Studying the evolution of populations

Introduction to Evolution and Scientific Inquiry

Dr. Spielman, spielman@rowan.edu

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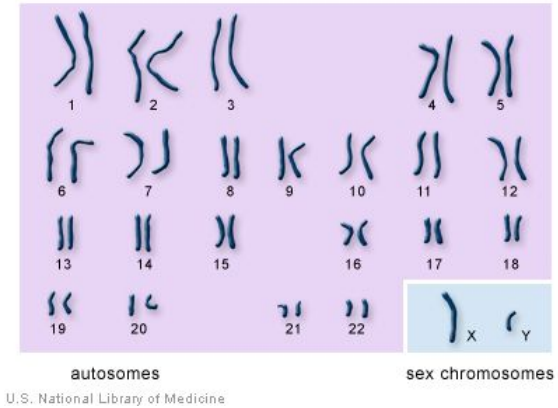
How do populations of organisms evolve?

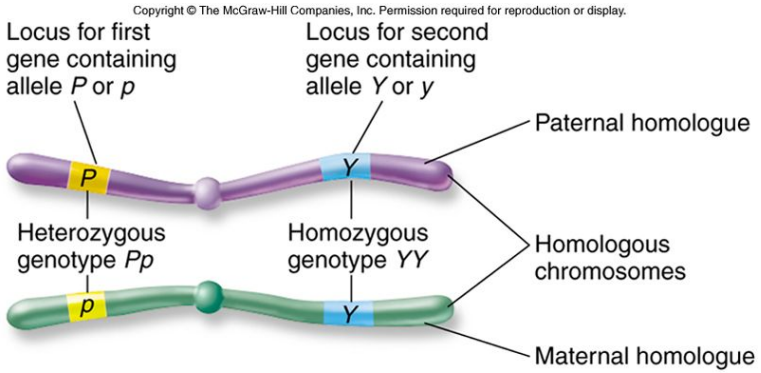
- A **population** is a group of organisms of the same species that live in a particular geographic area at the same time and interbreed
- **How can we study populations?**
  - *What are the allele frequencies in a population?*
    - If they change over generations, the population is evolving!
  - *What is the level of genetic variation in a population?*
    - More variation = "healthier" population (Think inbreeding)
  - *What is the fitness of individuals in the population? The average fitness of all individuals (aka fitness of the population)?*
  - *Is a population evolving?*
    - If so, what evolutionary forces are acting?
    - If natural selection is acting, what is the cause?
      - How strong is the selection? What traits/alleles are being selected and how?
    - If other forces are acting, how do forces *interact* with each other to change populations over time?

Recall alleles



U.S. National Library of Medicine

The human **diploid** karyotype



Homozygous: Same allele at both chromosomes (YY)

Heterozygous: Different allele at both chromosomes (Pp)

We refer to alleles as **p and q**

- For genotype Aa...
  - **p** = frequency/fraction/proportion of alleles in the POPULATION that are "A"
  - **q** = frequency/fraction/proportion of alleles in the POPULATION that are "a"

We refer to alleles as **p and q**

- For genotype Aa...
  - **p** = frequency/fraction/proportion of alleles in the POPULATION that are "A"
  - **q** = frequency/fraction/proportion of alleles in the POPULATION that are "a"
  - We will assume, for questions like this, that the gene ONLY HAS two alleles.

- Consider **five individuals**:
  - How many individuals?
  - How many **alleles?**
  - How many **alleles** are "A"? are "a"?
  - Now, as fraction out of total!
- **By definition, p+q = 1!**

Individual	**Genotype for this gene**
1	AA
2	Aa
3	aa
4	Aa
5	aa

Looking across time

Individuals in generation 1

Individual	**Genotype for this gene**
1	AA
2	Aa
3	aa
4	Aa
5	aa

Individuals in generation 2

Individual	**Genotype for this gene**
1	Aa
2	aa
3	AA
4	AA
5	Aa

Did the population evolve?

Individual 1 is NOT THE SAME INDIVIDUAL between generations!!!

Variation in populations

- **Heterozygosity**: The proportion (frequency/fraction/percentage) of individuals who are **heterozygous**

Individual	Genotype for this gene
1	AA
2	Aa
3	aa
4	Aa
5	aa

answer with your tables....

