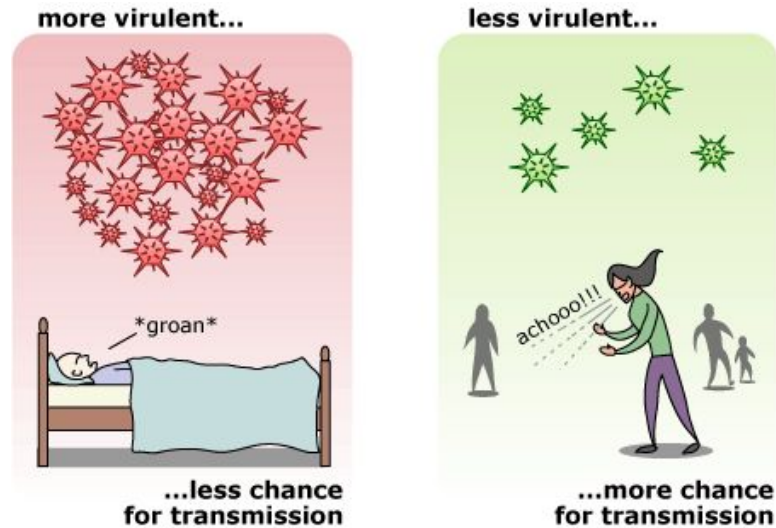


Other evolutionary forces

Introduction to Evolution and Scientific Inquiry

Dr. Spielman; spielman@rowan.edu

The evolution of **virulence**



In order to survive, pathogens must balance this **trade-off**

Other Evolutionary Forces beyond natural selection

- **Natural selection** → survivorship is based on fitness
 - Tends to *decrease variation, aka heterozygosity*. [Unless?]
- **Genetic drift** → survivorship is based on "sampling error"
 - Tends to *decrease heterozygosity*
- **Mutation** → raw source of all variation
 - By definition, *increases heterozygosity*
- **Migration ("gene flow")** → literally migration. individuals move between populations
 - Tends to *increase heterozygosity*
- **Recombination** → shuffling gene combinations in *sexual species*
 - Tends to *increase heterozygosity*

Mutation

- **Totally and completely random!!!!**

Two competing views on the theory of mutational effects on fitness

Selection theory



Most mutations are deleterious (decrease fitness)

A small proportion are advantageous (increase fitness)

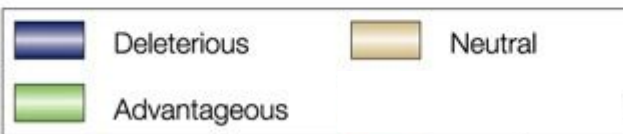
Neutral theory



~Half mutations are deleterious (decrease fitness)

~Half mutations are neutral (no effect on fitness)

