1) Genetic Drift

- Flip a coin 1000 times ➔ 700 heads and 300 tails ➔ very suspicious.
- Flip a coin 10 times ➔ 7 heads and 3 tails ➔ well within the bounds of possibility.

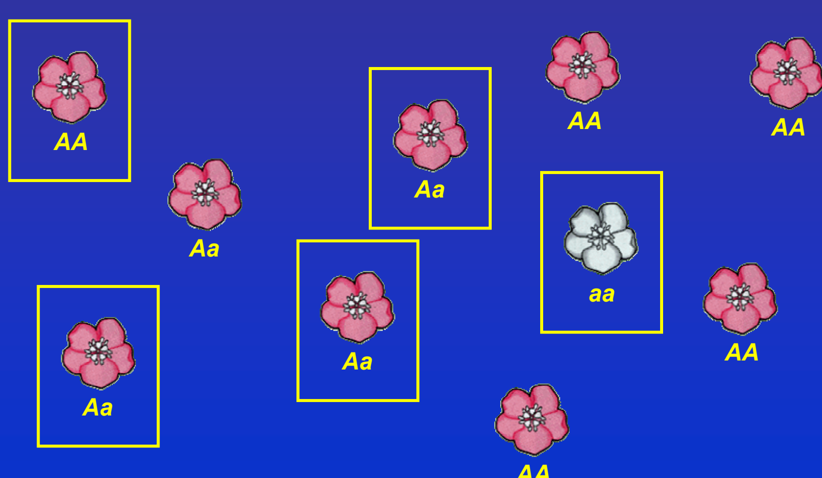
700 7

300 3

- The smaller the sample, the greater the chance of deviations from the expected result ➔ sampling error ➔important factor in the genetics of small populations.
- If a new generation draws its alleles at random, then the larger the sample size, the better it will represent the gene pool of the previous generation.

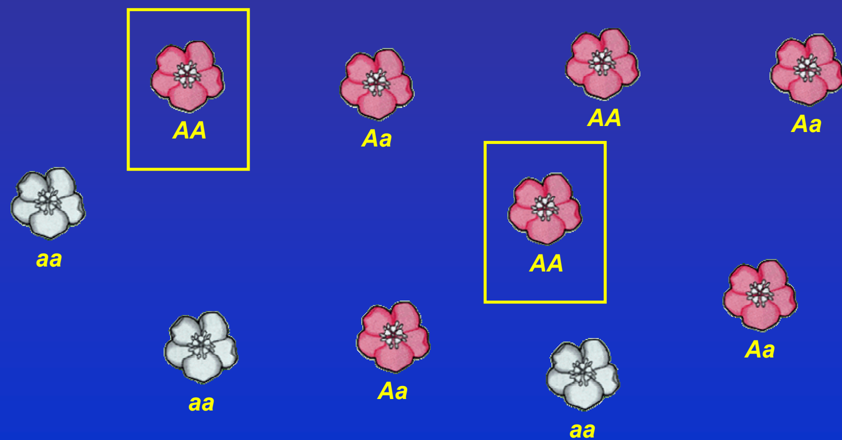
Genetic Drift - population with stable size ~ 10

Generation 0: p (frequency of A) = 0.7
q (frequency of a) = 0.3



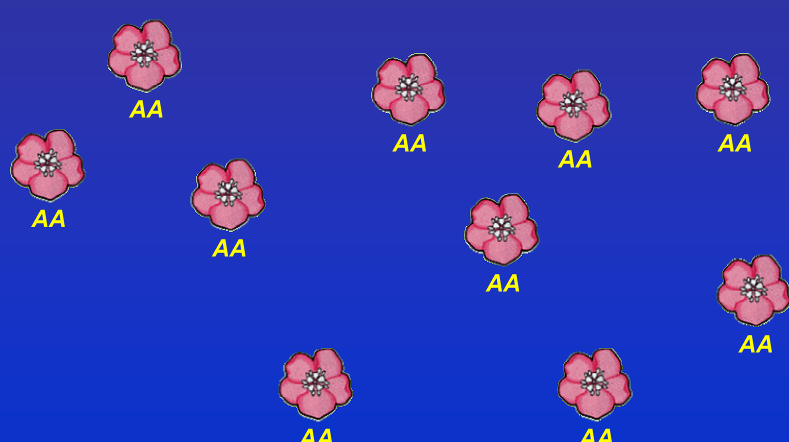
Genetic Drift - population with stable size ~ 10