- **Did the population evolve?** (did p and q change?)
- **Did the heterozygosity change? If so, which generation has the most VARIATION?**

Individuals in generation 1

Individual	Genotype for this gene
1	AA
2	Aa
3	aa
4	Aa
5	aa

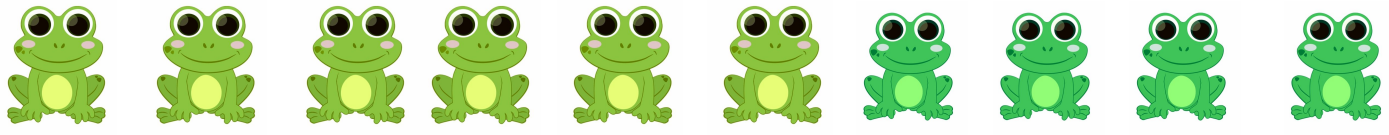
Individuals in generation 2

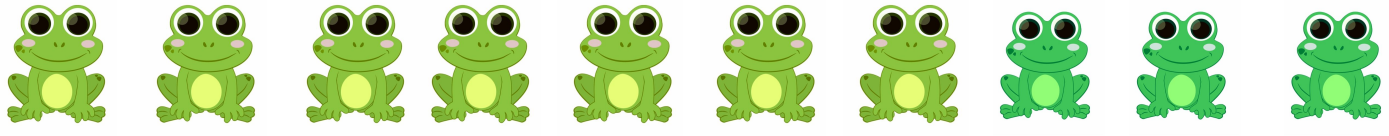
Individual	Genotype for this gene
1	Aa
2	aa
3	AA
4	AA
5	Aa

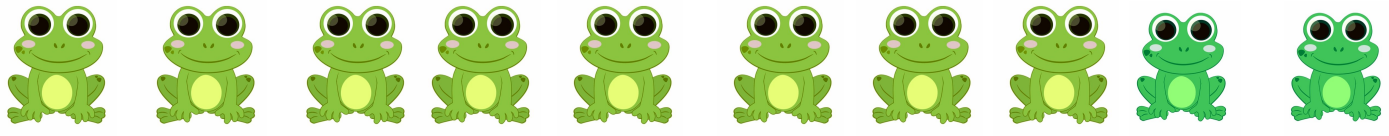
How affect does selection have on population variation/heterozygosity?

Population fitness?

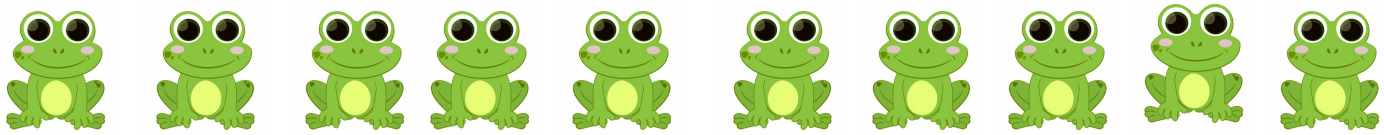
Generation 0  50% olive

Generation 1  60% olive

Generation 2  70% olive

Generation 3  80% olive

Generation 4  90% olive

Generation 5  100% olive

Quantifying population fitness

We measure fitness using a PROXY for survival or fecundity.

Scenario:

- There are 1,000 dragonflies in a population. Some dragonflies are blue and some are red. On average, birds eat 50% of blue dragonflies and 25% of red dragonflies.

    ➔ 50% of blue survive. 75% of red survive.

50% of blue survive. 75% of red survive.

Quantifying fitness and selection for phenotypes/genotypes

	Blue morph	**Red morph**	Notes
Absolute Fitness	**0.50**	**0.75**	*The actual measurements.* ***Must always CONVERT!***

Survival of these two phenotypes, *relative to each other*.
For every 10 surviving red dragonflies, we expect ~6.7 blue dragonflies will survive.

The strength of selection acting *against* the trait.
S = 0 → *relatively*, no selection against the trait (most fit phenotype)
S = 1 → complete selection against the trait (no survivors)

Quantifying fitness for the population

- In your population of 1000 dragonflies, 650 are red and 350 are blue. What is the fitness of the population?
  - *Average fitness across all individuals*

Imagine a population with 1 blue morph and 1 red morph. What is the mean fitness of the population?