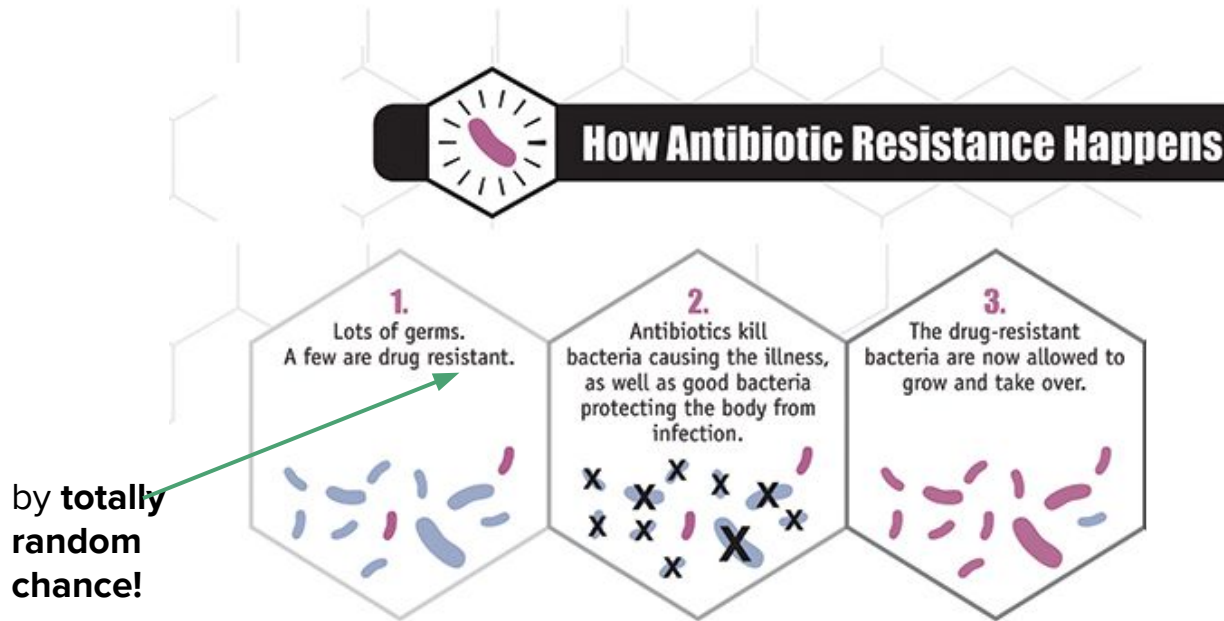
Very small proportion are advantageous (increase fitness)



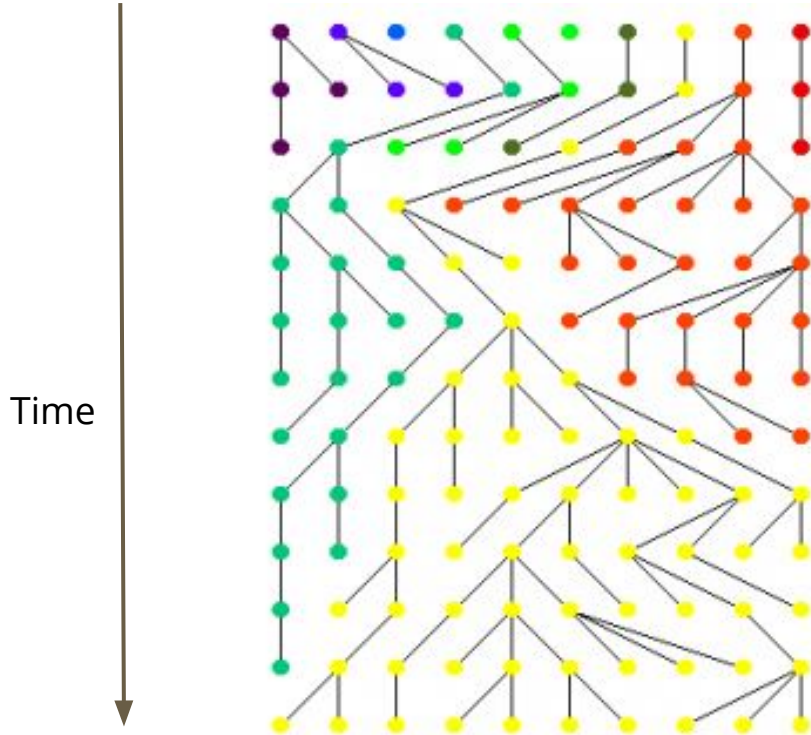
What is the FATE of a brand new mutation aka allele?