Generation 1: *p* = 0.5
q = 0.5



Genetic Drift - population with stable size ~ 10

Generation 2: *p* = 1.0
q = 0.0



Genetic Drift

- In this population of wildflowers, the frequencies of the alleles for pink and white flowers fluctuate over several generations.
- Only a fraction of the plants manage to leave offspring and over successive generations, genetic variation $\downarrow$ (fixed for *A* allele).
- Microevolution caused by **genetic drift**, changes in the gene pool of a small population due to chance.
- Only luck could result in random drift improving the population's adaptiveness to its environment.
- A population must be infinitely large for drift to be ruled out as an evolutionary process.
- Many populations are so large that drift is negligible.

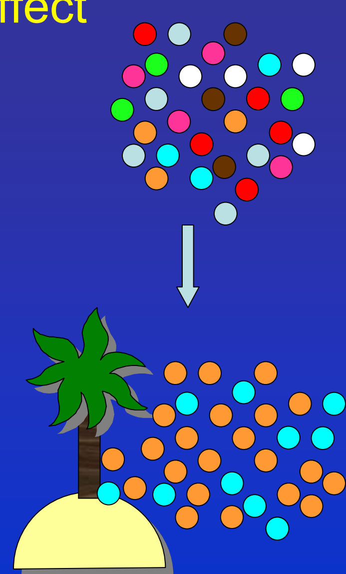
The Founder Effect

An extreme form of genetic drift is called the **founder effect.**

It is a particular example of the influence of random sampling.

It was defined by Ernst Mayr as:

"The establishment of a new population by a few original founders (in an extreme case, by a single fertilized female) which carry only a small fraction of the total genetic variation of the parental population."

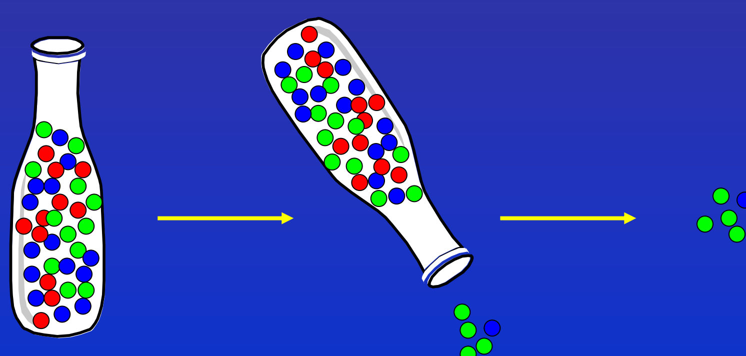


An example of the founder effect in humans

- Amish populations in the USA are descended from a few dozen founder individuals and tend to inter-marry.
- The result ➔ they exhibit some traits at higher frequencies than the general population, e.g. polydactyly, microcephaly
- Also Huntingtons disease in Venezuala – single founder, and retinitis pigmentosa on Tristan da Cunha – 15 British founders

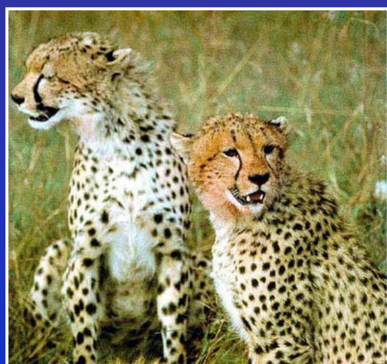
The Bottleneck Effect

- Natural calamities can drastically reduce a population - usually unselective.
- The result ➔ genetic composition of small surviving population ➔ unlikely to be representative of the original population.



