Beyond natural selection

Introduction to Evolution and Scientific Inquiry

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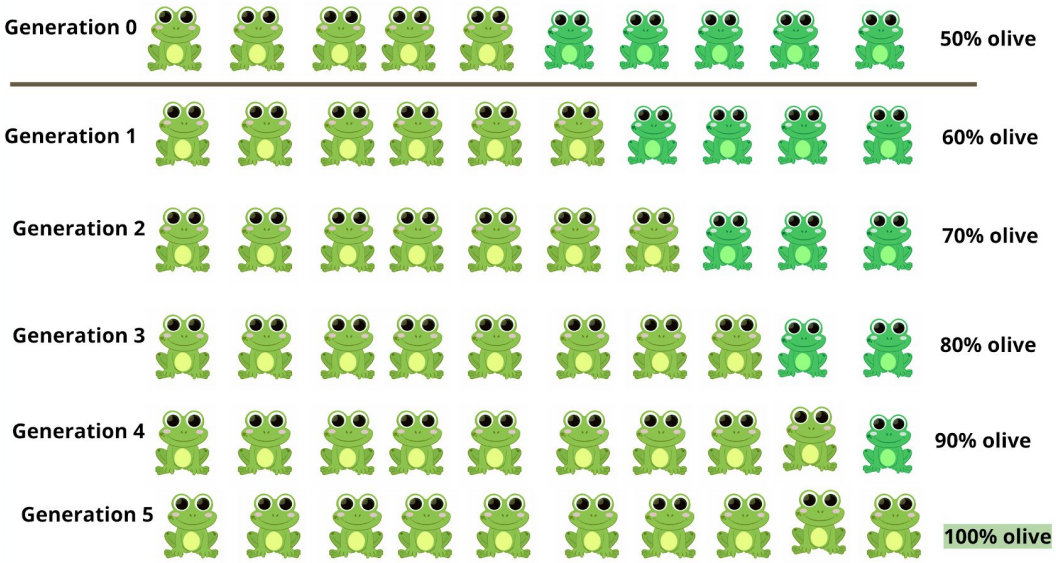
There are many evolutionary forces in addition to natural selection

- Selection
- Mutation
- Genetic drift
- Migration, aka *gene flow*
- Recombination (sexual species only..kind of)
- Assortative mating

Fixation occurs when an genotype or phenotype has 100% frequency in a population



Olive green fixes in generation 5

Bright green is lost by generation 5

Mutation provides the variation for natural selection to act on

- Mutation is the **ONLY** evolutionary force that adds **NEW** variation to populations

- Generally speaking, is evolution possible without mutation?

Mutation on a genetic level

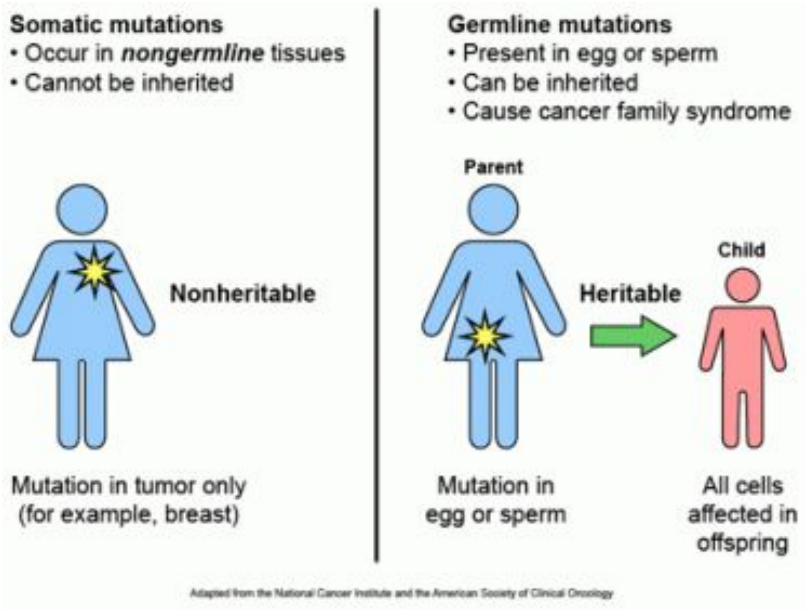
Point mutation

Insertion

Deletion

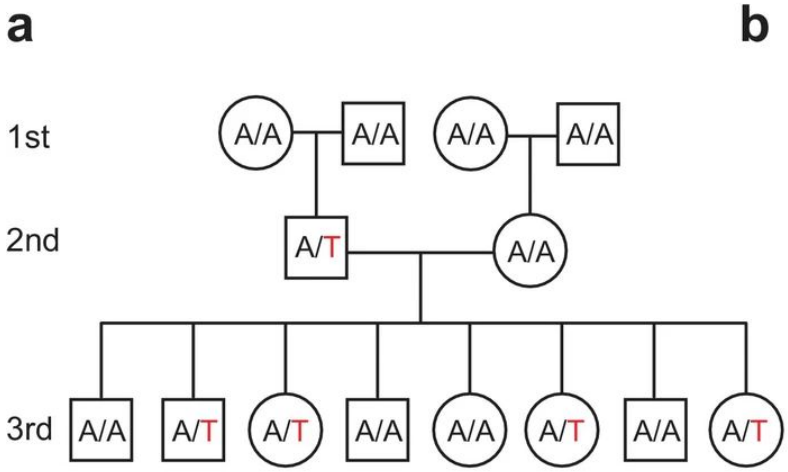
Mutation only contributes to evolution when it affects the germline

