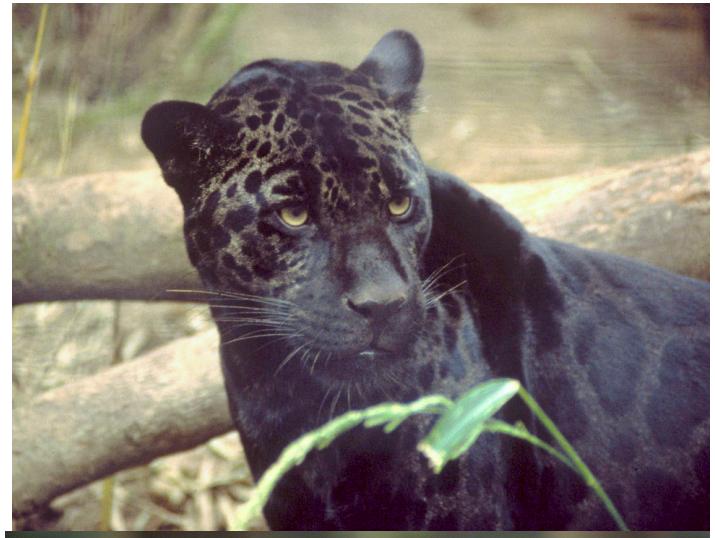
Population Genomics: Selective Sweeps

Polymorphism

The occurrence of two or more different phenotypes in the population of a species.

Polymorphisms are caused by heritable genetic variants.



Polymorphism

In genomics, polymorphism is when there are two or more variants of a particular DNA sequence.

- the two or more variants can also be called ***alleles*.**

Can be of a single base pair

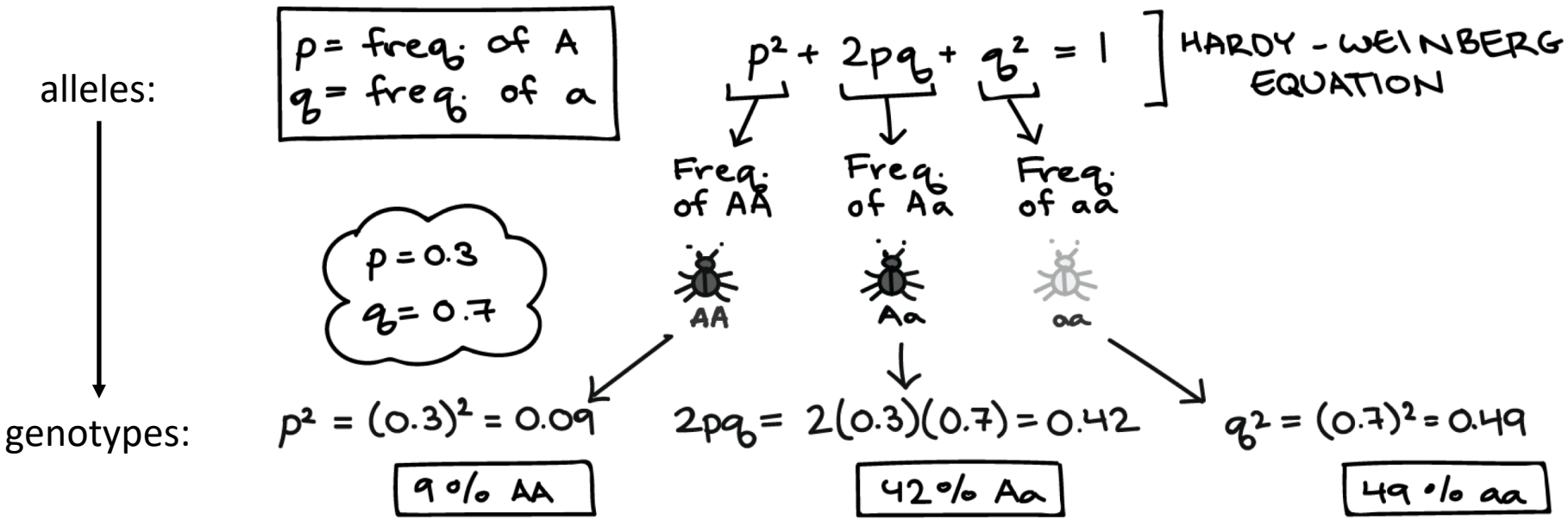
- single nucleotide polymorphism (SNP)

Can also be larger in size and involve longer stretches of DNA

- i.e. short tandem repeats

https://www.genome.gov/genetics-glossary/Polymorphism

Alleles in Populations



Khan Academy

When a population is in Hardy Weinberg ***equilibrium***, allele frequencies will not change between generations.

Evolution is when the Hardy Weinberg equilibrium is violated and there is a ***change in allele frequencies***.

Where does Evolution Begin?

There are five mechanisms of evolution that can change allele frequencies.

1. Mutation (the generation of new alleles)
2. Non-random mating
3. Gene flow
4. Genetic drift
5. Natural selection

"Evolution begins as one mutation, on one chromosome, in one individual."

Matthew Hahn, 2019.
First line of Chapter 1, *Molecular Population Genetics*

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The Neutral Theory

Deleterious mutations have little chance of becoming fixed in the population.

Most mutations are under such weak selection that drift they may become fixed due to drift.

Key to the neutral theory: the expected amount of genetic variation in a population can be estimated as $\theta = 4N_e\mu$

Motoo Kimura. 1983.
The Neutral Theory of Molecular Evolution

Genetic Drift

In each generation some individuals leave behind more descendants by chance.