Alleles in original population | Bottleneck event | Surviving population

The Bottleneck Effect



The Cheetah (*Acinoyx jubatus*) originally had a wide range across Africa and Asia.

Population bottleneck at the end of the last Ice Age about 10-12000 years ago.

Climate change reduced habitat.

2nd bottleneck during the last 150 years as it was hunted almost to extinction.

Cheetah are so genetically similar → almost like clones.

Skin can be grafted between individuals.

Very susceptible to disease outbreaks.

The Bottleneck Effect

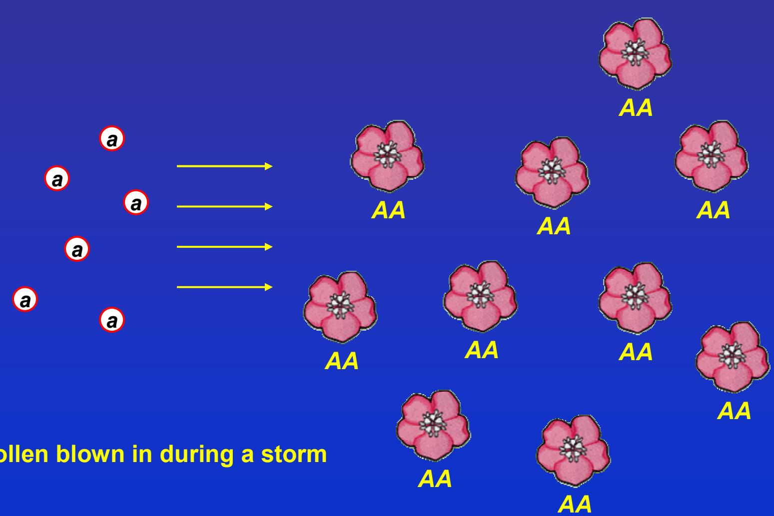
- Modern humans (*Homo sapiens sapiens*) may also have undergone a bottleneck ~ 120,000 years ago (very low molecular genetic diversity compared to chimps, gorillas etc.)

2) Gene Flow

- HWE requires the gene pool to be a closed system - most populations are not completely isolated.
- Population can gain or lose alleles by **gene flow** —genetic exchange due to migration of fertile individuals or gametes between populations.
- Gene flow tends to reduce differences between populations that have accumulated because of natural selection or genetic drift.
- If gene flow is extensive enough ➔ amalgamate neighbouring populations.

Gene flow between populations

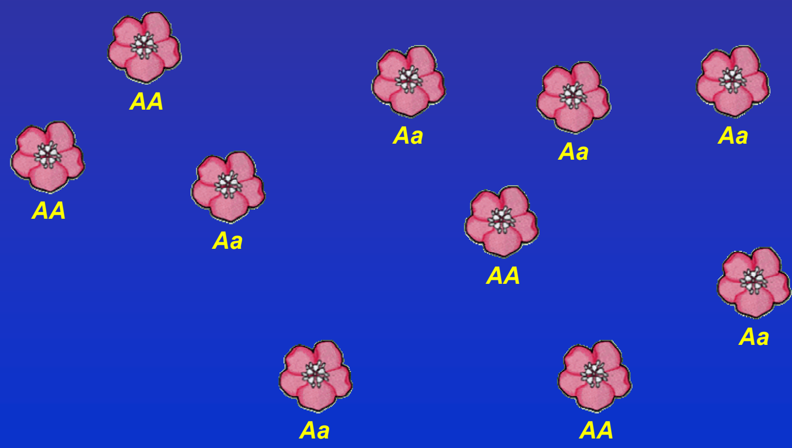
Fixed for the pink allele $p = 1.0$
$q = 0.0$



