

Metapopulations and Population Genetics

BIOL/BOT 160 – Ecology

Delivered by Dr. Uricchio

Prepared by Drs. Shaffer & Uricchio

Office hour

- Wednesday 9/20 in DH 547/548, 9am-11am
- Email me today if you'd like to come but you can't make it, I *may* be able to meet in the afternoon depending on your schedule
- If not we can correspond by email
- Also available immediately after class today

Learning objectives

- Students should be able to
 - Calculate R_0 from life tables, explain the relevance of exponential growth and logistic growth models to population ecology, and calculate future population sizes in exponential models (review)
 - Predict extinction probabilities for metapopulations using a simple model, and explain the relevance of habitat suitability, migration, and population variation to dynamics of metapopulations
 - Analyze simple genetic data to make predictions about phenotype prevalence in populations using the concept of Hardy-Weinberg equilibrium

Review of growth models

$$\frac{dN}{dt} = rN$$

Exponential

$$\frac{dN}{dt} = rN \left(\frac{K - N}{K} \right)$$

Logistic

So far we have assumed

- Populations are closed (no immigration or emigration)
- Individuals are all the same within a population (no genetic variation)

Closed populations

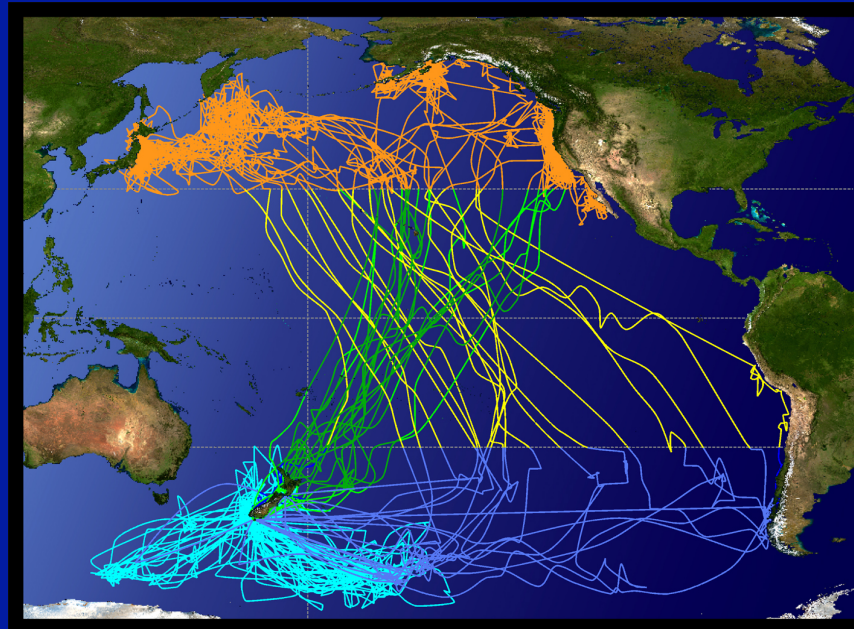
- Exponential & logistic models rely on changes in the per capita births and deaths
- Recall that $r = [B]irths - [D]eaths$, but we were ignoring immigration and emigration

$$dN = [B + I] - [D + E]$$

Populations are more dynamic

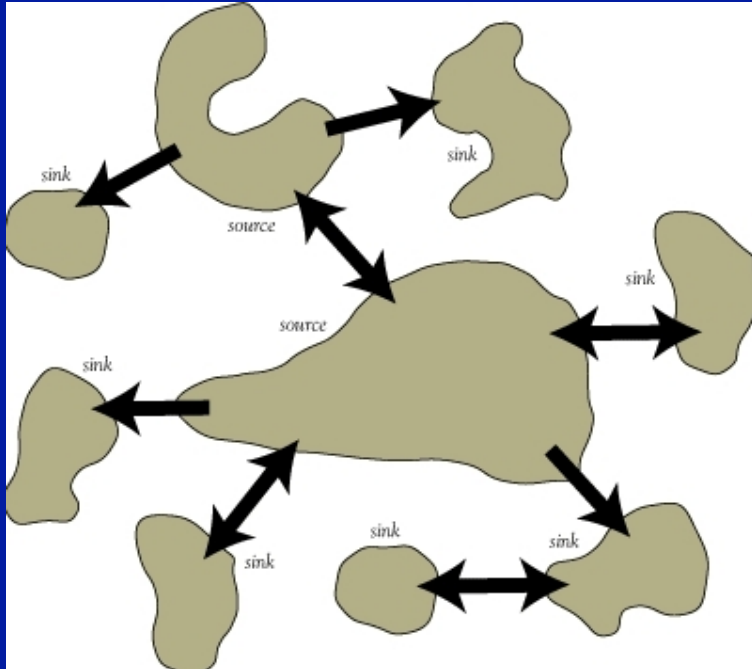
- Closed populations are convenient for modeling
- Not usually biologically relevant

