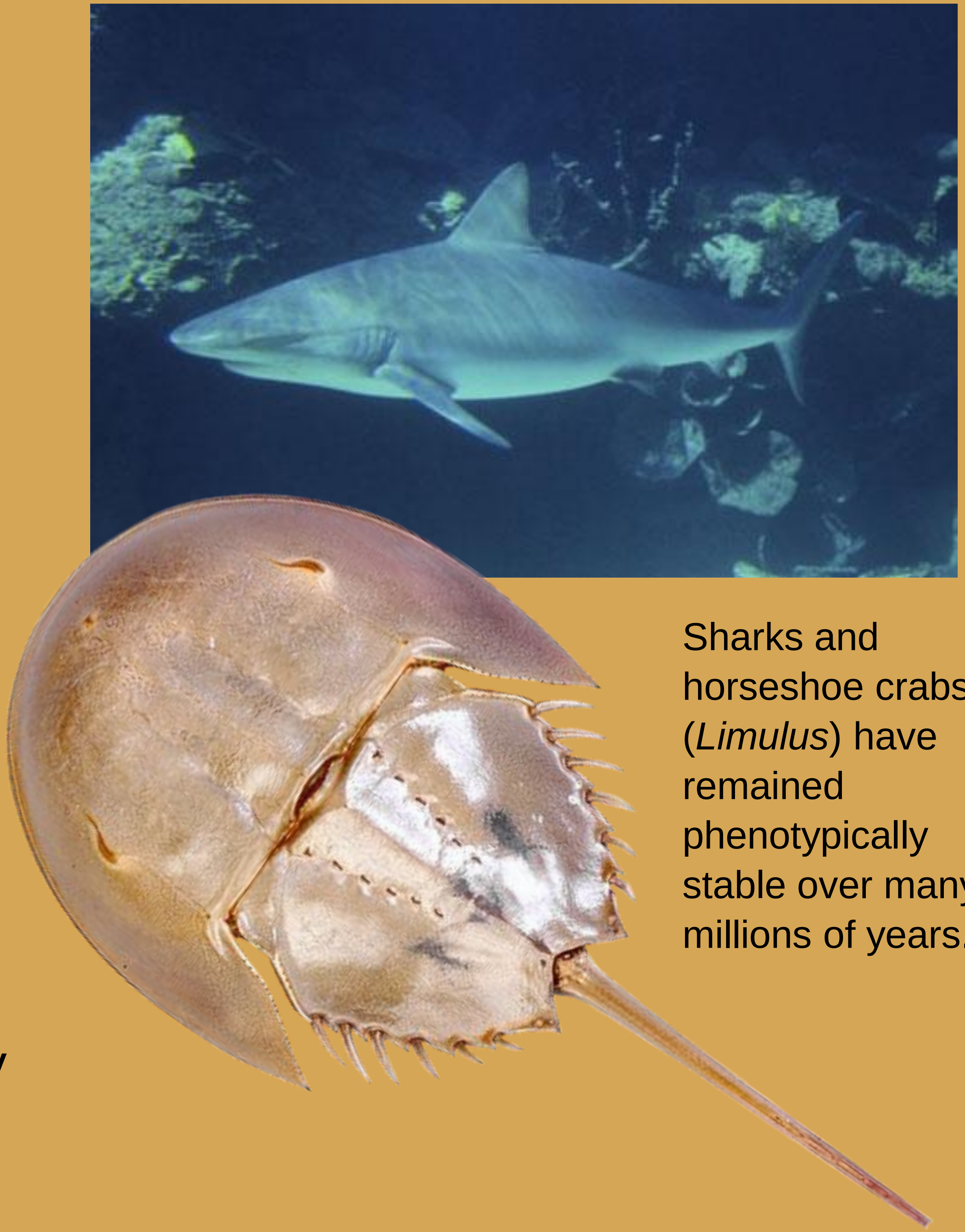
- To determine the frequencies of different genotypes in the population, count up the actual number of each genotype in the population and divide by the total number of individuals:
  - homozygous dominant (AA)
  - heterozygous (Aa)
  - homozygous recessive (aa).



READ

Hardy-Weinberg Equilibrium

- Populations that show no phenotypic change over many generations are said to be stable. This stability over time was described mathematically by two scientists:
  - G. Hardy: an English mathematician
  - W. Weinberg: a German physician
- The **Hardy-Weinberg law** describes the **genetic equilibrium** of large sexually reproducing populations.
  - The **frequencies of alleles** in a population will remain constant from one generation to the next unless acted on by outside forces.