Pollen blown in during a storm

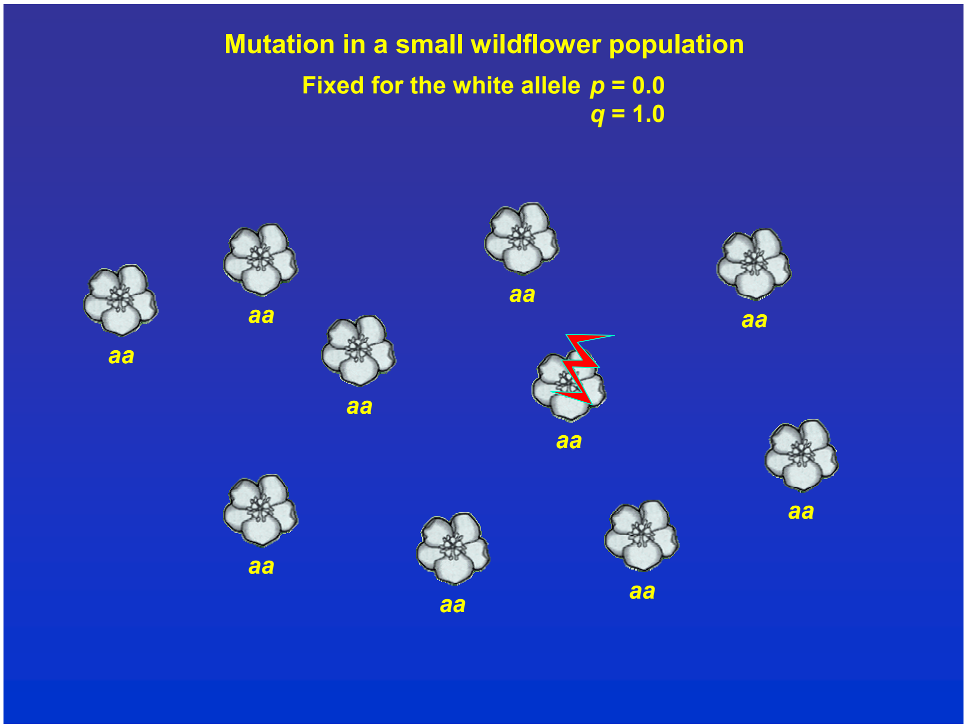
Next generation after gene flow

$p = 0.7$
$q = 0.3$

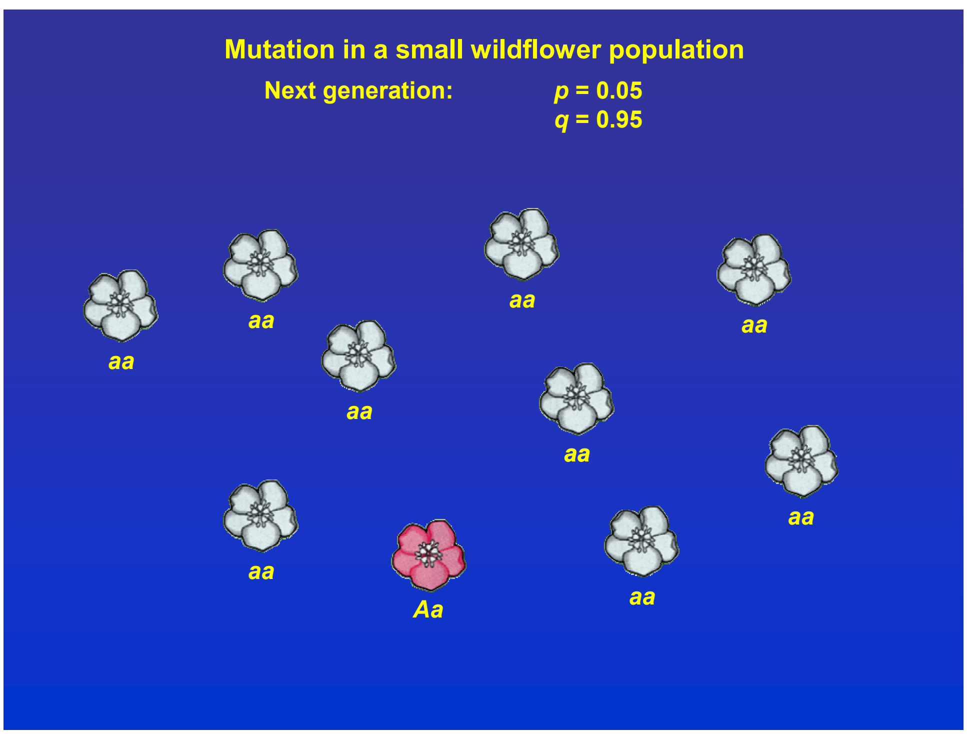


3) Mutation

- A mutation is a change in an organism's DNA.
- New mutation ➔ transmitted in gametes will immediately change the gene pool ➔ either completely new allele or converted to the other allele.
- A mutation that causes the white-flowered plant (*aa*) to produce gametes bearing dominant pink allele (*A*) would decrease freq. of *a* allele and increase freq. of *A* allele.
- For any one gene ➔ mutation does not have much of an effect on a large population in a single generation.
- Mutation at any given genetic locus is usually very rare.
- Rate of one mutation per 10^5 - 10^6 gametes is typical.
- Example: an allele has frequency of 0.5 in the gene pool. Mutates to another allele at a rate of 0.00001 mutations per generation ➔ 2000 generations to reduce the frequency of the original allele from 0.50 to 0.49.



Mutation in a small wildflower population