This chance has profound effects on allele frequencies, and is random.

$\frac{3}{9}$

33%

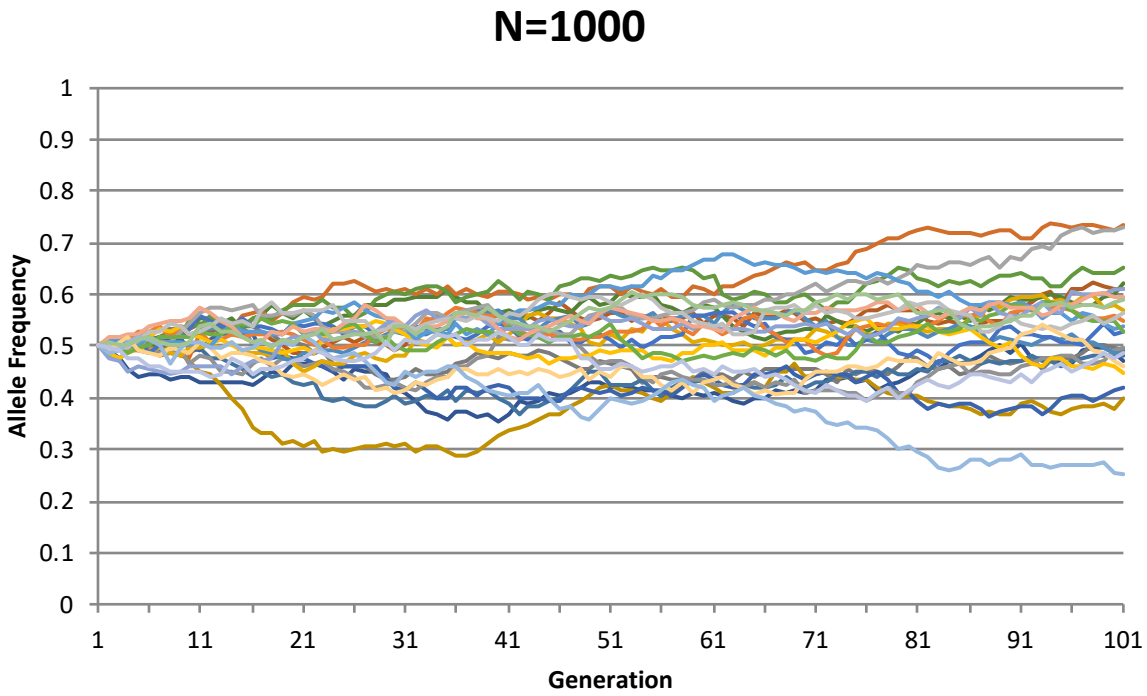
$\frac{1}{7}$

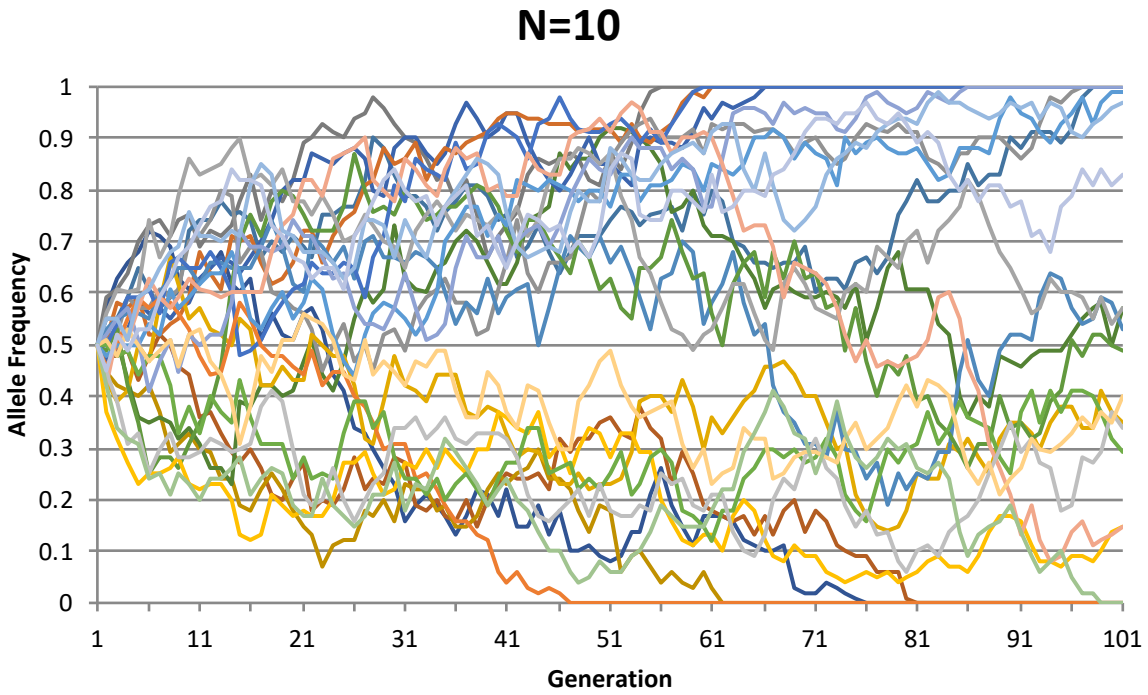
14%

https://evolution.berkeley.edu/evolibrary/article/evo_24

Because of this random act of violence, the frequency of green beetles went from a third to 14%