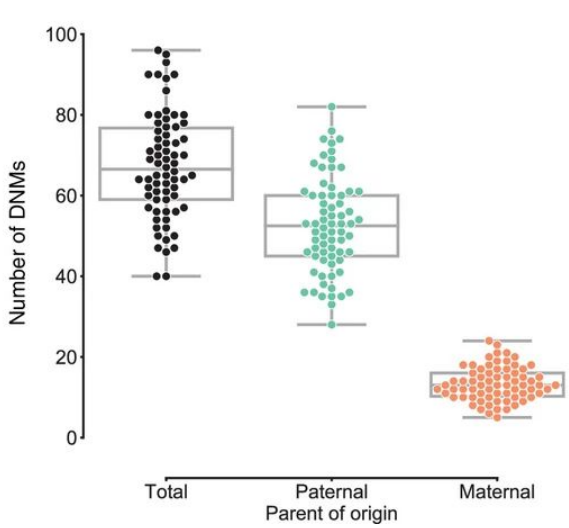
Not relevant to evolution



INCREDIBLY relevant to evolution!

Each of us has an average 70 brand new mutations!





https://elifesciences.org/articles/46922

What causes mutations?

- Environmental factors (radiation, mutagenic chemicals..)

- DNA isn't perfect at copying itself - mistakes in DNA replication cause mutations
  - Most mutations are **deleterious** (harmful)

- "Need" for a certain trait does NOT lead to mutation! *Mutations are random with respect to the environment*
  - Example: I would love to be able to fly, but I have not yet sprouted wings :(

The consequences of a mutation

Two competing views on the theory of mutational effects on fitness

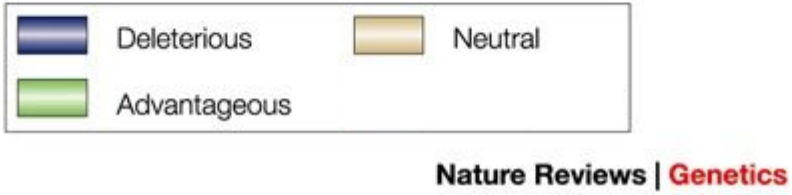
Most mutations are deleterious (decrease fitness)

A small proportion are advantageous (increase fitness)

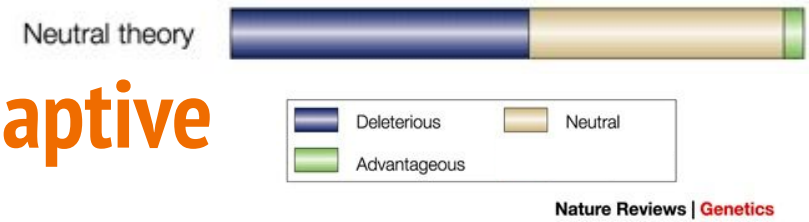
~Half mutations are deleterious (decrease fitness)

~Half mutations are *neutral* (no effect on fitness)

Very small proportion are advantageous (increase fitness)



Mutations are only rarely adaptive



When an **advantageous** mutation occurs that is, we consider it an adaptation

What a **neutral** mutation occurs, it contributes to "standing genetic variation"

- Many generations later, it may prove advantageous or deleterious, and *then* natural selection will act on it
- Question: How do neutral traits evolve if not by natural selection?

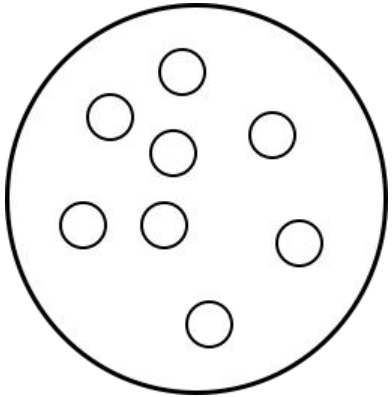
Mutation is *random* with respect to environment

- Experiment from Lederberg and Lederberg (1952) showed that that advantageous (good for fitness) mutations occur without exposure to the environment where they would be advantageous

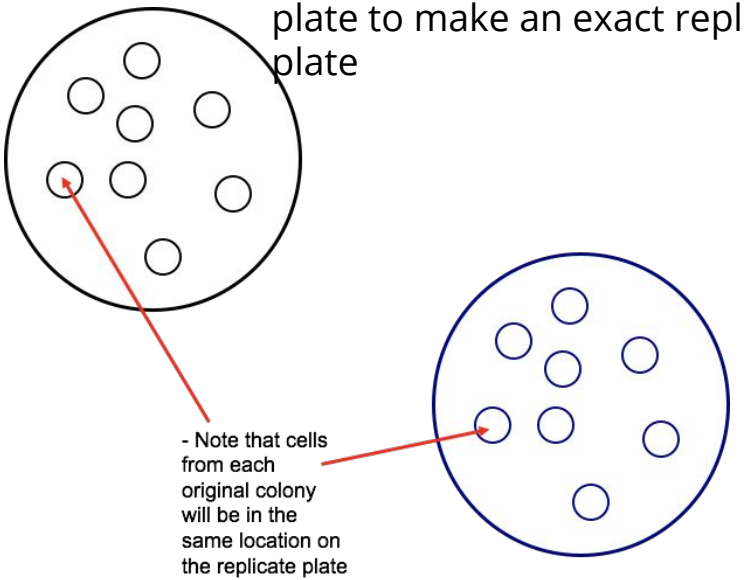
- Used “replica plating technique” with bacteria