Fixed for the white allele $p = 0.0$
$q = 1.0$
aa
aa
aa
aa
aa
aa
aa
aa
aa
aa



Mutation in a small wildflower population
Next generation: $p = 0.05$
$q = 0.95$
aa
aa
aa
aa
aa
aa
aa
aa
Aa
aa

Mutation

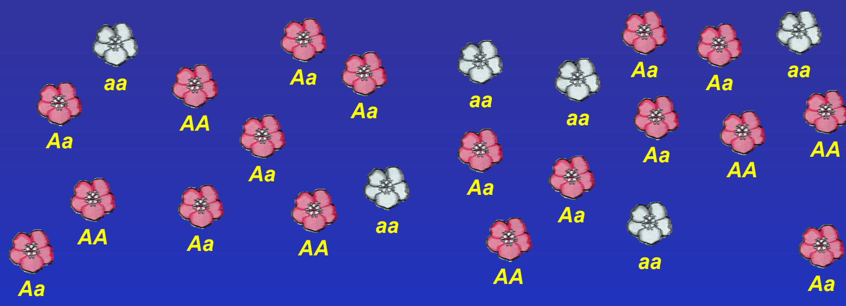
- If a new allele increases its frequency significantly in a population ➔ usually because it confers a selective advantage not because mutation is continually generating it.
- Mutations at a particular locus ➔ rare. However, impact of mutation at all genes is significant - Each individual: 1000's of genes.
- Mutation is the original source of genetic variation ➔ raw material for natural selection.

4) Nonrandom mating

- For HWE to hold ➔ individual of any genotype must choose its mates at random from the population.
- In reality ➔ individuals usually mate with close neighbours ➔ promotes inbreeding.
- Most extreme example of inbreeding ➔ self-fertilisation (selfing).
- Inbreeding causes relative genotype frequencies to deviate from HWE.
- Heterozygotes will only produce 50% heterozygotes in the next generation.