Sharks and horseshoe crabs (*Limulus*) have remained phenotypically stable over many millions of years.

Conditions Required for Hardy-Weinberg Equilibrium

- The genetic equilibrium described by the Hardy-Weinberg law is only maintained in the absence of destabilizing events; all the **stabilizing** conditions described below must be met:

1	**Large population**: The population size is large.
2	**Random mating**: Every individual of reproductive age has an equal chance of finding a mate.
3	**No migration**: There is no movement of individuals into or out of the population (no gene flow).
4	**No selection pressure**: All genotypes have an equal chance of reproductive success.
5	**No mutation**: There are no mutations, which might create new alleles in the population.

IMPORTANT NOTE…

Natural populations **seldom** meet all these requirements….

…..therefore allele frequencies will change

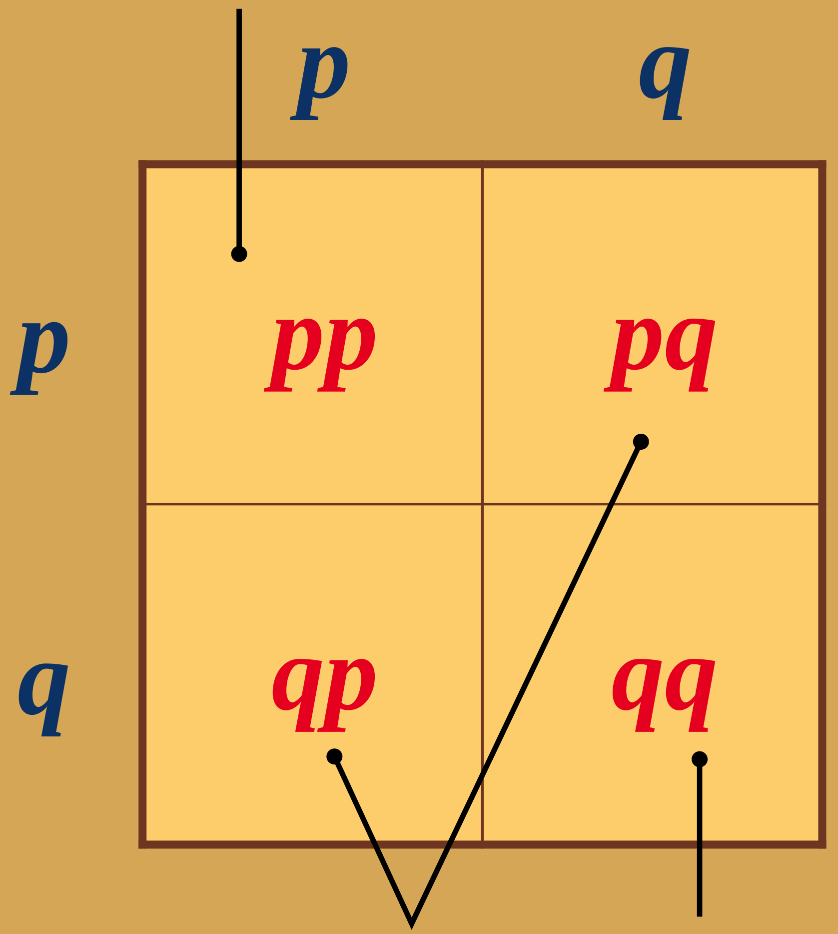
A change in the allele frequencies in a population is the definition of **evolution**

READ

The Hardy-Weinberg Equation

- The Hardy-Weinberg equation provides a simple mathematical model of genetic equilibrium.
- It is applied to populations with a simple genetic situation: recessive and dominant alleles controlling a single trait.
- The frequency of all of the dominant alleles and recessive alleles equals the total genetic complement, and adds up to **1** (or **100%**) of the alleles present.
- **p** represents the frequency of the dominant allele while **q** represents the frequency of the recessive allele