The importance of Population Size

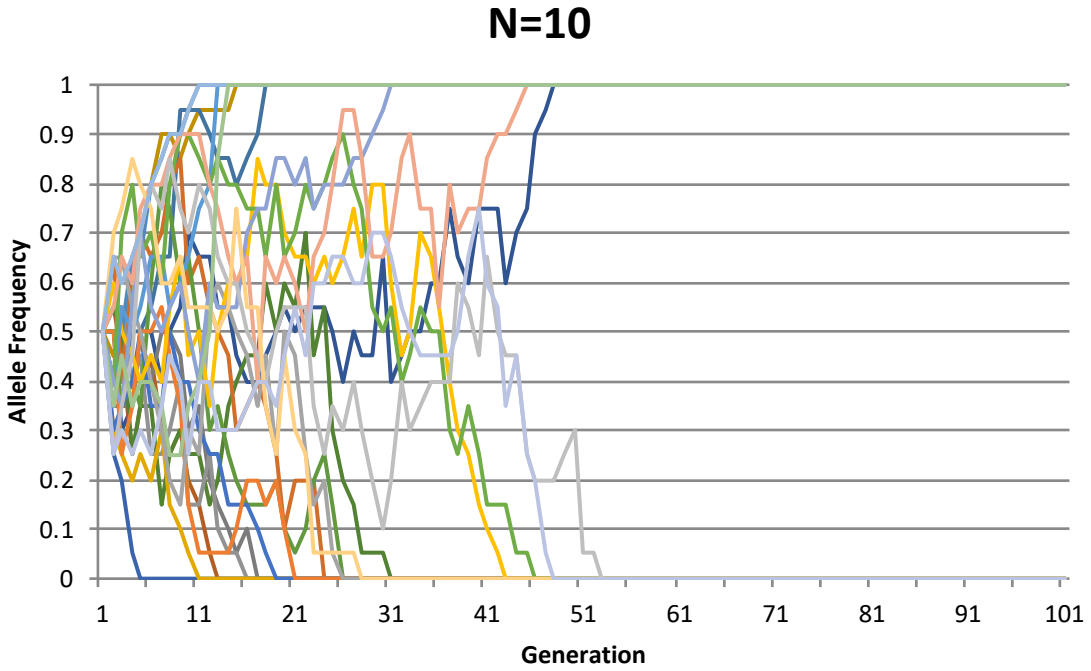


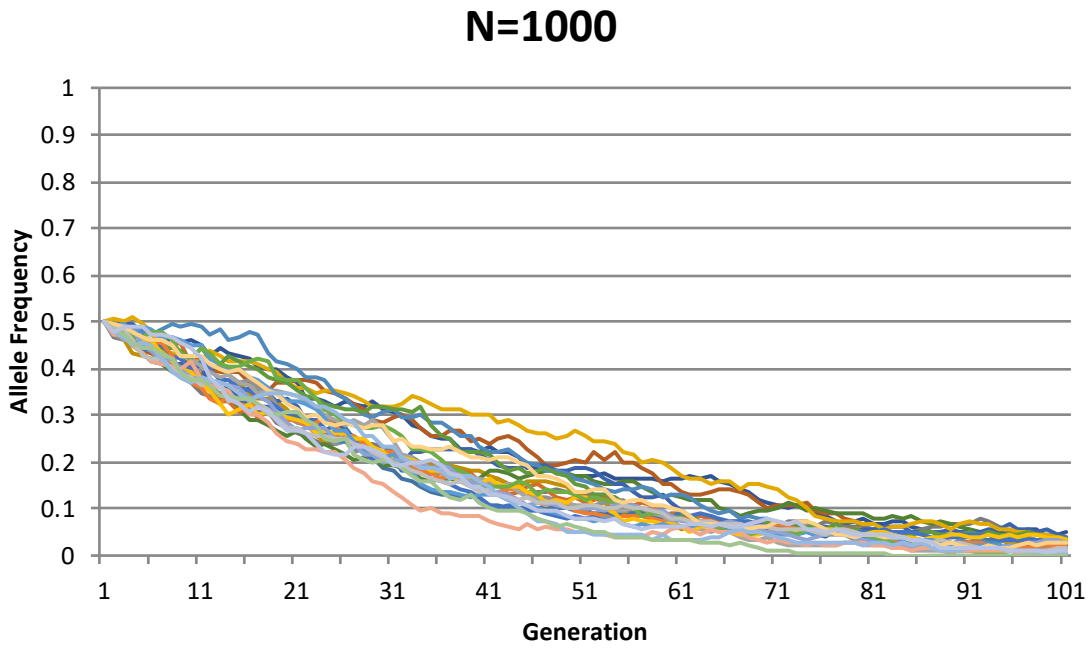


- Allele frequencies fluctuate in populations of small N_e
- In this model, the allele is selectively neutral

- The relationship between population size and allele frequency is known as the ***mutation-drift balance***.