Nonrandom mating - selfing in 24 plants

Generation 0: p (frequency of A) = 0.5
q (frequency of a) = 0.5



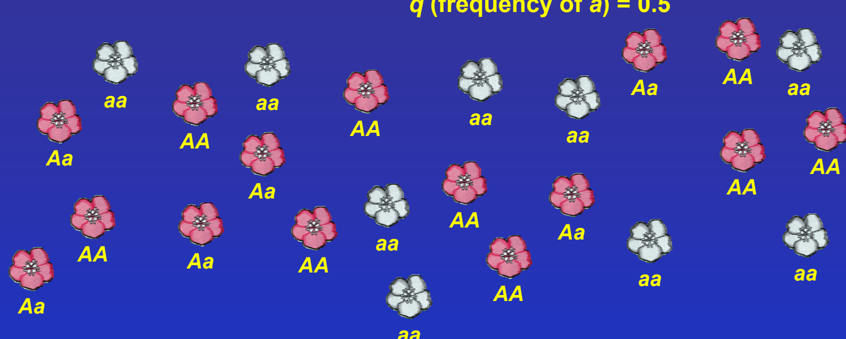
$p^2 = 0.50^2 = 0.25 = 6$

$q^2 = 0.50^2 = 0.25 = 6$

$2pq = 2 \times 0.50 \times 0.50 = 0.50 = 12$

Complete selfing

Generation 1: p (frequency of A) = 0.5
q (frequency of a) = 0.5



$p^2 = 0.50^2 = 0.25 = 6$ (expected) 9 observed

$q^2 = 0.50^2 = 0.25 = 6$ (expected) 9 observed

$2pq = 2 \times 0.50 \times 0.50 = 0.50 = 12$ (expected) 6 observed

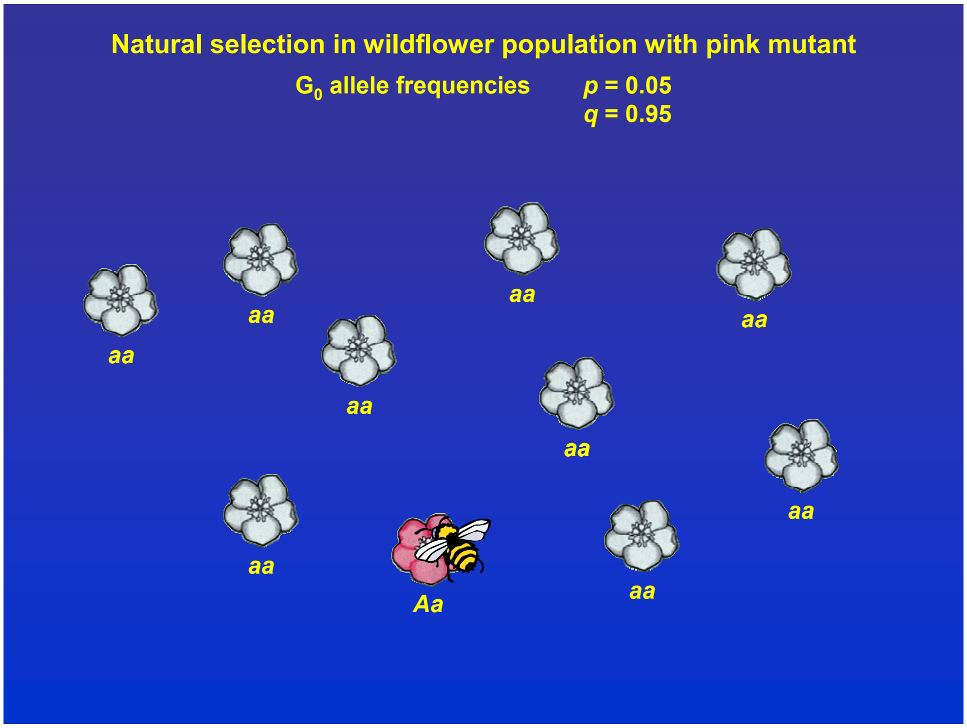
Not in HWE

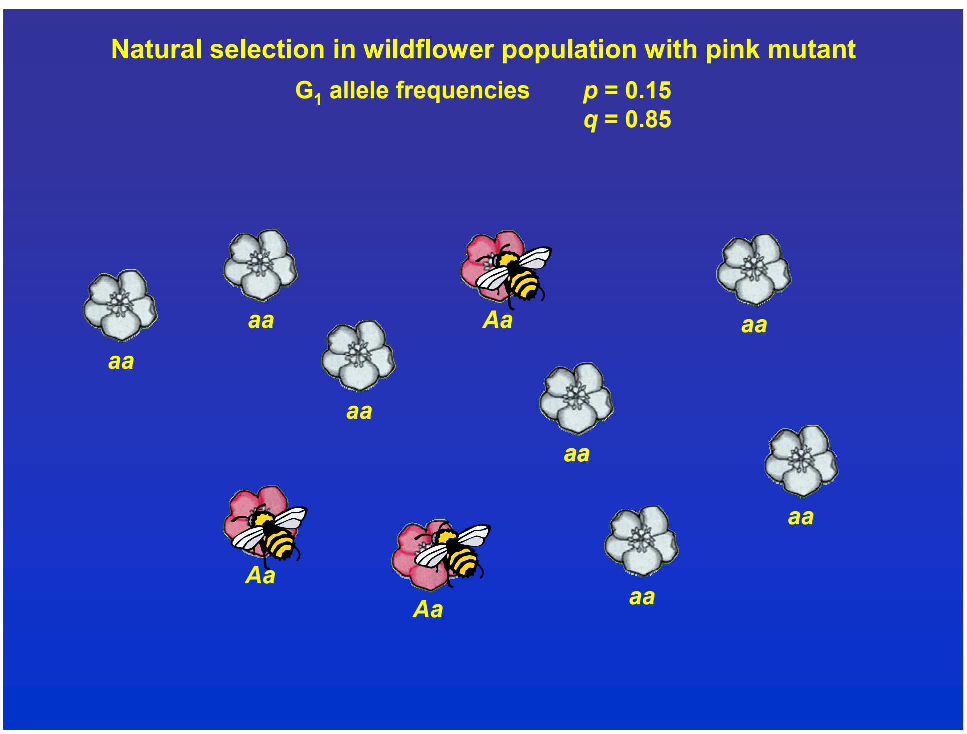
Nonrandom mating

- Even in less extreme cases of inbreeding ➔ proportion of heterozygotes will decrease (more slowly).
- From a purely phenotypic perspective ➔ proportion of recessive phenotypes will increase (white flowered plants).
