One minute responses

- Practice problems are up on the web site!
- Q: What do you mean by "neutrality"?
- A: Something is neutral if selection does not affect it either positively or negatively

One minute responses

- Q: How does Neanderthal admixture affect affect the HKA test?
- Gene 1 common ancestor inside humans (300,000 years) so)
- Gene 2 common ancestor in the Neanderthal/human ancestral population (600,000 years)
  - Which gene will have more polymorphism?
  - Does this necessarily indicate selection?
- Bad case of the "ancestral polymorphism" problem

HKA practice problem

- Wang et al (2010) looked at domesticated rice versus a wild relative
- They used four pseudogenes as neutral controls, and studied small RNA sequences proposed to be involved in controlling other genes
- Four RNA genes showed a significant excess of divergence (relative to polymorphism) in domestic rice versus the wild relative
- What is the interpretation?
- Why couldn't we use ω for this project?

Population subdivision and migration

- Effects of population isolation
- Adding migration
- Migration and drft
- Migration and selection
- Clines

Isolated populations

- Populations with no possibility of interbreeding are independent gene pools
- Each one has its own population size
- Each one moves independently when driven by drift
- We have already seen this with PopG

Isolated populations

- Suppose a population of size 10,000 is suddenly split in half by a barrier
- It is now two populations of size 5000
- Over a long period of time:
  - Neutral polymorphism will decline to the level expected for a population of size 5000 in each subpopulation
  - Some alleles will fix by drift in each subpopulation
  - Because they are independent, different alleles may fix
- Isolated populations will tend to diverge even without selection

A counter-intuitive result

- Suppose we had a population and wanted to ensure that as much as possible of its neutral genetic variation was preserved
- We could keep it as 1 big population
- Or we could split it into many small ones
- The math says we would keep more alleles by splitting!

A counter-intuitive result

- The big population will eventually fix one allele or the other
- Each tiny population will eventually fix one allele or the other
- With many populations, we have more chances to keep both alleles

A counter-intuitive result

- This is the opposite of what conservation biologists do
- Multiple reasons:
  - Drift in a big population is slow; faster processes are a bigger problem
  - If a small population goes extinct its alleles are lost
  - Fixation of bad alleles by drift
  - Loss of overdominant alleles by drift
  - Low diversity makes populations vulnerable to disease

Effects of isolation

Isolation:

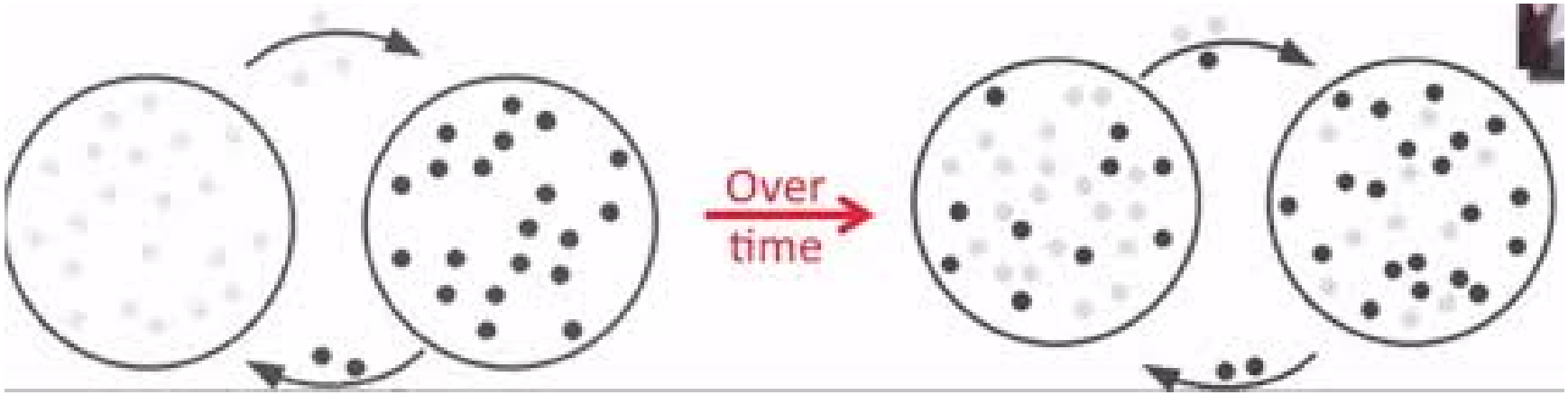
- Increases the divergence **between** populations
- Reduces the diversity **within** populations
- Isolation may be critical for the formation of new species
- Speciation without isolation is a hotly debated topic