Replicate plating

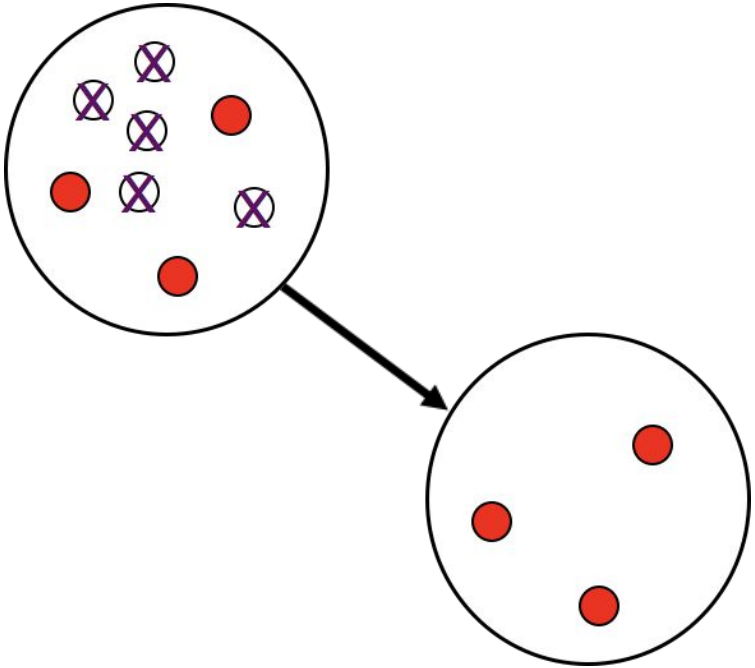
1. Start with a plate of bacteria colonies



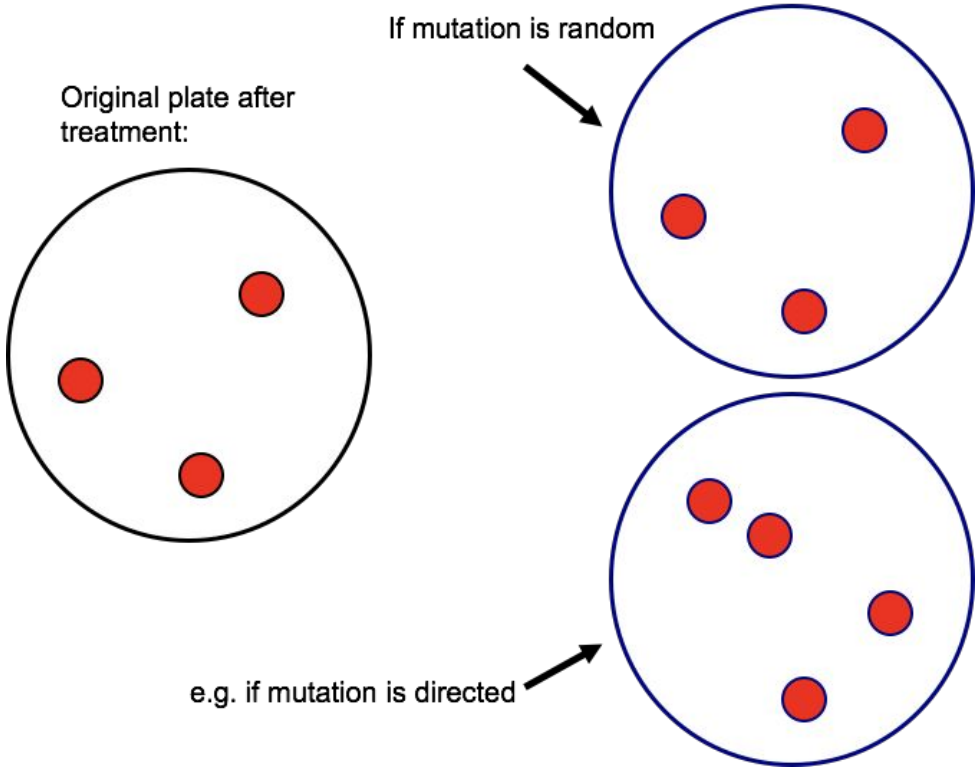
2. Press velvet onto original plate, and then onto new agar plate to make an exact replicate plate