- This is essentially why inbreeding is not a good idea ➔ recessive disorders become more frequent.
- Another type of nonrandom mating ➔ assortative mating.
- Assortative mating ➔ individuals select partners with phenotypic characters similar to themselves (e.g. height in humans).
- Assortative mating ➔ tend to increase homozygosity at certain genes.

5) Natural selection

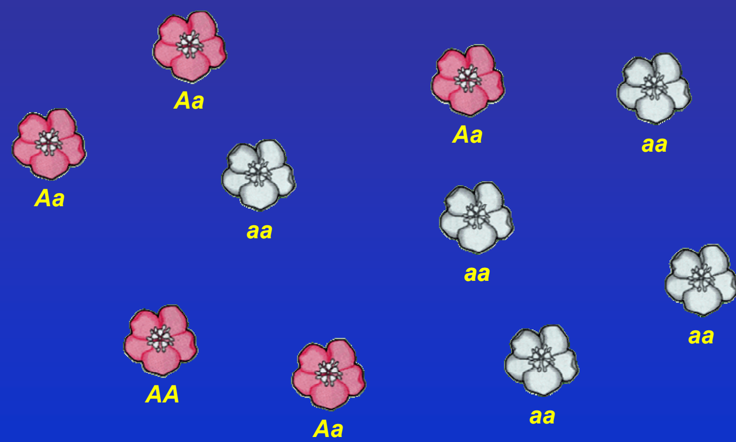
- HWE requires that all individuals in a population be equal in their ability to survive and produce viable offspring (very unusual in reality).
- Imagine pink flowers are more visible to pollen-collecting bees.
- Over time, the frequency of the *A* allele will increase and the *a* allele will decrease because pink flowers more likely to be visited by bees.
- HWE is disturbed - population is evolving.
- Microevolution through natural selection ➔ adaptation to environment.