Population Size is Crucial Even in the Presence of Selection





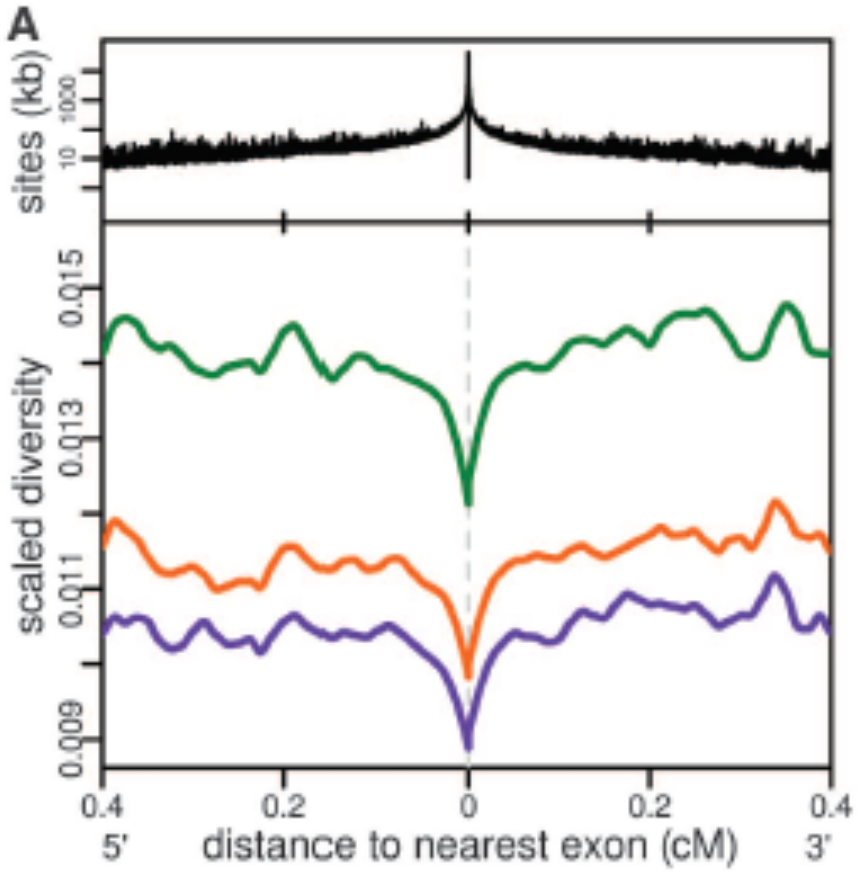
- Codominant allele with s = -0.08 (deleterious)
- Otherwise harmful alleles can drift to high frequencies when N_e is small
- Selection-drift balance important for understanding the evolution of genomic features

What else can effect the strength of selection?

In the human genome, population diversity levels decrease sharply near exons.

This suggests that physical distance to selected sites is an important factor.

This is where ***recombination*** comes in.



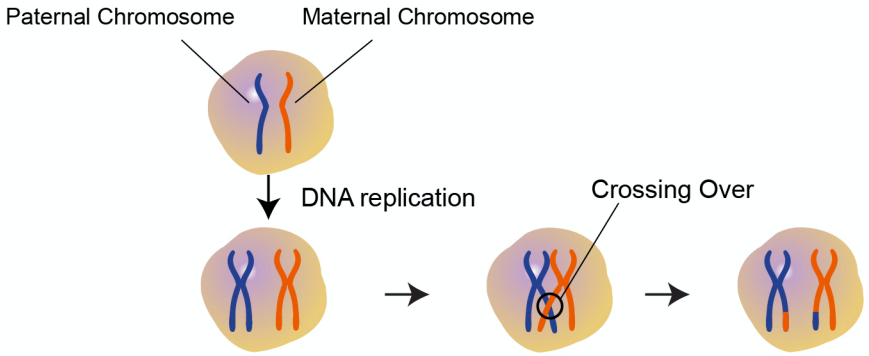
Hernandez et al. 2011. Classis Selective Sweeps Were Rare in Recent Human Evolution. *Science*.

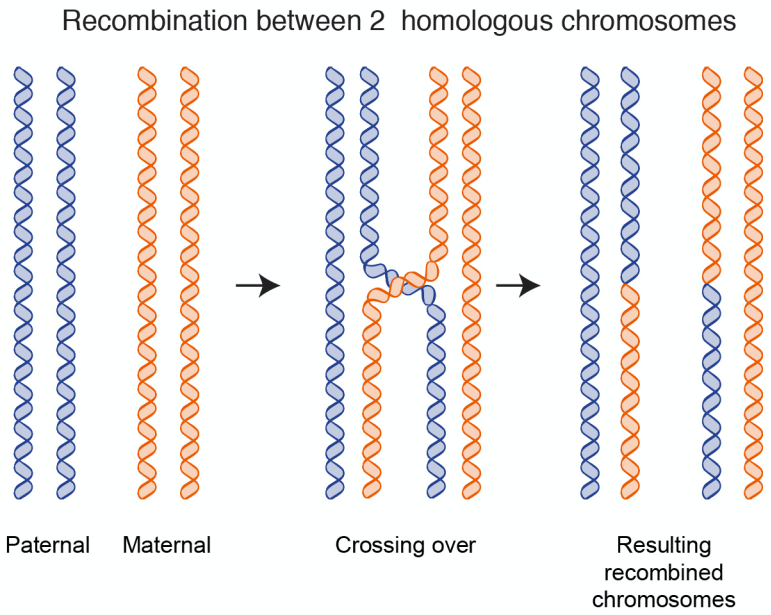
Recombination

Homologous chromosomes carry the same genes, one from each parental source.

During the production of gametes, ‘crossing over’ occurs.