Treated with penicillin; some colonies survived, some died

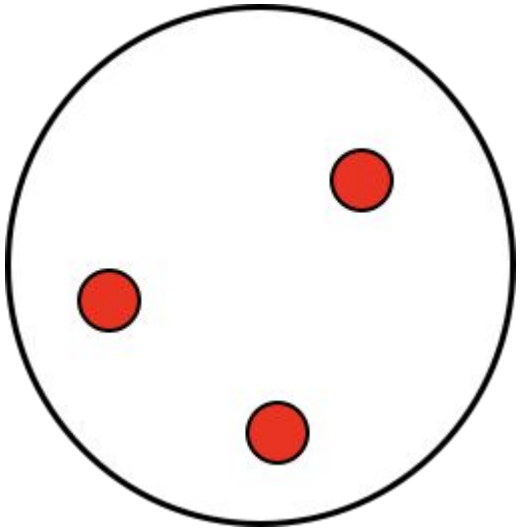


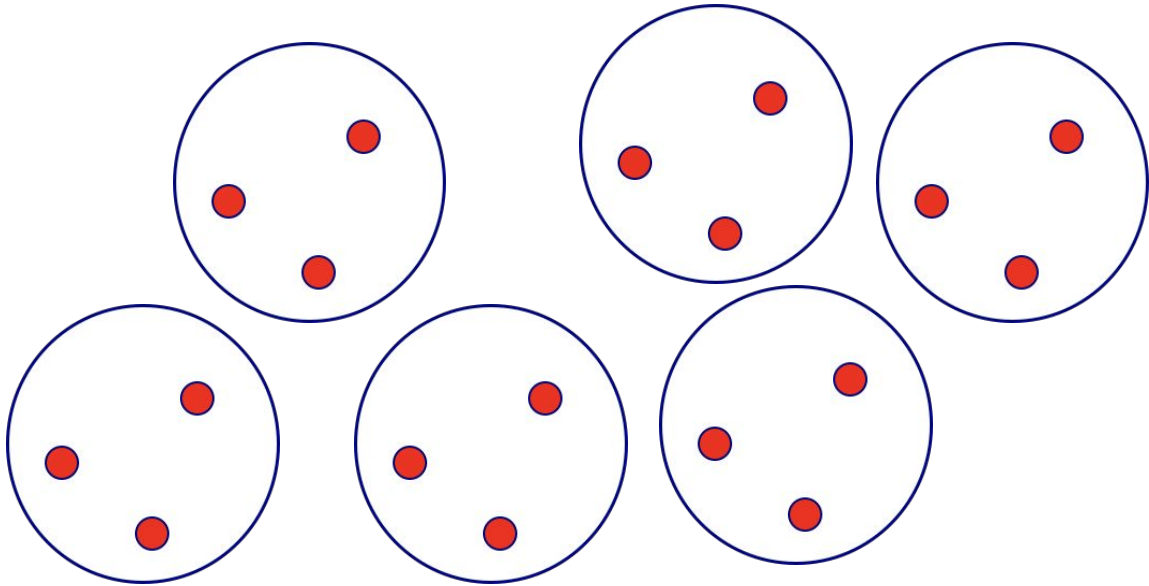
Predictions



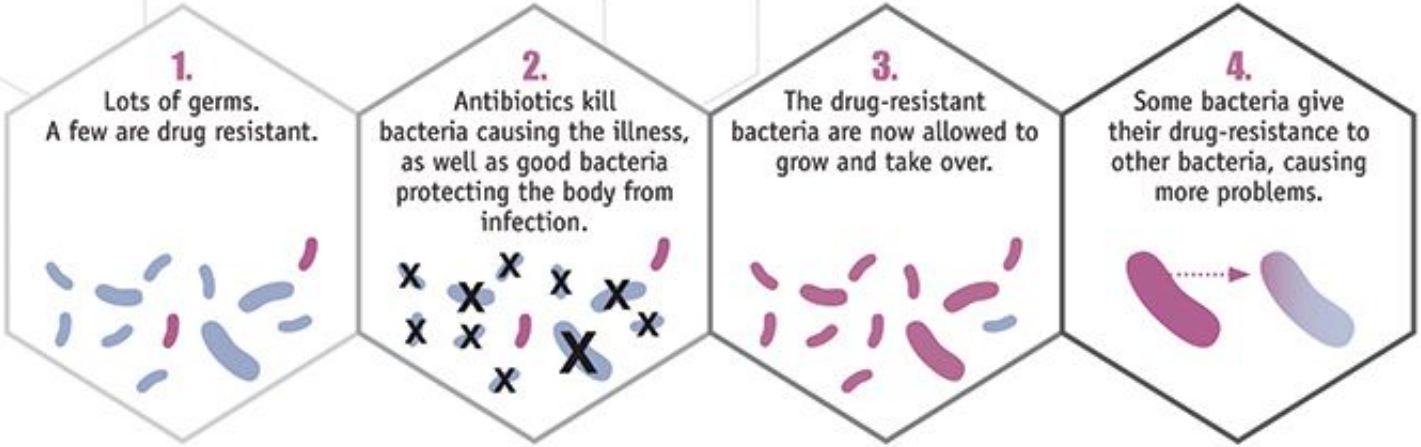
Actual results

- The **same** colonies in all replicates survived.
  - Advantageous mutations occurred BEFORE penicillin! Mutation is **random** and **undirected.**





How Antibiotic Resistance Happens



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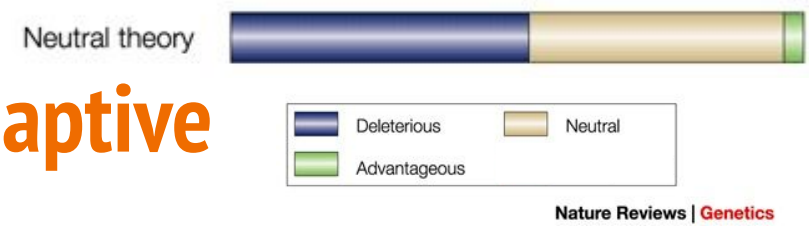

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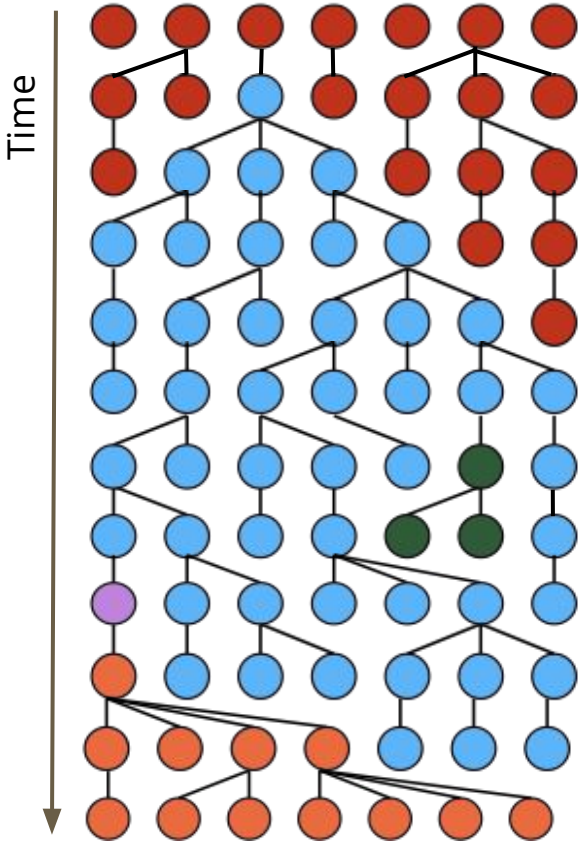
Random Genetic Drift