Migration

- In population genetics, NOT birds flying south for the winter
- Migration (gene flow) is movement of genes from one gene pool (population) to another
- Could be gametes, young, or adults moving
- Salmon born in Lake Washington who spawn in the Columbia represent migration

Migration

- Migration OUT OF a population (emigration) won't change allele frequencies
- Migration INTO a population (immigration) can, if the populations initially different
- If the origin of the migrants had different allele frequencies, the frequencies in the destination population will change



Idealized migration model

- Parent population produces a gamete pool
- Migration contributes gametes to the pool
- Next generation is formed at random from the pool
- The offspring will be in H-W for their allele frequencies, though not necessarily for the population's previous allele frequencies

Idealized migration model

Frequencies	AA	Aa	aa	p(A)	p(a)
Source population	0.01	0.18	0.81	0.1	0.9
Destination population	0.64	0.32	0.04	0.8	0.2

These populations are both in H-W equilibrium.

Suppose that 15% of the next generation in the destination population comes from gametes contributed by the source population.

What will the new allele frequencies in the destination population be?

Idealized migration model

$p(A) = 0.85 * 0.8 + 0.15 * 0.1 = 0.695$
$p(a) = 1 - p(A) = 0.305$
Since we assume migration happened at the gamete stage, this is the composition of the new gamete pool, and we are still in H-W but with new allele frequencies.

Idealized migration model

$p(A) = 0.85 * 0.8 + 0.15 * 0.1 = 0.695$
$p(a) = 1 - p(A) = 0.305$

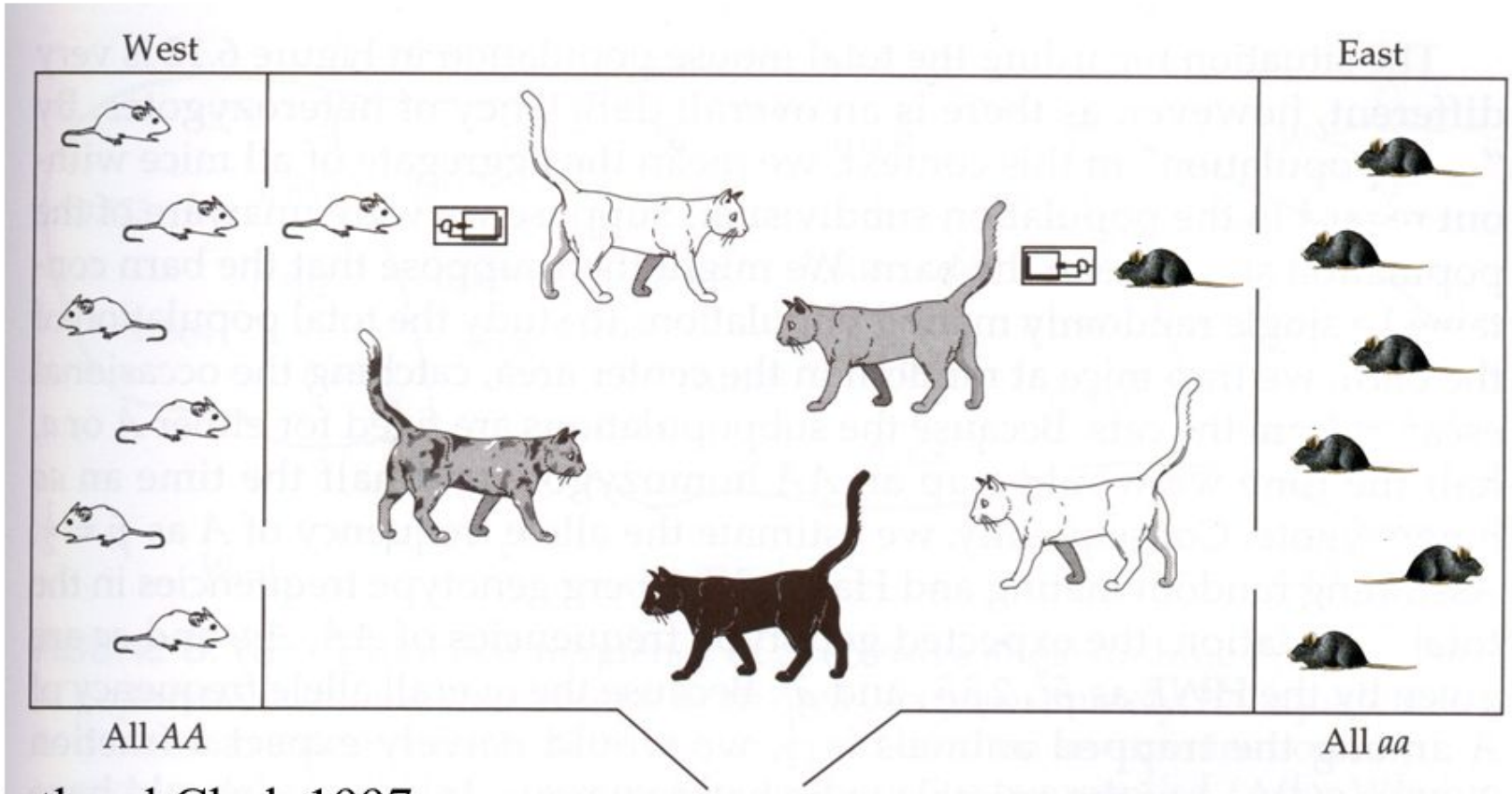
Frequencies	AA	Aa	aa
Pre-migration	0.64	0.32	0.04
Post-migration	0.483	0.424	0.093