Animal Migration



Metapopulations

- What is a metapopulation?
 - Population of populations
 - Based on multiple 'distinct' populations

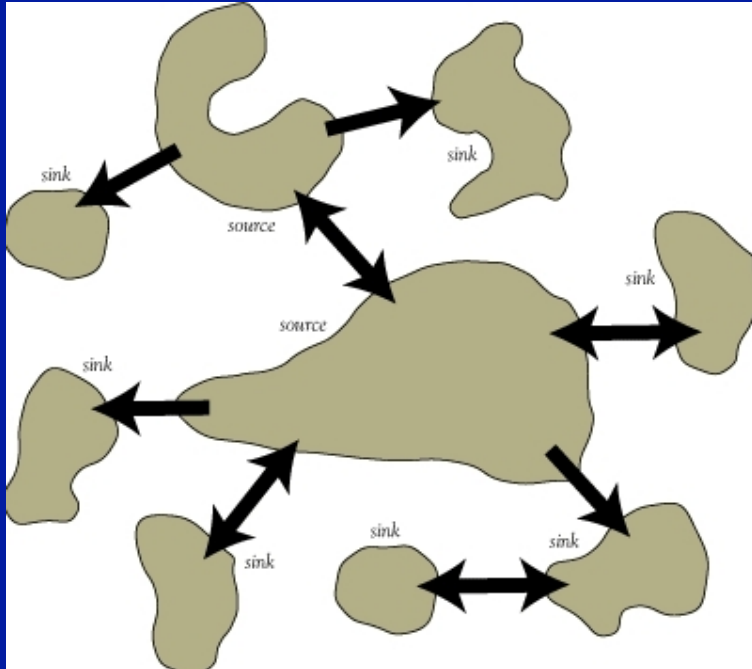


Populations separated by
fragmentation of habitat

Potential mixing between
populations

Metapopulations

- Dynamics of metapopulations
 - Depends on number of populations
 - Amount of occupied or unoccupied habitat