- It can **be lost** from the population
 - No more individuals ever carry the mutation. That new variation is gone, back to the start!
- It can **remain circulating** in the population
 - Some individuals will always carry it at some frequency in the population.
 - Variation is maintained
 - It may later be lost or fixed, or it can circulate forever indefinitely
- It can **fix** in the population (aka **go to fixation**)
 - EVERY INDIVIDUAL now has this allele and there are NO MORE OTHER ALLELES at this gene
 - All individuals are homozygous at that gene and there is NO variation

Mutation, selection, and antibiotic resistance



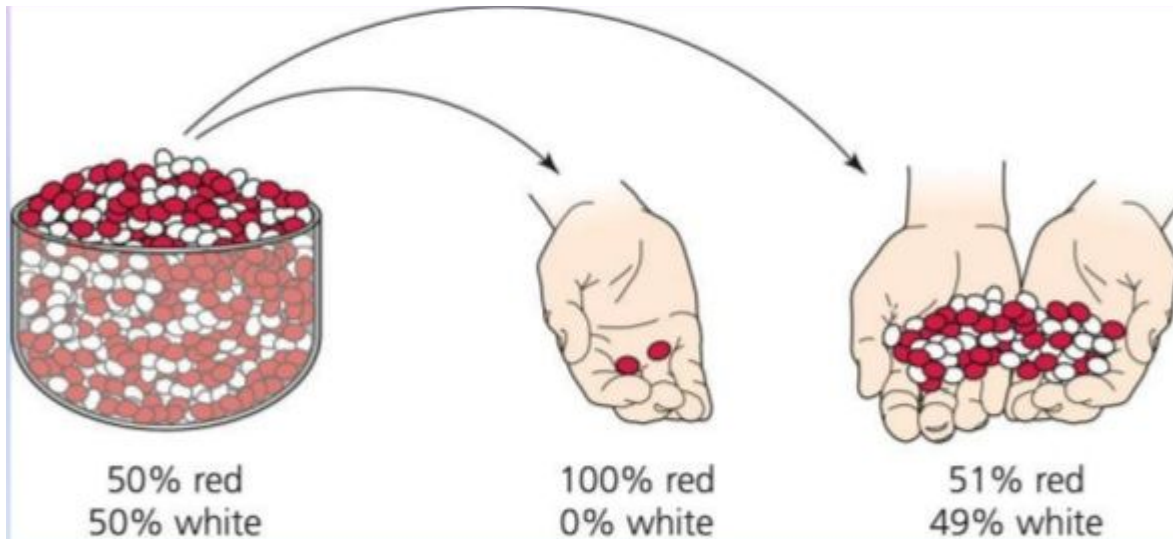
This is an example of **genetic drift**



Is yellow actually the most fit, compared to all other phenotypes?

Genetic drift: the influence of "luck"

- Genetic drift = evolution due to **random sampling**
 - Remember experimental design: Large sample sizes are "better" for approximating truth
 - Small sample sizes don't represent the "truth" - they usually do not capture all *the variation*



Genetic drift

- 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	<ul style="list-style-type: none">• Deleterious alleles can fix (selection is weak)• Population may not achieve maximum fitness
Large N	Natural selection	<ul style="list-style-type: none">• Advantageous alleles will likely fix• Population will generally achieve higher fitness

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

Selection theory



Most mutations are deleterious (decrease fitness)

A small proportion are advantageous (increase fitness)



Nature Reviews | **Genetics**

Under neutral theory, most evolution occurs via DRIFT!

Neutral theory



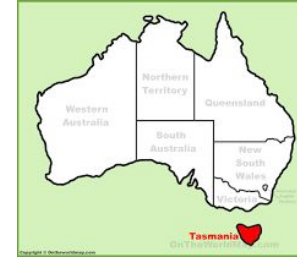
~Half mutations are deleterious (decrease fitness)

~Half mutations are neutral (no effect on fitness)

Very small proportion are advantageous (increase fitness)