The influence of randomness

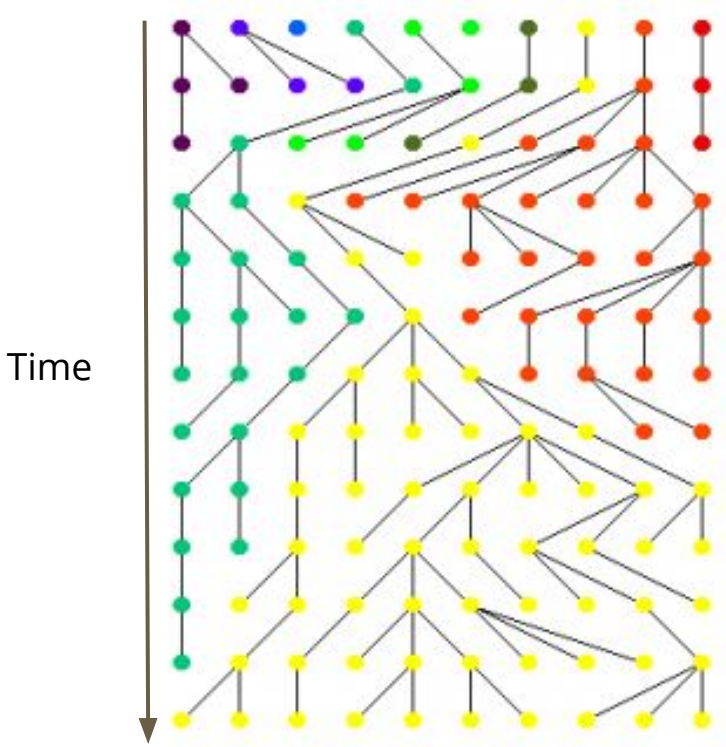


1. How many mutations occurred?
2. Which mutations, if any, **fixed**?

3. Which individual in the first generation is the **most fit**?
4. Which individual is the **common ancestor** for all living dots in the current generation?

5. Are green and purple phenotypes necessarily low-fitness?

Randomness alone (no selection!) can produce patterns like this:



Genetic drift

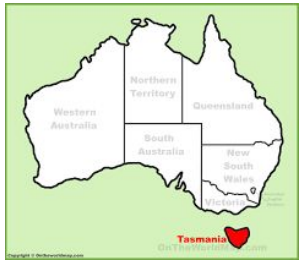
- Random changes in allele frequencies over time due to *chance*
- An "opposing" force to natural selection, depending on the **population size N**
  - Infinite population = no genetic drift

	Dominating force	**Consequences for population**
Small N	Genetic drift	• Deleterious alleles can fix (selection is weak) • Population may not achieve maximum fitness • The evolutionary force acting on neutral variation
Large N	Natural selection	• Advantageous alleles will likely fix • Population will generally achieve higher fitness • The evolutionary force acting on traits whose variation impacts fitness

- Genetic drift tends to **reduce population variation** (aka reduce *heterozygosity*)
  - Heterozygosity = proportion of individuals who are heterozygous (have two different alleles)

Consequences of genetic drift: Tasmanian Devils

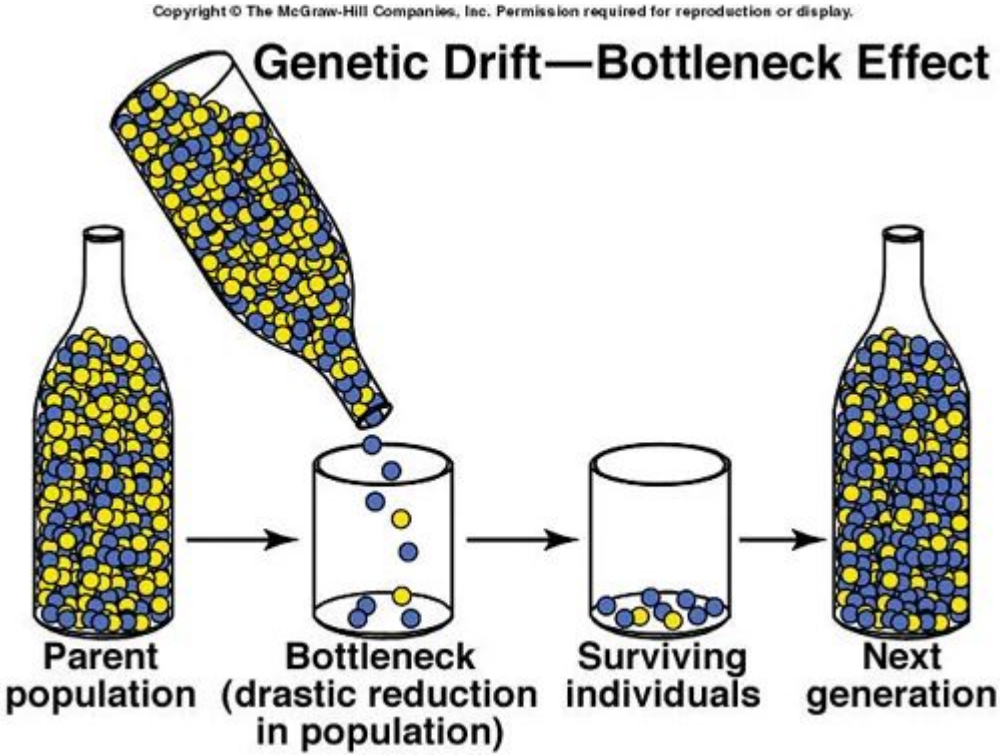
DFTD = Devil Facial Tumor Disease



Heterozygosity = proportion of individuals who are heterozygous (Aa, not aa or AA)