(0.67 + 1.0 +) / 2 = 0.833

Imagine a population with 2 red morphs and 1 blue morph (so *N=3*). What is the mean fitness of the population?

(1.0 + 1.0 + 0.67) / 3 = 0.89

1.0 x 2/3 + 0.67 x 1/3 = **0.89**

Formula for mean population fitness

$$\bar{w} = \sum_{i}^{N} F_i w_i$$

i = each phenotype/genotype

N = total number of the given phenotype/genotype

F = frequency of phenotype/genotype in the population

w = fitness of phenotype/genotype

Fitness is closely linked to the environment

- Natural selection is the process by which organisms **adapt** to their environment

How would natural selection act on a brown bear in the forest?
A brown bear in the Arctic? A polar bear in the forest?

Climate change is inducing major environmental and therefore fitness shifts

- They evolved ~150,000 years ago from a brown bear ancestor
- Polar bears are *specialized* (highly adapted!) to their environment:
  - Hunt for seals with the "sit and wait" approach
  - They have not evolved to be efficient at walking long distances to hunt
- ...What now? **They are no longer well-adapted to environment**

Why is variation (heterozygosity) so important?

Species are usually endangered when variation is too low. It also helps us understand which evolutionary force(s) are acting.

Modes of natural selection. Consider AA, Aa, aa.

- **Directional selection**
  - Individuals at **one** trait **extreme** are favored
  - ONE of the homozygotes (AA or aa) is the most fit genotype

- **Balancing selection ("stabilizing selection")**
  - Individuals with an **intermediate** trait value are favored
  - Heterozygotes (Aa) are the most fit

What kind of selection was **EvoDots?**

(for the circumstances when NS occurred)

- **Disruptive selection**
  - Individuals at **both** extremes are favored, i.e. **selection against the mean**
  - BOTH homozygotes (AA and aa) are more fit than heterozygotes (Aa)

Thought experiment

Consider a population where a gene has two alleles, "A" and "a". At the "beginning", all is equal: ⅓ are AA ⅓ are Aa ⅓ are aa

What happens to the frequency of genotypes after many many many generations experiencing...

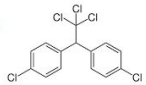
- **Directional selection?**
- **Balancing selection?**
- **Disruptive selection?**

Example: Directional selection

- DDT resistance in mosquitoes

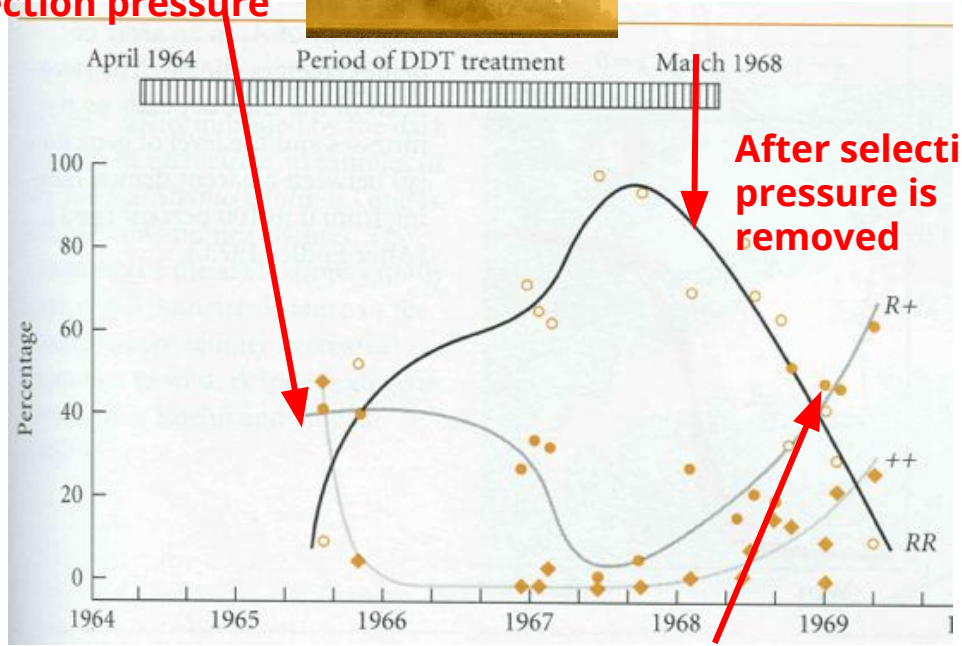
- RR = resistant genotype
  - mosquitoes survive DDT
- R+ and ++ = susceptible genotypes
  - DDT kills mosquitoes
- Which genotype is better for **mosquito fitness?**