Consequences of genetic drift: Tasmanian Devils

DFTD = Devil Facial Tumor Disease



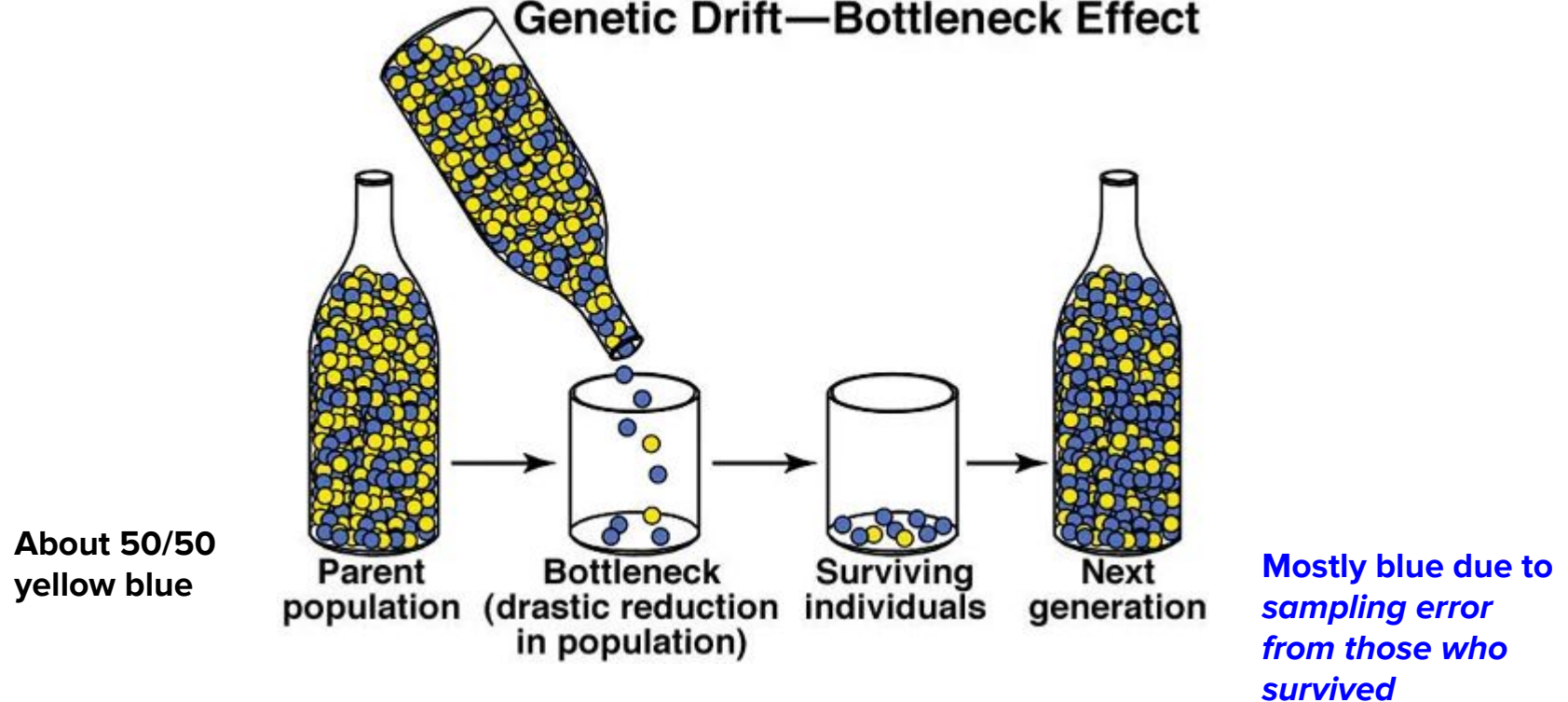
Species		Heterozygosity	Alleles/locus
Tasmanian devil	marsupial	0.39 – 0.47	2.7 – 3.3
Koala	marsupial	0.54 – 0.78	5.6 – 8.0
Western quoll	marsupial	0.79 – 0.88	8.8. – 9.2
Allied rock wallaby	marsupial	0.86	11.2
Grey wolf	placental	0.57 – 0.64	3.4 – 6.4
Pine martens	placental	0.62 – 0.68	6.2 – 6.6
Polar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