Because the two populations have very different allele frequencies and migration was high, there has been a large frequency change in one generation.

Not so ideal migration

- Migration could also happen to adults
- If we sample a mix of native adults and immigrants, we will NOT observe H-W proportions if the two populations have different allele frequencies
- The proportion of homozygotes will always be unexpectedly high: "Wahlund Effect"
- If migration stops, 1 generation of random mating will restore H-W
- A population experiencing continual migration may never be in H-W

Wahlund Effect

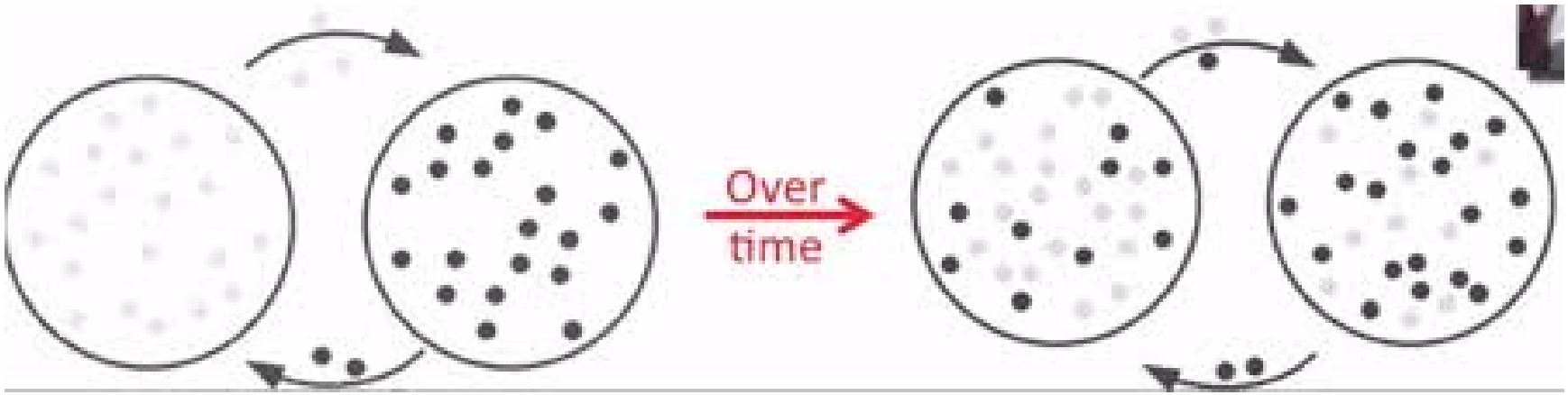


Hartl and Clark 1997

Trapped mice will always be homozygous even though $H_E = 0.5$

Migration is a homogenizing force

- Migration makes allele frequencies move to the weighted average of the two populations
- The higher the migration rate, the quicker this will happen



Migration rate

- Migration rate m: chance that any given gene copy is a new immigrant this generation
- $m = 0.15$ means 15% of genes are new immigrants
- Only immigration matters
- Individuals randomly leaving are just like individuals randomly dying–no change in allele frequencies

Migration versus drift

PopG demonstrations:

$N_e = 100$
$m = 0.001$
The important figure is the product $N_e m = 0.1$.

A different case:

$N_e = 100$
$m = 0.1$
$N_e m = 10$

Migration versus drift

- When $N_e m$ is very small, populations drift nearly independently
- When it is very big, they drift as one large population
- The breakpoint is approximately $2N_e m = 1$ (in a diploid)

Migration blocks fixation

- Even weak migration stops permanent fixation
- Populations can lose one allele but it eventually comes back
- Only when all populations lose the allele is it really gone

Migration versus drift

- $2N_em$ is the number of migrant gametes per generation
- Two populations are effectively united if there is more than one migrant gamete per generation!
- This is much less migration than I expected
- (Why is migration more effective in a big population? Because drift, which drives populations apart, is weaker)

Discussion question: Migration versus drift

- Current human $2N_em$ is MUCH larger than 1
- Why do humans show population subdivision?