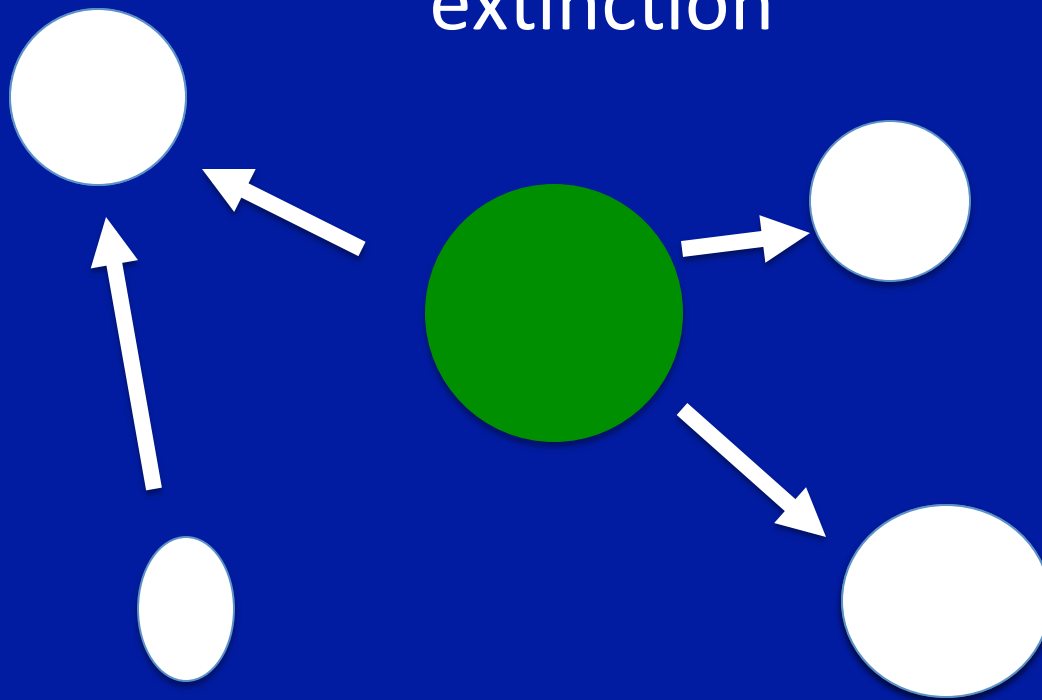
Distance between habitats

Size of habitats

Quality of habitats

Metapopulation Dynamics

Based local persistence and/or extinction



Local populations can go extinct then recolonize

Habitat suitability can change

Simple Model of Persistence

$$P_x = 1 - (p_e)^x$$

From Gotelli 2008

P_x = probability of population persistence

p_e = probability of extinction (0 to 1)

x = numbers of populations

Example 1

$p_e = 0.7$ and we have 1 populations

$P_1 = 1 - (0.7)^1 = 0.30$ low chance our population will persist to the following year

Simple Model of Persistence

$$P_x = 1 - (p_e)^x$$

From Gotelli 2008

Example 2

$p_e = 0.7$ and we have 10 populations

$P_{10} = 1 - (0.7)^{10} = 0.97$ high chance that at least one of our populations will persist

What does this mean:

The more populations we have, the lower the risk of regional extinction

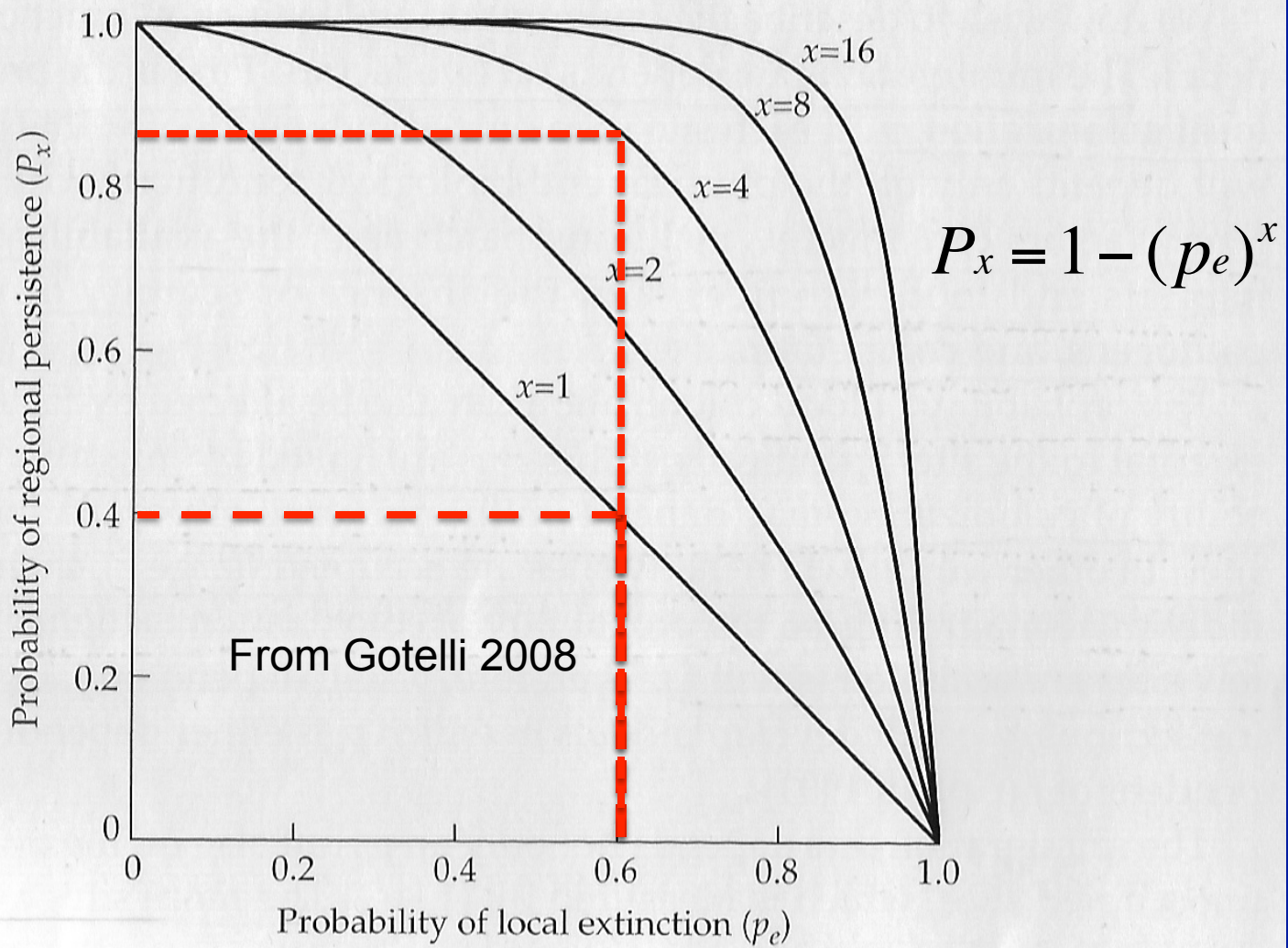
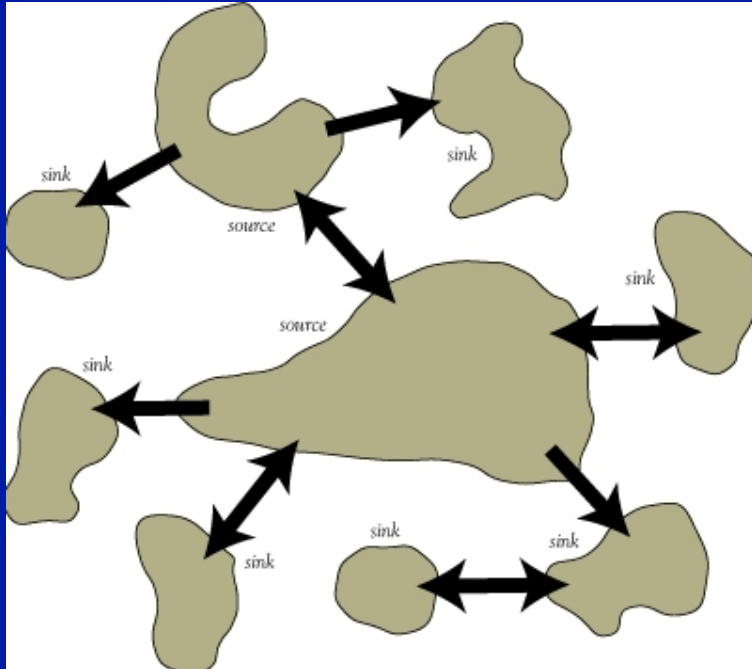


Figure 4.1 The relationship between the probability of regional persistence (P_x), the probability of local extinction (p_e), and the number of populations (x). Note that as the number of populations is increased, the probability of regional persistence is substantially higher, for a given probability of local extinction.