The Bottleneck Effect

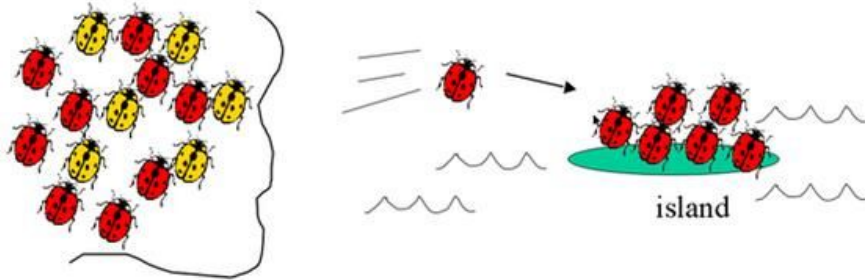
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Genetic Drift—Bottleneck Effect



The Founder Effect

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



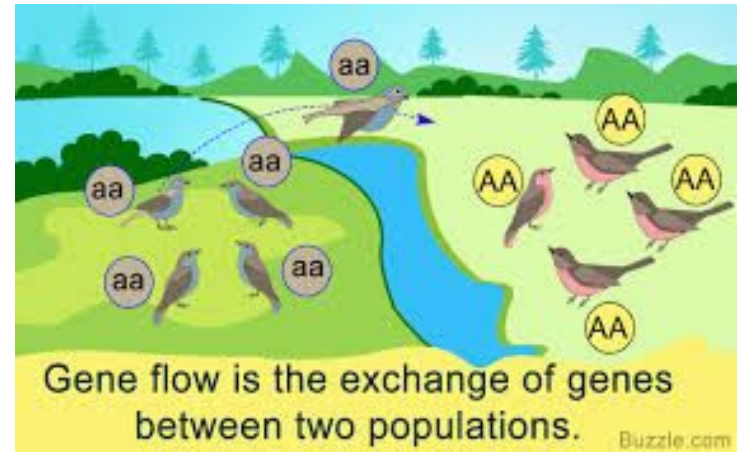
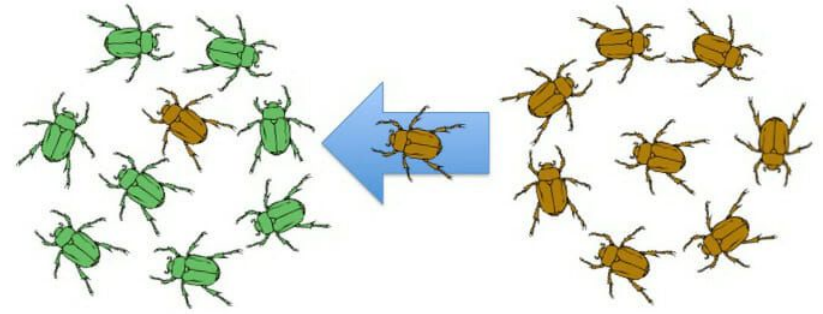
Island population is **fixed** for red, but this NOT because red is more fit than yellow!



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?
3. Imagine migration goes in both directions. What about variation then?



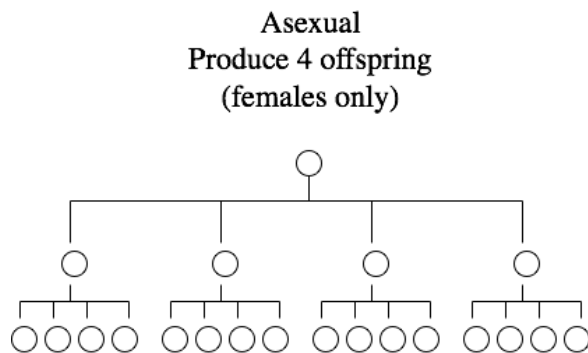
Recombination "shuffles genes" in sexual species