Portions of homologous chromosomes (with similar sequence) are exchanged.





https://www.genome.gov/genetics-glossary/homologous-recombination

Recombination

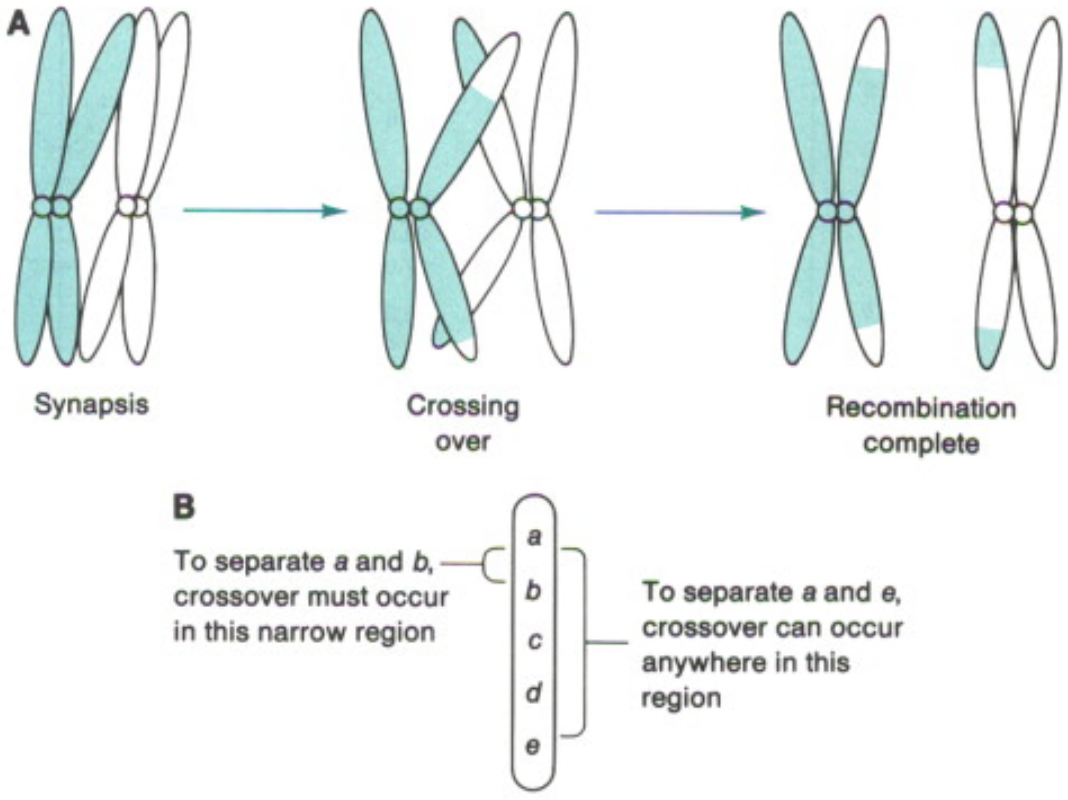
Homologous chromosomes carry the same genes, one from each parental source.

During the production of gametes, ‘crossing over’ occurs.

Portions of homologous chromosomes (with similar sequence) are exchanged.

Genes closer together will be linked more often than those further apart.

Linked genes are often found close together on the chromosome.



Fosket DE. 1994. *The Genetic Basis of Plant Development.* In *Plant Growth and Development*

Genetic Hitchhiking

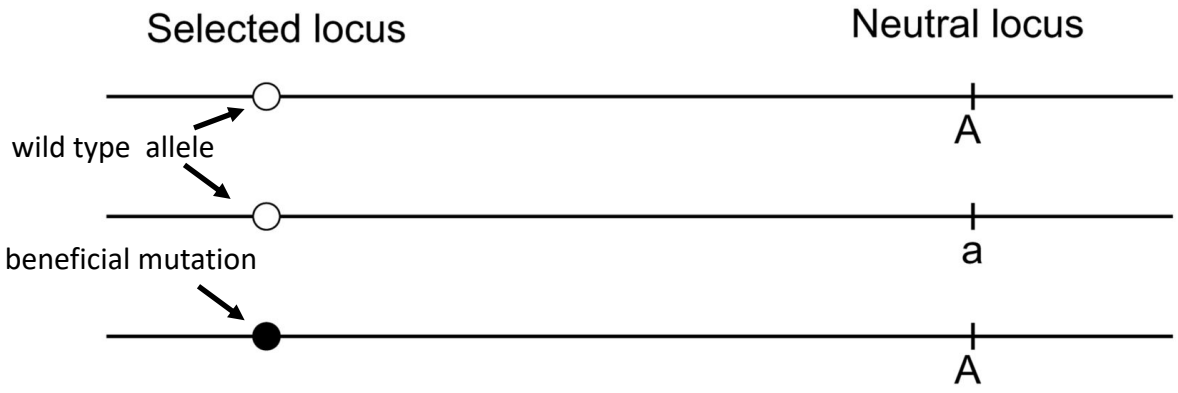
Consider three haplotypes present in a population.