Sources and sinks

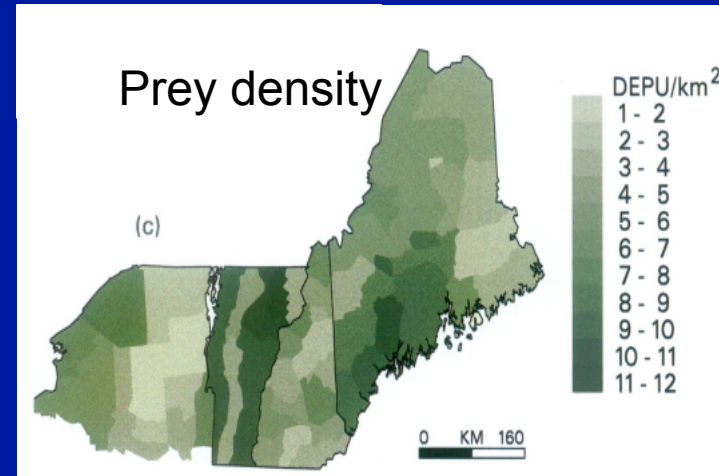
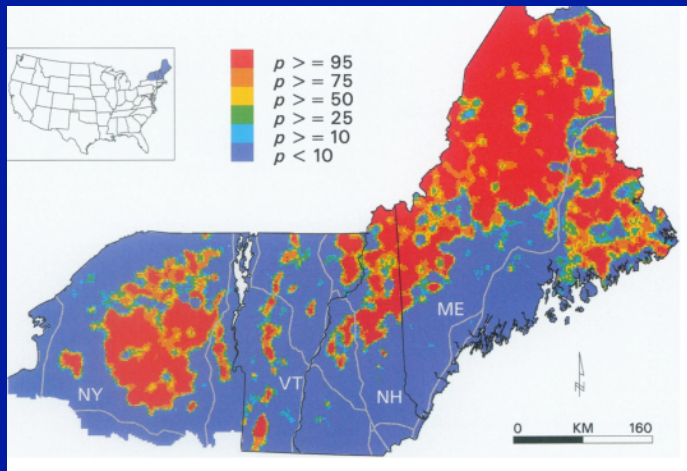
- Source population(s)
 - Typically large, robust habitat
 - Source dynamics are often density-dependent



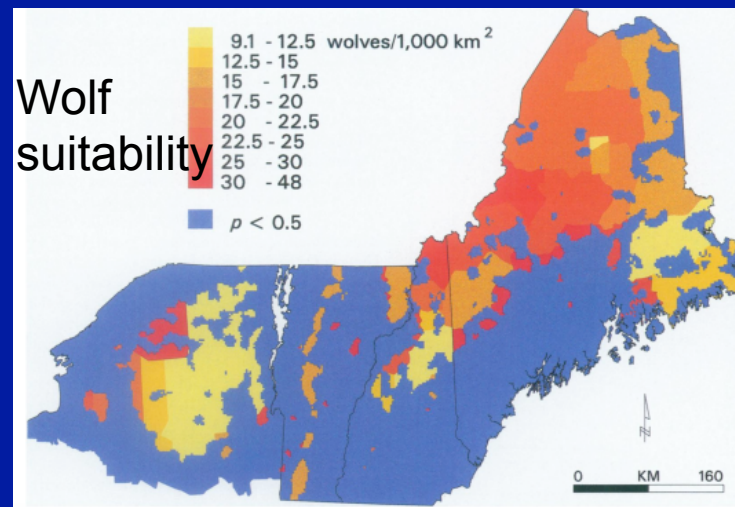
- Sink population(s)
 - Variable size
 - Population growth poor
 - Declining unless fed

Example – hypothetical wolf reintroduction in Northeast

Habitat suitability



- Different areas may support distinct wolf populations
- Large, well connected habitats may support large source population
- Could overflow to less suitable areas



Mladenoff & Sickley 1998

Genetic variation within populations

- *Mutations* arise randomly within populations and can cause variation in *phenotypes*
- Contributes to maintaining *heterozygosity* (genetic differences)

Why is this important to maintain?

- Mutations can drive EVOLUTION, defined as *'Change in gene frequency in a population over time'*