Sexual species take genetic material from a male and female parent

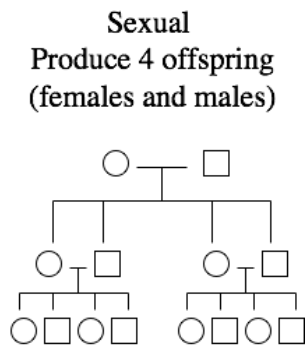
Asexual species are clones of the mother - there are no fathers

The two-fold cost of sex

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

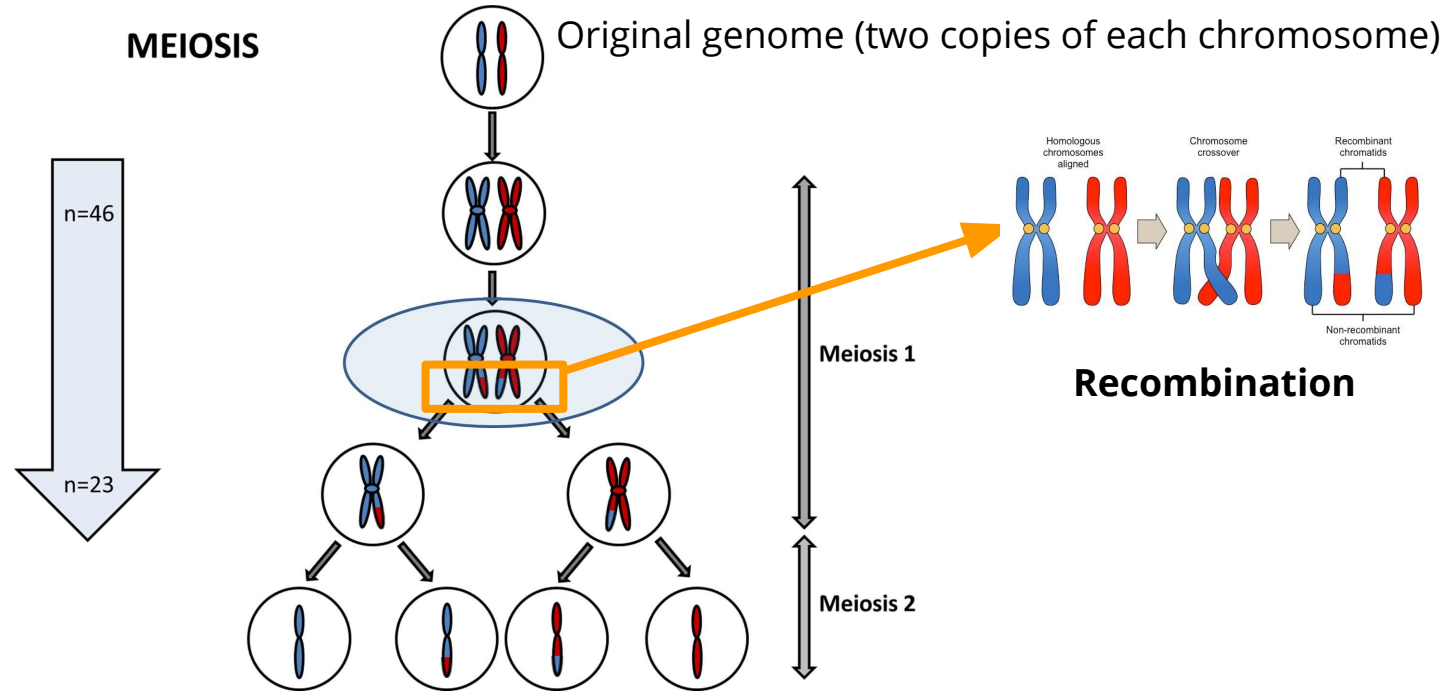


16 grand children: all productive



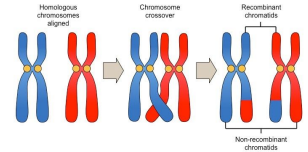
8 grandchildren:
Half productive