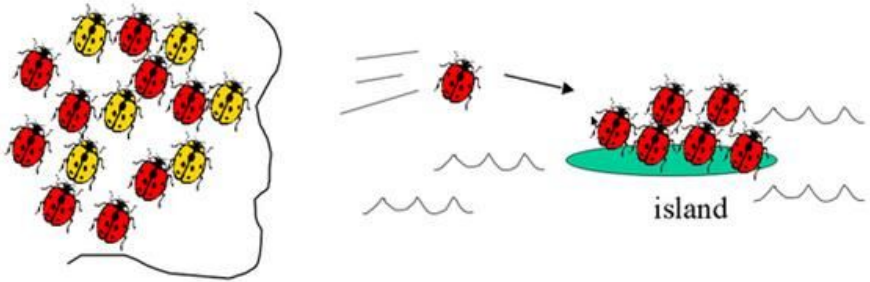
Species		Heterozygosity	Alleles/locus
Tasmanian devil	marsupial	0.39 – 0.47	2.7 – 3.3
Koala	marsupial	0.54 – 0.78	5.6 – 8.0
Western quoll	marsupial	0.79 – 0.88	8.8. – 9.2
Allied rock wallaby	marsupial	0.86	11.2
Grey wolf	placental	0.57 – 0.64	3.4 – 6.4
Pine martens	placental	0.62 – 0.68	6.2 – 6.6
Polar bear	placental	0.84 -0.94	6.0 – 6.9

The Bottleneck Effect



The Founder Effect

- **founder effect**: a few individuals from a population start a new population with a different allele frequency than the original population



Island population is **fixed** for red, but this BIT because red is more fit than yellow!

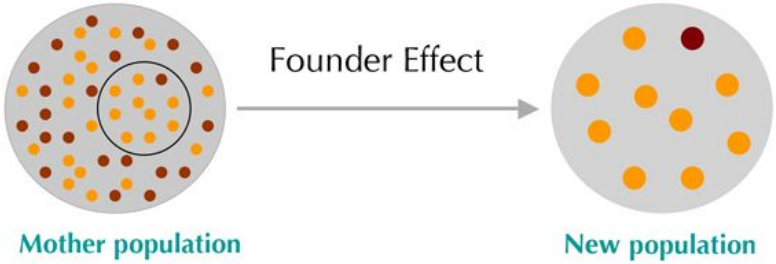
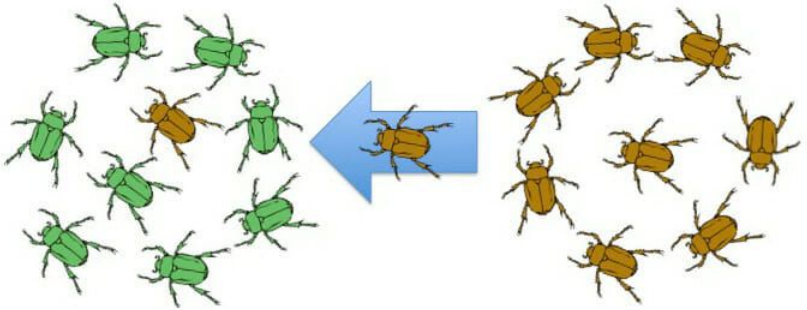


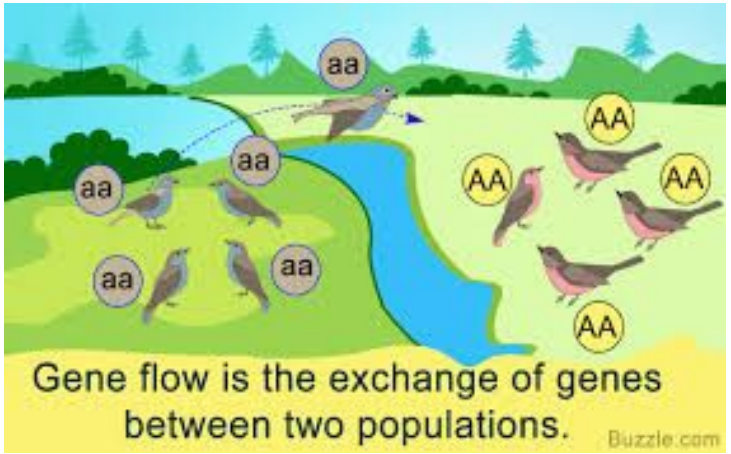
Image design: COSNET Lab

Migration, or gene flow



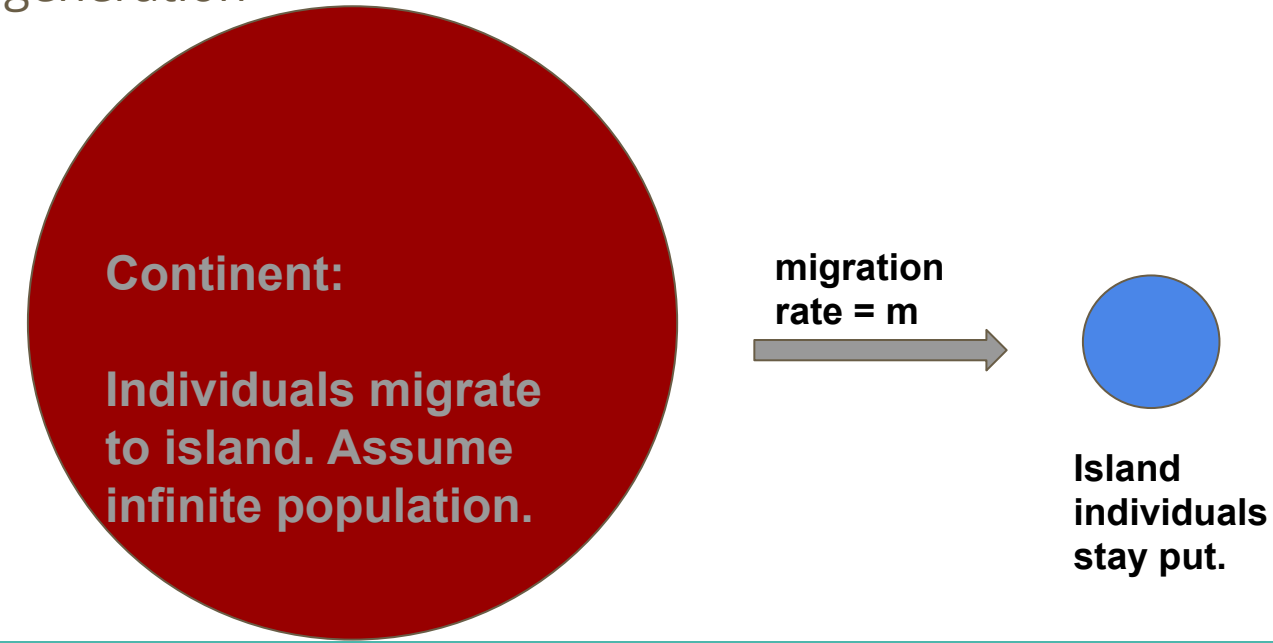
Introduces genetic variation from one population to another