Types of Variation

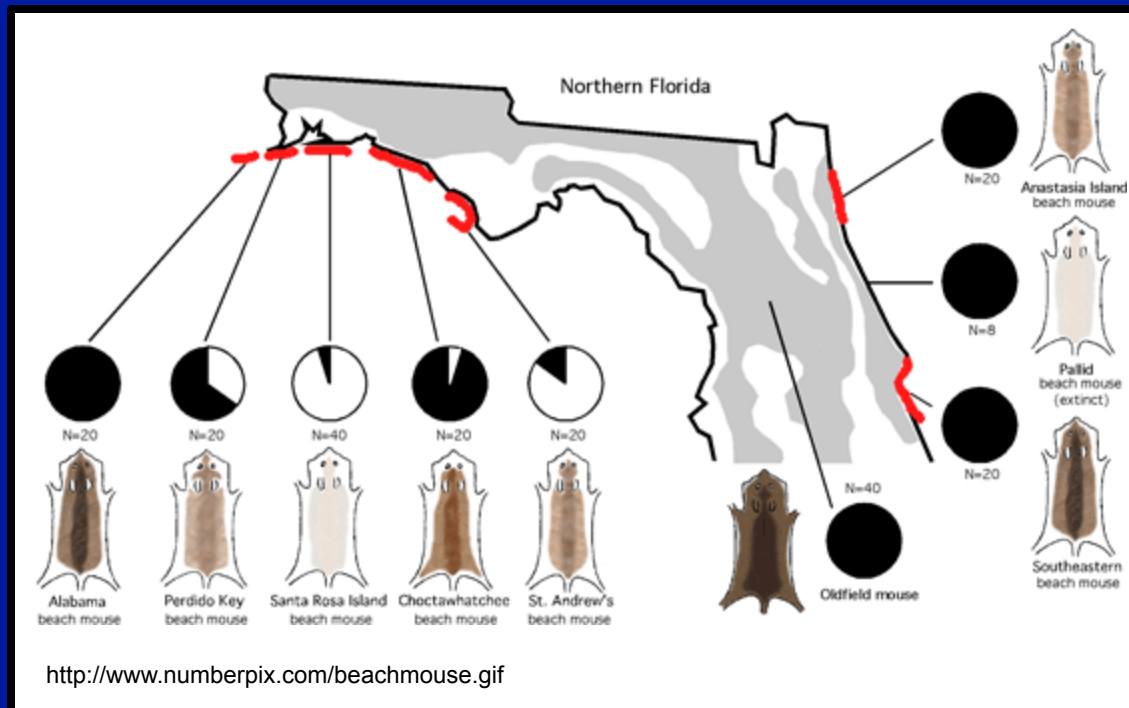
- Discrete



E.g. Variation in color

Types of Variation

- Continuous



E.g. Variation in height



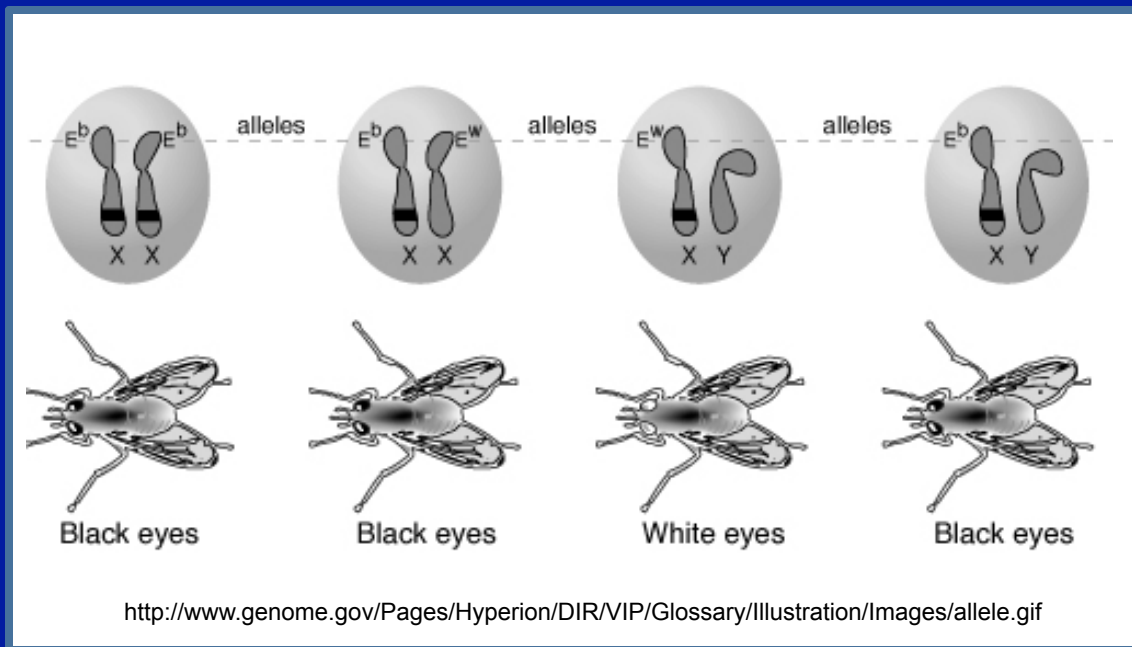
E.g. Variation in color

Genotype vs Phenotype

- Genotype – hereditary information (i.e. alleles and gene sequences)
- Phenotype – expression of the hereditary information