Meiosis is the process that makes gametes



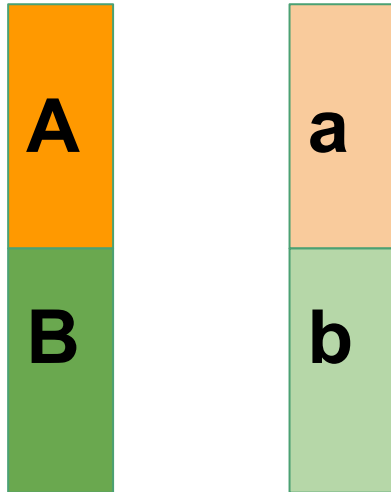
Four gametes (egg or sperm) that result from this process

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

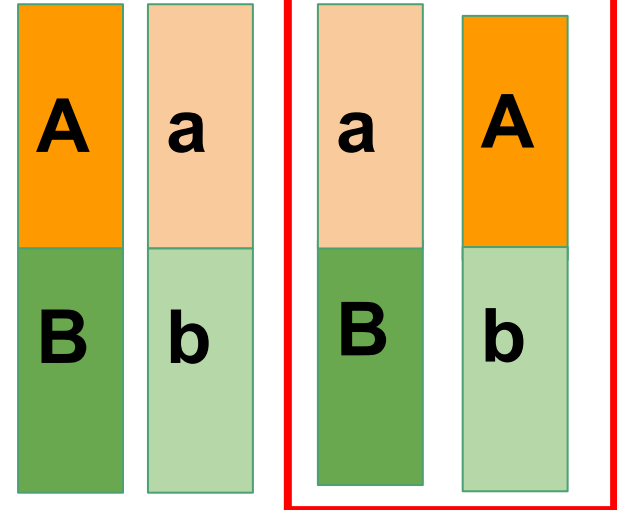
Parent's genome



Recombination



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

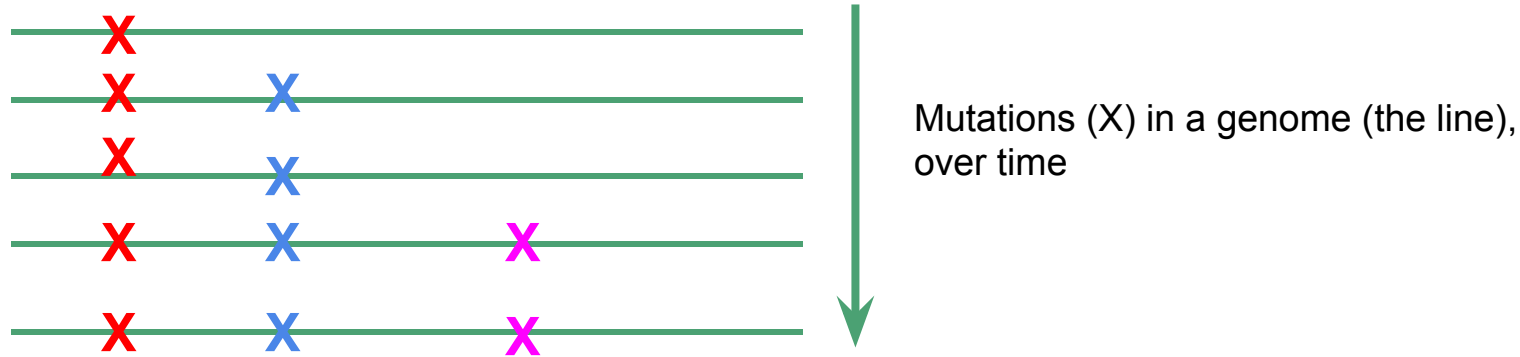
What are some potential consequences of recombination?