- ***haplotype: a set of genes inherited from a parent.***

*There is a **selected** locus and a **neutral** locus.*

- *Note that a beneficial mutation has occurred at the selected locus.*
- *there are now two alleles at the selected locus.*

The neutral locus contains two alleles (A and a)



Stephan W. 2019. Selective Sweeps. *Genetics.*

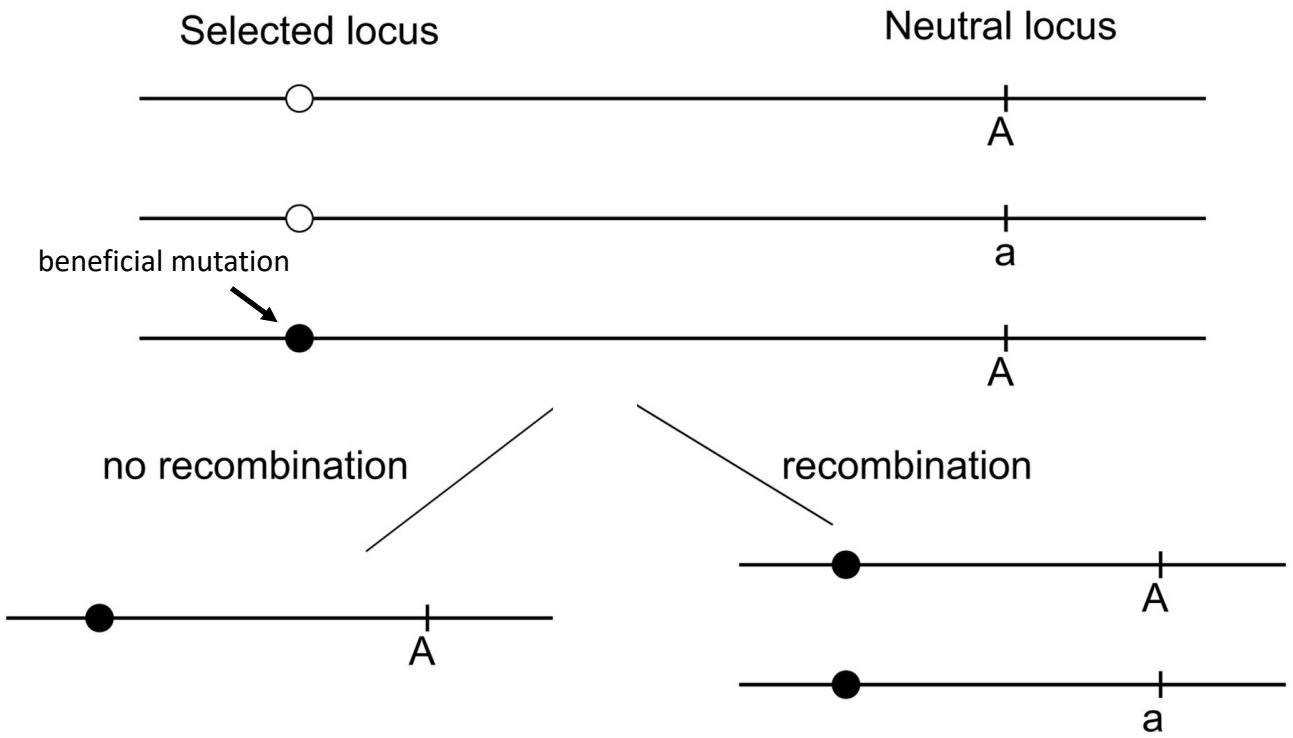
Genetic Hitchhiking

If no recombination occurs, one haplotype is present.

With recombination, the neutral locus stays ***polymorphic.***

With recombination, two haplotypes remain.

Recombination rate is positively correlated with polymorphism.

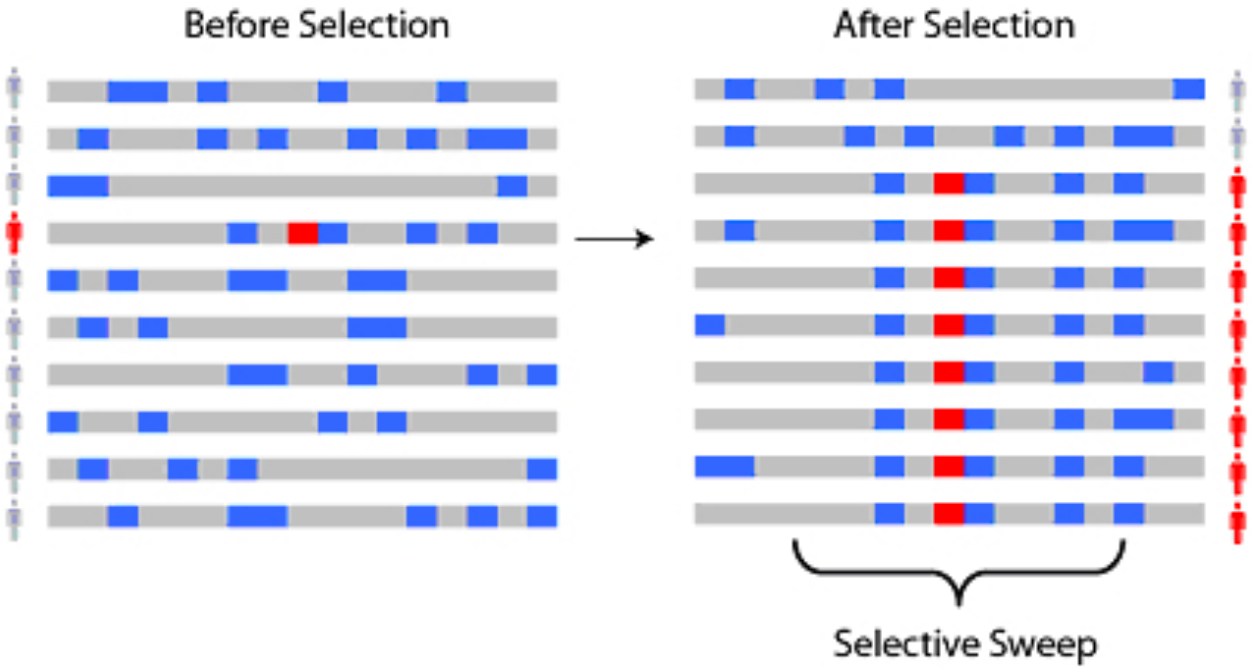


Stephan W. 2019. Selective Sweeps. *Genetics.*

Selective Sweeps

A new beneficial mutation will rise in frequency in the population.