Natural selection in wildflower population with pink mutant
G0 allele frequencies
p = 0.05
q = 0.95
aa
aa
aa
aa
aa
aa
aa
aa
Aa
aa


Natural selection in wildflower population with pink mutant
G1 allele frequencies
p = 0.15
q = 0.85
aa
aa
Aa
aa
aa
aa
aa
Aa
Aa
aa

Natural selection in wildflower population with pink mutant

G_2 allele frequencies $p = 0.30$
$q = 0.70$



This kind of selection is also referred to as **directional selection**

It favours a single allele and may drive it to fixation

Most famous classical example is the peppered moth.

Common type of peppered moth found around Manchester pre 19th century is referred to as *typica*.

Carbonaria form appeared in 1848, and reached a frequency of 98% by 1895

New “clean air” laws introduced – frequency of *carbonaria* reduced

Alternatively balancing selection acts to maintain genetic polymorphism/multiple alleles in the population

Multiple alleles are maintained by:

-heterozygote advantage/overdominance

-selective advantage of certain allele combinations

-frequency dependent selection – sex ratios

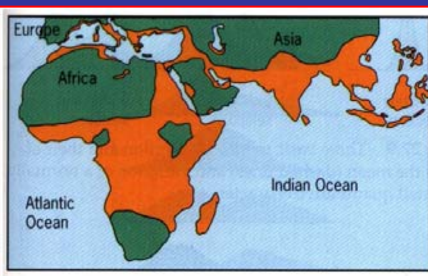
-environmental heterogeneity

Genetic selection in humans: heterozygote advantage

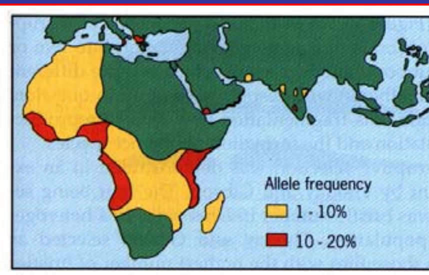
- Relatively high frequencies of certain alleles that confer reduced fitness on homozygotes (e.g. cystic fibrosis in Caucasians and sickle-cell anaemia in Africans) have arisen because the heterozygotes (Aa) have greater evolutionary fitness than either of the homozygotes (AA or aa).
- For cystic fibrosis, it seems that heterozygotes are more resistant to the dehydrating effects of diseases associated with severe diarrhoea (e.g. cholera).
- For sickle-cell anaemia there is good evidence that heterozygotes for HbS have increased resistance to death from malarial infection than the normal HbAHbA homozygotes.

Wild type

Sickle-cell



(a) Distribution of Falciparum malaria.



(b) Distribution of sickle-cell anemia allele (Hb^S).

Figure 27.7 Distribution of Falciparum malaria (a) and the distribution of the sickle-cell anemia allele (Hb^S) (b) in the Old World.

(1920's - before extensive malaria-control programmes)

Question

- In a population that is in HWE, 16% of the individuals show the recessive trait. What is the frequency of the dominant allele in the population?

a) 0.84

b) 0.36

c) 0.6

d) 0.4

e) 0.48

Useful Reading

The Essentials of Genetics
by John Murray – Jones Karp Giddings

Biology
by Campbell and Reece – Pearson Education

Principles of Population Genetics
by Daniel L Clark and Andrew G Clark - Sinauer

Genetics of Populations
by Philip W. Hedrick

“Genetics and the origin of species: An introducion”
Ayala and Fitch
PNAS, Vol. 94, p 7691-7697