1. Initial (before any migration) variation left and right of river?
2. Over many generations, variation left and right of river?



Island-continent model

m = percentage of **island** individuals who come from continent, each generation



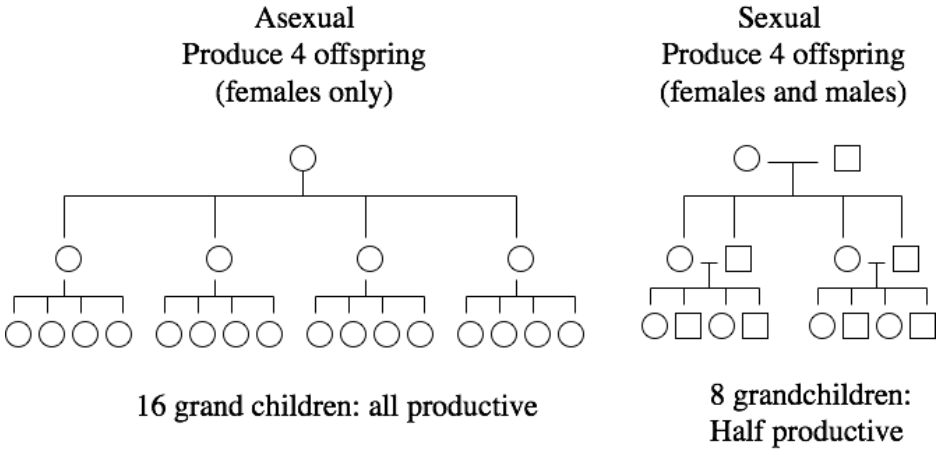
Recombination "shuffles genes" in sexual species

Sexual species take genetic material from a male and female parent

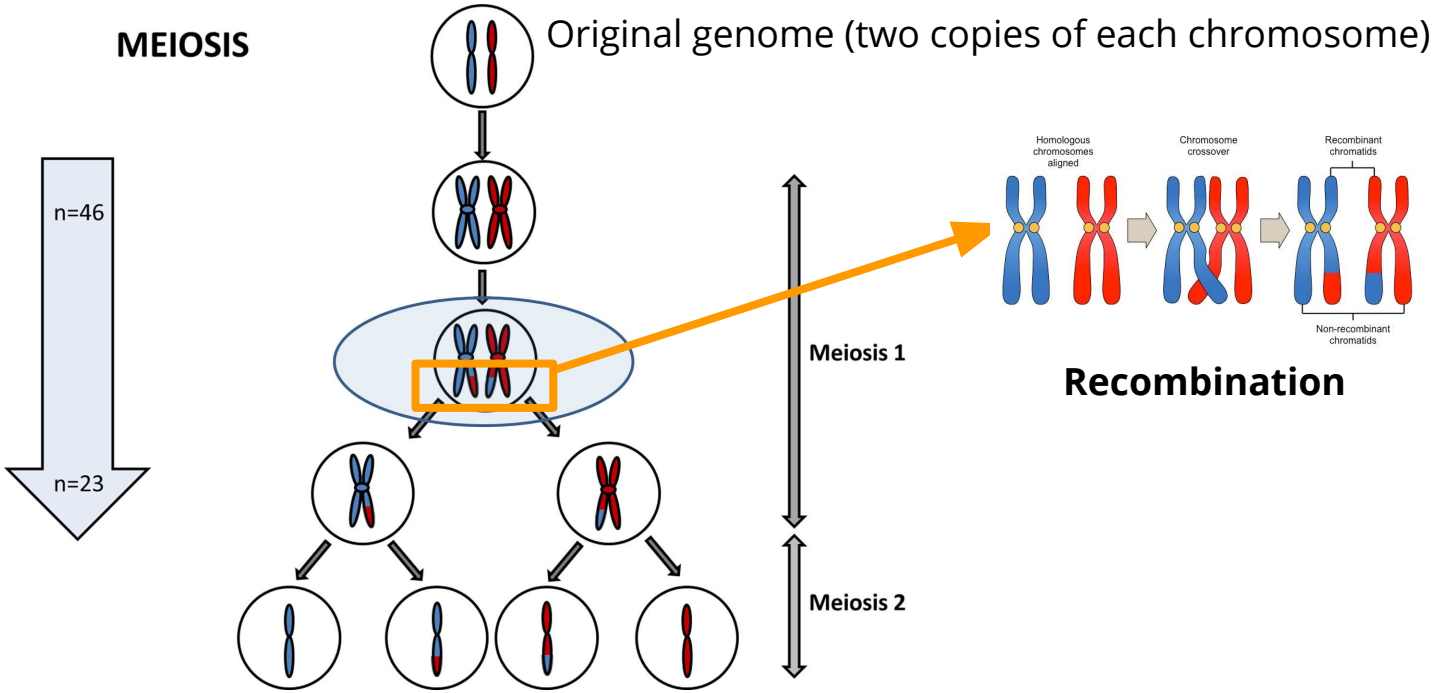
Asexual species are clones of the mother - there are no fathers