DDT



Dichlorodiphenyl trichloroethane

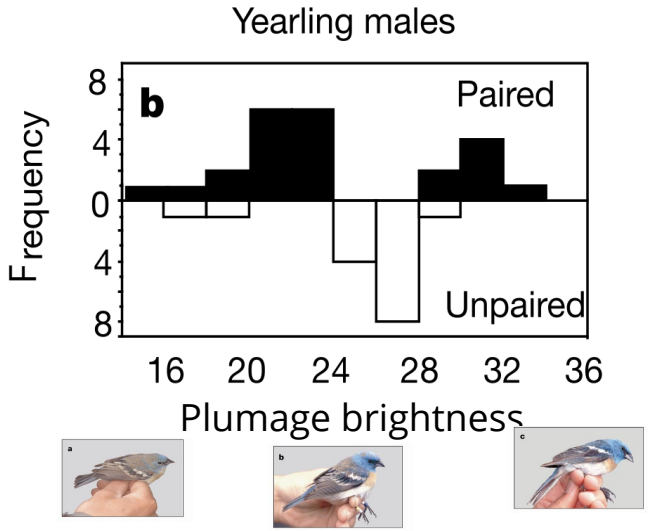
Before (early stages of) selection pressure

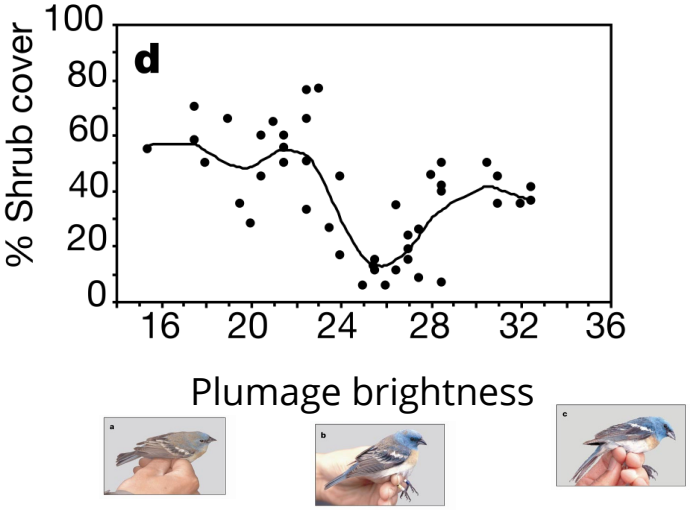


After selection pressure is removed

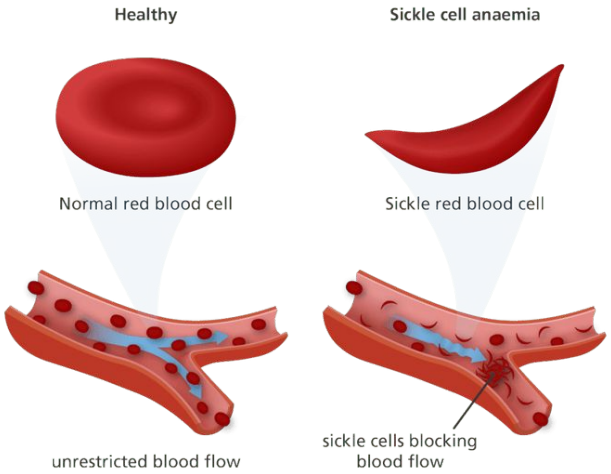
Why the change?

Example: Disruptive selection





Example: Balancing selection



- Sickle cell anemia is a recessive genetic disorder caused by **S** allele (**A** is the “wild type”)
  - SS = sickle cell
  - SA, AA = healthy (but what is SA?)
- SS is up to 20% in certain regions…?????