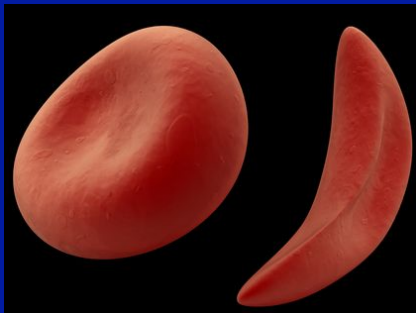
Genotype

Phenotype



Source of variation

- Mutation – inheritable change in genotype
 - SNPs (Single Nucleotide Polymorphism)



HBB Sequence in Normal Adult Hemoglobin (Hb A):

Nucleotide	CTG	ACT	CCT	GAG	GAG	AAG	TCT
Amino Acid	Leu	Thr	Pro	Glu	Glu	Lys	Ser
	3			6			9

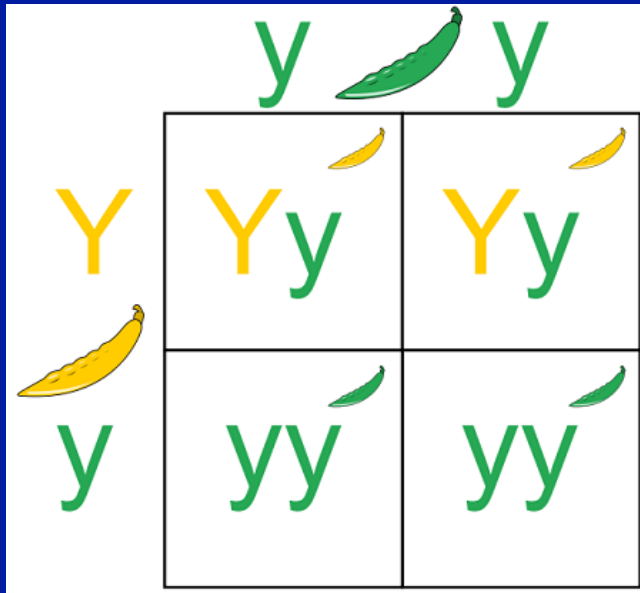
HBB Sequence in Mutant Adult Hemoglobin (Hb S):

Nucleotide	CTG	ACT	CCT	GTG	GAG	AAG	TCT
Amino Acid	Leu	Thr	Pro	Val	Glu	Lys	Ser
	3			6			9

http://edtech.suhsd.k12.ca.us/inprogress/cvh/hhuckaby/bioweb/sicklecellgeneprofile_files/image004.gif








How to model population variation?

Punnett square (known parent genotypes)

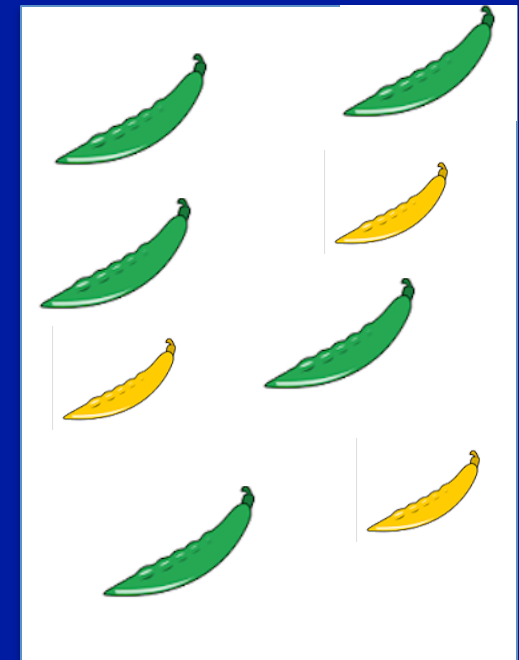


How to model population variation?