The two-fold cost of sex

- Aka, "two-fold cost of males"
- Asexual species reproduce twice as quickly compared to sexual species

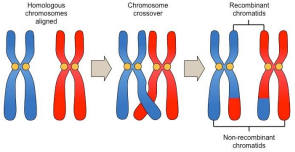


Meoisis is the process that makes gametes



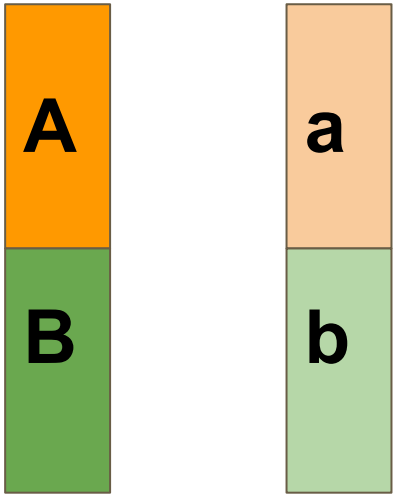
Four gametes (egg or sperm) that result from this process

Recombination shuffles gene combinations

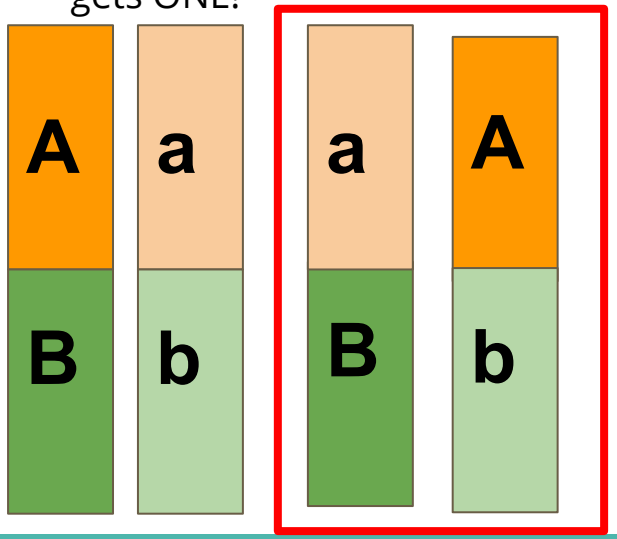


- Gene/allele combinations get shuffled
- Rearranges existing alleles; does not specifically create new alleles!
    - But... sometimes if recombination goes wrong, new alleles actually do get created = recombination-induced mutation

Parent's genome



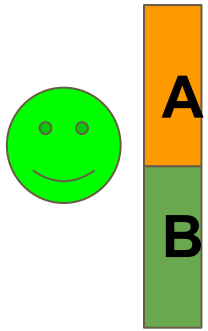
Gamete genome options (child gets ONE!

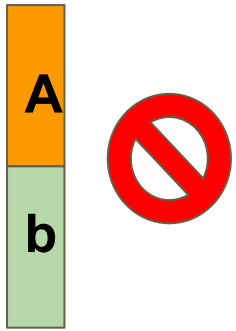


Epistasis: A very fancy vocabulary word

Epistasis: When different genes *interact* to produce different phenotypes

For example, maybe allele "A" is really really good! But if paired with "b" instead of "B", it becomes very bad.





Recombination shuffles gene combinations

What are some potential consequences of recombination?

- Can create beneficial gene combinations
  - The a/B pair might be better than A/B :)

- Can destroy beneficial gene combinations
  - The a/B pair might be worse than A/B :(

Muller's Ratchet: A predicted consequence of asexual reproduction

Asexual organisms' genomes are expected to show an **accumulation of deleterious mutations**

Mutations (X) in a genome (the line), over time

Is there no hope for the asexuals?

- Asexual **animals** are usually "blips" on the radar (with some exceptions!)

- There are "sex-like" processes that asexuals undergo, like **horizontal gene transfer**

Massive Horizontal Gene Transfer in Bdelloid Rotifers

Eugene A. Gladyshev,[1] Matthew Meselson,[1,2]* Irina R. Arkhipova[1,2]*

Horizontal gene transfer in metazoans has been documented in only a few species and is usually associated with endosymbiosis or parasitism. By contrast, in bdelloid rotifers we found many genes that appear to have originated in bacteria, fungi, and plants, concentrated in telomeric regions along with diverse mobile genetic elements. Bdelloid proximal gene-rich regions, however, appeared to lack foreign genes, thereby resembling those of model metazoan organisms. Some of the foreign genes were defective, whereas others were intact and transcribed; some of the latter contained functional spliceosomal introns. One such gene, apparently of bacterial origin, was overexpressed in *Escherichia coli* and yielded an active enzyme. The capture and functional assimilation of exogenous genes may represent an important force in bdelloid evolution.

Evolutionary forces' effects on population variation

Evolutionary force	**Affect on population variation**
Directional selection (most common type of selection!)	Decreases
Balancing selection	Maintains (also maintains variation in individuals)
Disruptive selection	Maintains (but reduces variation in individuals)
Mutation	Increases
Random genetic drift	Decreases
Migration	Increases
Recombination	Increases (applies only to sexual species)