Nearby linked alleles will also rise in frequency.

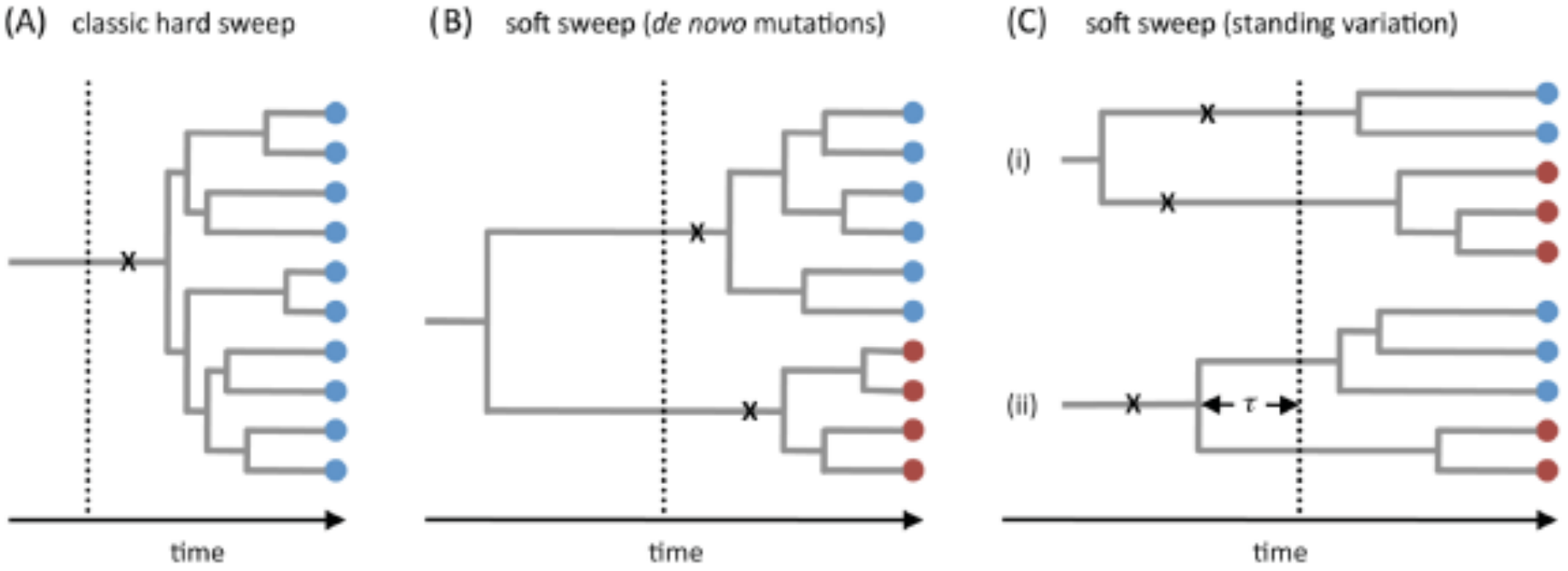


Schaffner SF. 2008. Evolutionary Adaptation in the Human Lineage. *Nature Education.*

Hard versus Soft Selective Sweeps

In a ‘hard’ sweep, a new mutation sweeps through the population.

This would mean that a genealogy of all samples would coalesce more recently than the the onset of positive selection.