- 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**



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**

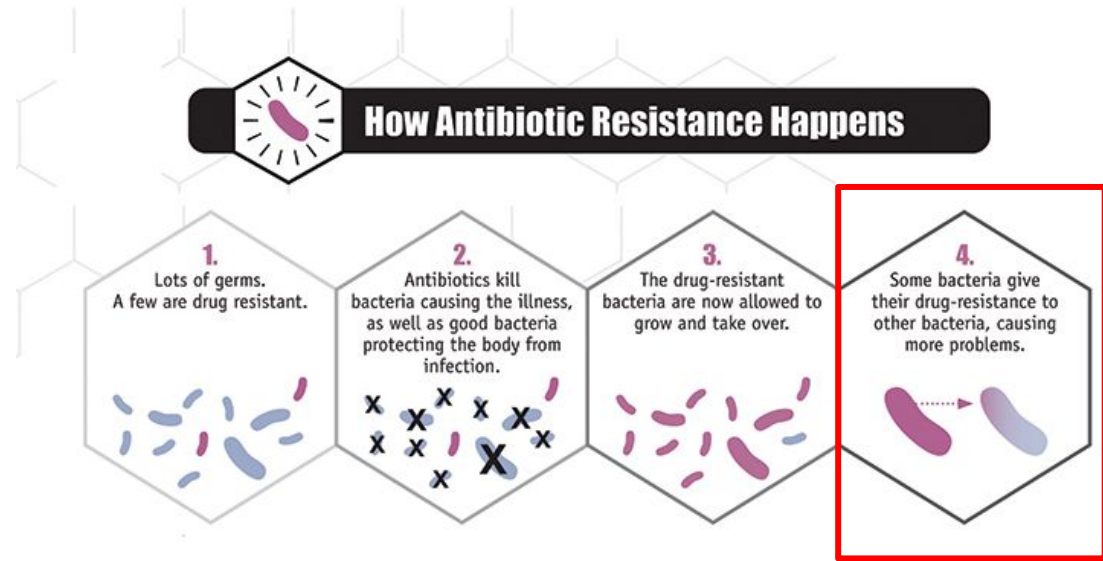
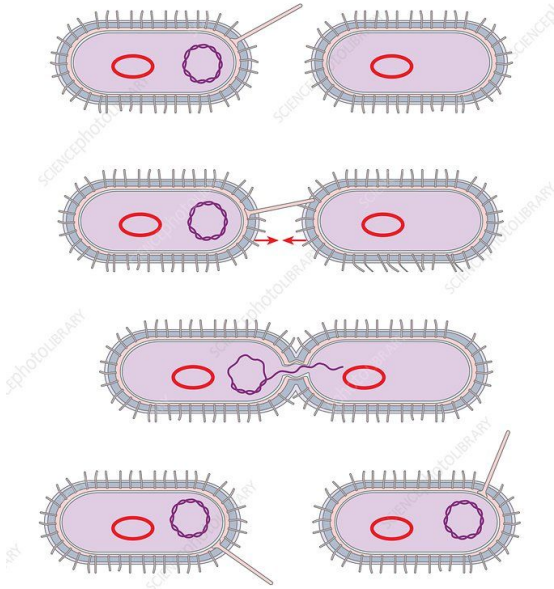


Massive Horizontal Gene Transfer in Bdelloid Rotifers

Eugene A. Gladyshev,² Matthew Meselson,^{1,2*} Irina R. Arkhipova^{2,2*}

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.

Horizontal gene transfer (HGT) in bacteria



Evolutionary forces' effects on population variation

Evolutionary force	Affect on <u>population</u> genetic variation
Directional selection (most common type of selection!)	Decreases
Balancing selection	Maintains (will never go to 0)
Mutation	Increases
Random genetic drift	Decreases
Migration	Increases (or, <i>homogenizes</i>)
Recombination	Increases (applies only to sexual species; asexual undergo HGT which increases variation too)