Punnett square



	p	q
p	pp	pq
q	qp	qq

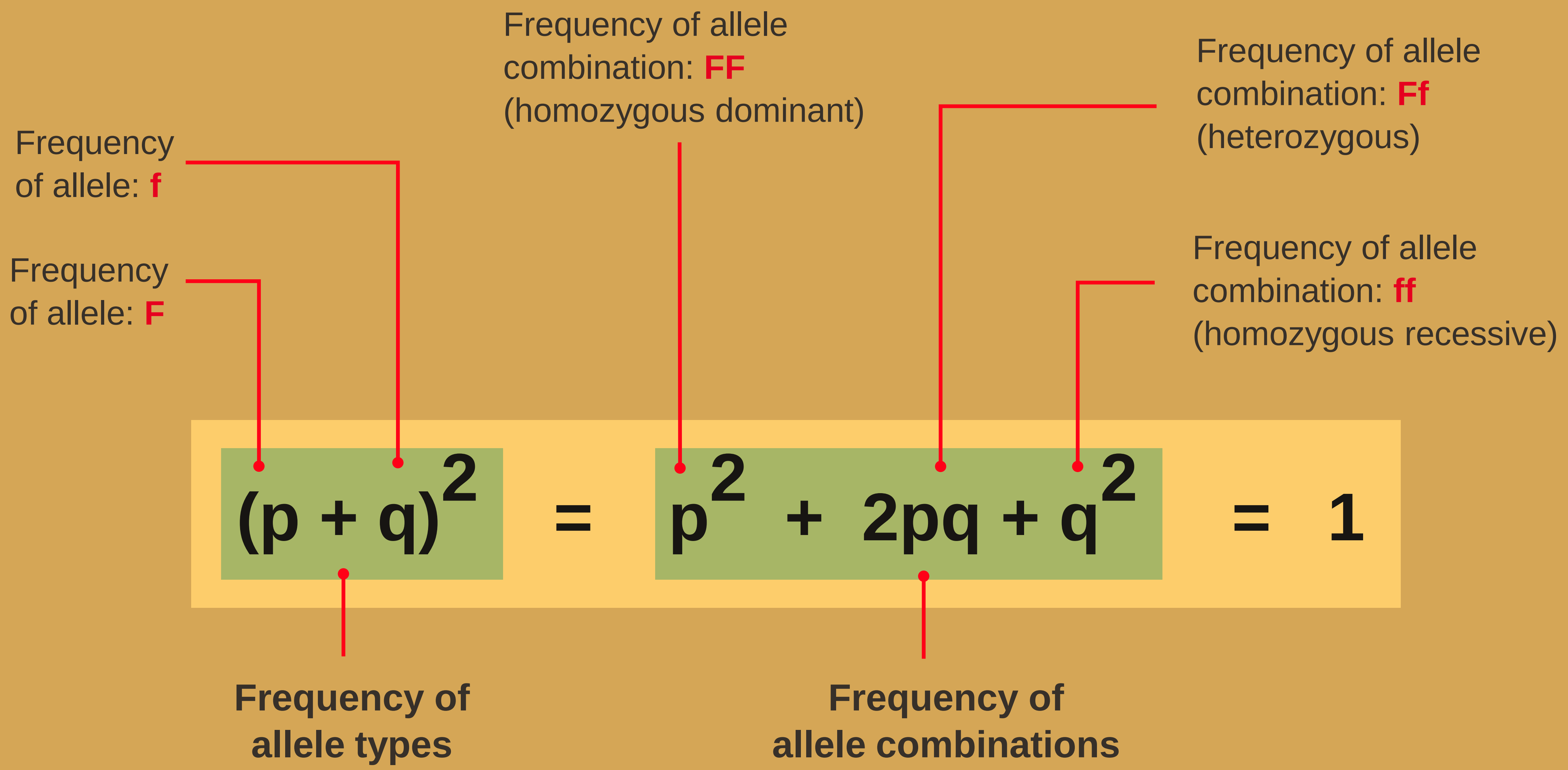
Frequency of allele combination **FF** in the population

Frequency of allele combination **Ff** in the population (add these together to get **2pq**)

Frequency of allele combination **ff** in the population

The Hardy-Weinberg Equation

- The **Hardy-Weinberg equilibrium** can be expressed mathematically by giving the frequency of all the allele types in the population:
  - The sum of all the **allele types**: **A** and **a** = 1 (or 100%)
  - The sum of all the **allele combinations**: **AA**, **Aa**, and **aa** = 1 (or 100%)



Frequency of allele combination: **FF** (homozygous dominant)

Frequency of allele combination: **Ff** (heterozygous)

Frequency of allele: **f**

Frequency of allele: **F**

Frequency of allele combination: **ff** (homozygous recessive)