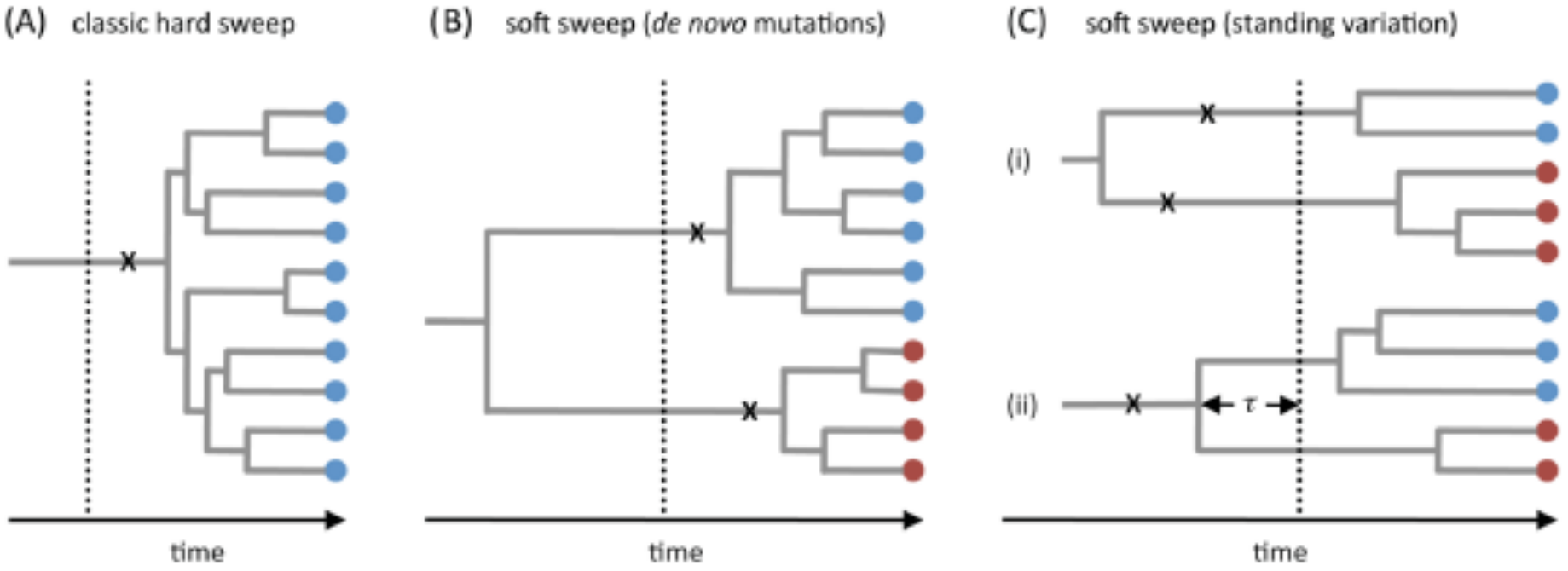


Messer and Petrov. 2013. Population genomics of rapid adaptation by soft selective sweeps. *Trends in Ecology and Evolution*.

Hard versus Soft Selective Sweeps

In contrast, a ‘soft’ sweep is when multiple adaptive alleles at the same locus sweep through the population to high frequency.

In this case, a genealogy would reveal coalescence ***before*** the onset of positive selection.

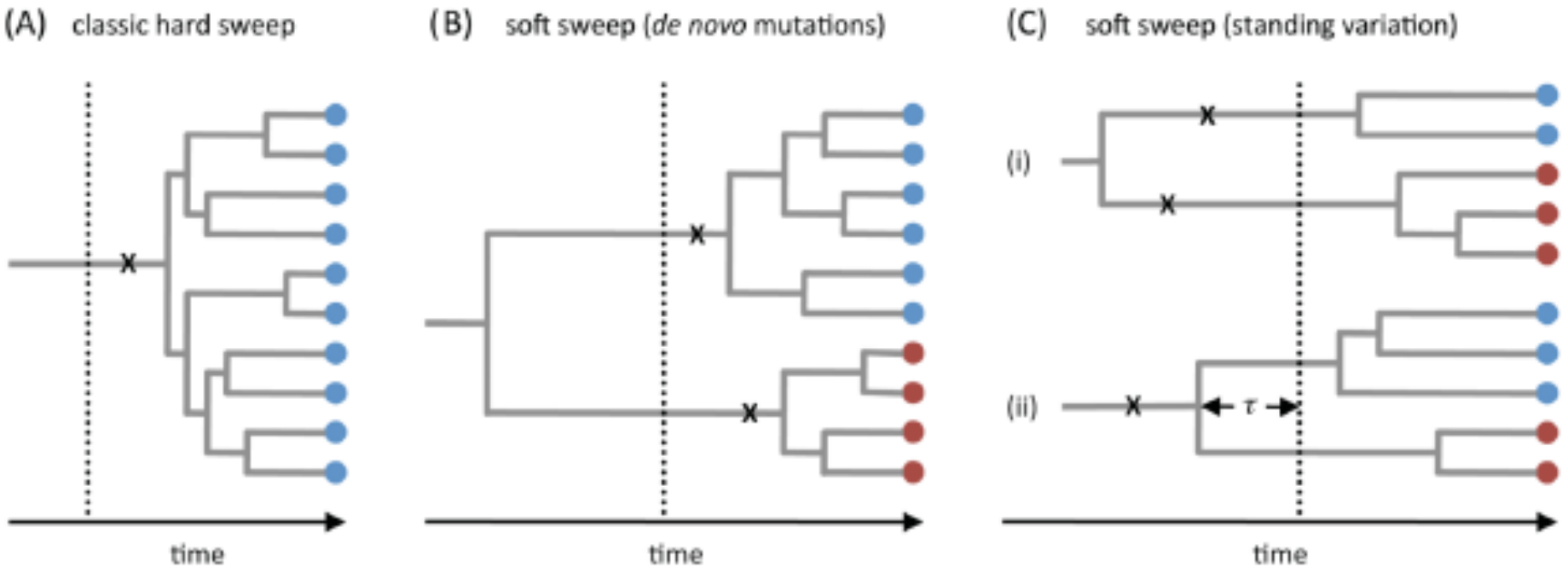


Messer and Petrov. 2013. Population genomics of rapid adaptation by soft selective sweeps. *Trends in Ecology and Evolution*.

Hard versus Soft Selective Sweeps

In B, the mutations arose *de novo* after the onset of positive selection.

In C, they may have arose *de novo* after positive selection (top) or were already present as ***standing variation***.



Messer and Petrov. 2013. Population genomics of rapid adaptation by soft selective sweeps. *Trends in Ecology and Evolution*.

Next

- The end is nigh!!! And we have flexibility