Punnett square (known parent genotypes)

	y  y	
Y 	Yy 	Yy 
y 	yy 	yy 

Suppose instead we pick a random parent from the population



Hardy-Weinberg equilibrium principles will tell us how to model the rate of occurrence of genotypes and phenotypes in the population

Predicting phenotypes & genotypes in populations: Hardy Weinberg Equilibrium



<http://plainview.files.wordpress.com/2009/02/coin-flip.jpg>

$$\text{Probability of A \& B} = P_A * P_B$$

Hardy Weinberg Equilibrium

2nd Coin



1st Coin



HH	HT
TH	TT

Hardy Weinberg Equilibrium

$P_H * P_H = 0.5 * 0.5$	0.25
$P_H * P_T + P_T * P_H = 0.5 * 0.5 + 0.5 * 0.5$	0.50
$P_T * P_T = 0.5 * 0.5$	0.25

1st Coin



Probability of heads $P_H = 0.5$
Probability of tails $P_T = 0.5$
2nd Coin



HH	HT
TH	TT

Hardy Weinberg Equilibrium

LET Probability of heads $P_H = p$
Probability of tails $P_T = q$



$p * p$	p^2
$2 * p * q$	$2pq$
$q * q$	q^2

Hardy Weinberg Equilibrium

LET Probability of heads $P_H = p$
Probability of tails $P_T = q$



$$p * p$$

$$p^2$$

Notice that p and q do not have to be equal!

$$q * q$$

$$q^2$$

Hardy Weinberg Equilibrium

LET Probability of heads $P_H = p$

Probability of tails $P_T = q$



$p * p$

p^2

$$p^2 + 2pq + q^2 = p^2 + 2p(1-p) + (1-p)^2 = 1$$



$q * q$

q^2



Main assumptions of HWE

- No new mutations
- Random mating
- No linkage
- No natural selection

Note: Hardy-Weinberg Equilibrium represents what happens by chance alone!

Can be used to determine if something other than chance occurred

Hardy Weinberg application

- Suppose you are looking at one loci with two alleles (Blue and Brown eyes) in a population.
- Let p = brown eyes = 0.8
- q = blue eyes = 0.2 remember $1-p = q$
- What would be the expected probability of getting a heterozygote?

$$2pq = 2 * 0.8 * 0.2 = 0.32$$




Hardy Weinberg

- If the population size was 1000, how many should be heterozygotes if only chance was operating?

$$0.32 * 1000 = 320$$

Hardy Weinberg



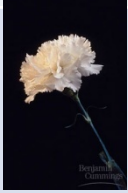
- Let's assume that p and q express incomplete dominance and that p = red and q = white
- Given the following data, solve for p (number of red alleles divided by total number of alleles) .

	Frequency	P alleles per flower	# of p alleles
	25	2	50
	200	1	200
	75	0	0

Hardy Weinberg

- Given the following data

Remember that there are 2 alleles per flower

	Frequency of flowers	P alleles per flower
	25	2
	200	1
	75	0
$2 * 300 = 600$		

$$\begin{array}{r}
 250 \\
 \hline
 600
 \end{array}$$




Hardy Weinberg

- Given the following data, solve for p.

$$p = \frac{250}{600} = 0.417$$

Hardy Weinberg

- Is this population at HWE?

	Frequency of flowers	P alleles per flower	# of p alleles	Expected flower frequency
	25	2	50	$=300 \cdot p^2$ $=300(0.417)^2$ $=52.1$
	200	1	200	$=300 \cdot 2pq$ $=300(0.417)(0.583)$ $=145.9$
	75	0	0	$=300 \cdot q^2$ $=300 \cdot (0.583)^2$ $=102$

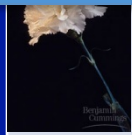
This population is not exactly in HWE

Think-pair-share

	Frequency of flowers	P alleles per flower	# of p alleles	Expected flower frequency
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Suppose we observe a population out of Hardy-Weinberg Equilibrium

- What hypotheses might we have to explain this difference between our expectations and our observations?
- Are any of these hypotheses relevant to predicting population sizes or population persistence ?



75

0

0

$$=300*(0.417)^2$$

$$=102$$

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