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

Frequency of allele types

Frequency of allele combinations

How to Solve H-W Problems

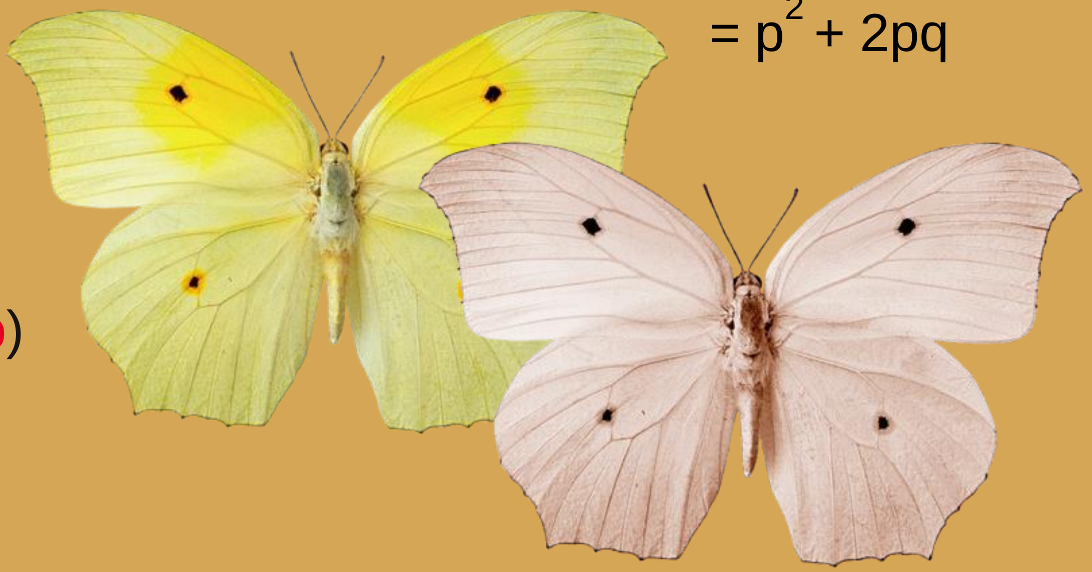
- The procedure for solving a Hardy-Weinberg problem is straightforward.
- Use **decimals** (NOT PERCENTAGES) for all calculations!

1. Determine what information you have about the population. In most cases, it is the percentage or frequency of the recessive phenotype (**q^2**) or the dominant phenotype (**$p^2 + 2pq$**). These provide the only visible means of gathering data about the gene pool.
2. The first objective is to find out the value of **p** or **q**. If this is achieved, then every other value in the equation can be determined by simple calculation. If necessary **q^2** can be obtained by:

1 – frequency of the dominant phenotype

3. Take the square root of **q^2** to find **q**
4. Determine **p** by subtracting **q** from 1 (i.e. **$p = 1 - q$**)
5. Determine **p^2** by multiplying **p** by itself (i.e. **$p^2 = p \times p$**)
6. Determine **$2pq$** by multiplying **p** X **q** X **2**
7. Check the calculations by adding **$p^2 + 2pq + q^2$**: these should always equal **1**.

Dominant phenotype
$= p^2 + 2pq$



Recessive phenotype
$= q^2$

A Worked Example

- Around 70% of caucasian Americans can taste the chemical **P.T.C.** (the dominant phenotype). 30% are non-tasters (the recessive phenotype).
  - Frequency of the dominant phenotype = 70% or 0.7
  - Frequency of the recessive phenotype = 30% or 0.3
- Recessive phenotype: $\mathbf{q^2} = 0.30$
  - therefore: $\mathbf{q} = 0.5477$ (square root of 0.30)
  - therefore: $\mathbf{p} = 0.4523$ ($1 - 0.5477 = 0.4523$)
- Use p and q in the equation to solve any unknown:
  - Homozygous dominant: $\mathbf{p^2} = 0.2046$ (0.4523×0.4523)
  - Heterozygous: $\mathbf{2pq} = 0.4953$ ($2 \times 0.4522 \times 0.5477$)
    - Frequency of homozygous recessive phenotype = $\mathbf{q^2}$ = 30%
    - Frequency of dominant allele (**p**) = 45.2%
    - Frequency of homozygous tasters ($\mathbf{p^2}$) = 20.5% and heterozygous tasters (2pq) = 49.5%