Migration versus drift

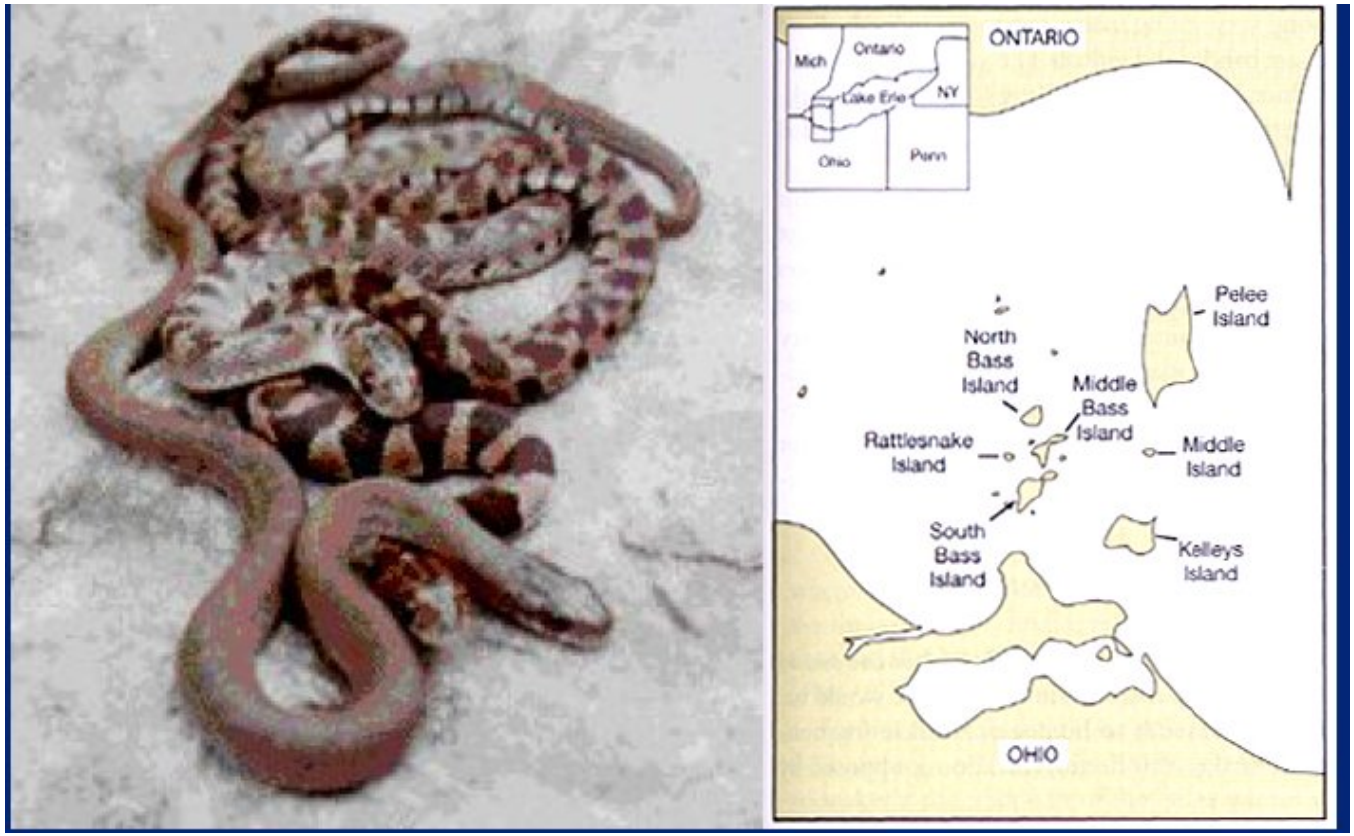
- Some ideas:
  - Population sizes were much lower in the past so drift was stronger
  - Migration was much lower in the past, and there has not been enough time to homogenize
  - Natural selection is driving populations in different directions (i.e. DuffyO in malaria country versus elsewhere)
  - Different populations interbred with other hominids (Neanderthals, Denisovans, others?)

- Relative importance of these factors is hotly debated

Migration versus selection

- Same selection in both populations:
  - Migration doesn't affect average outcome
  - Strong migration couples the populations together (and reduces drift)
- Different selection in the two populations:
  - Migration interferes with selection
  - Migration lowers population mean fitness

Migration versus selection



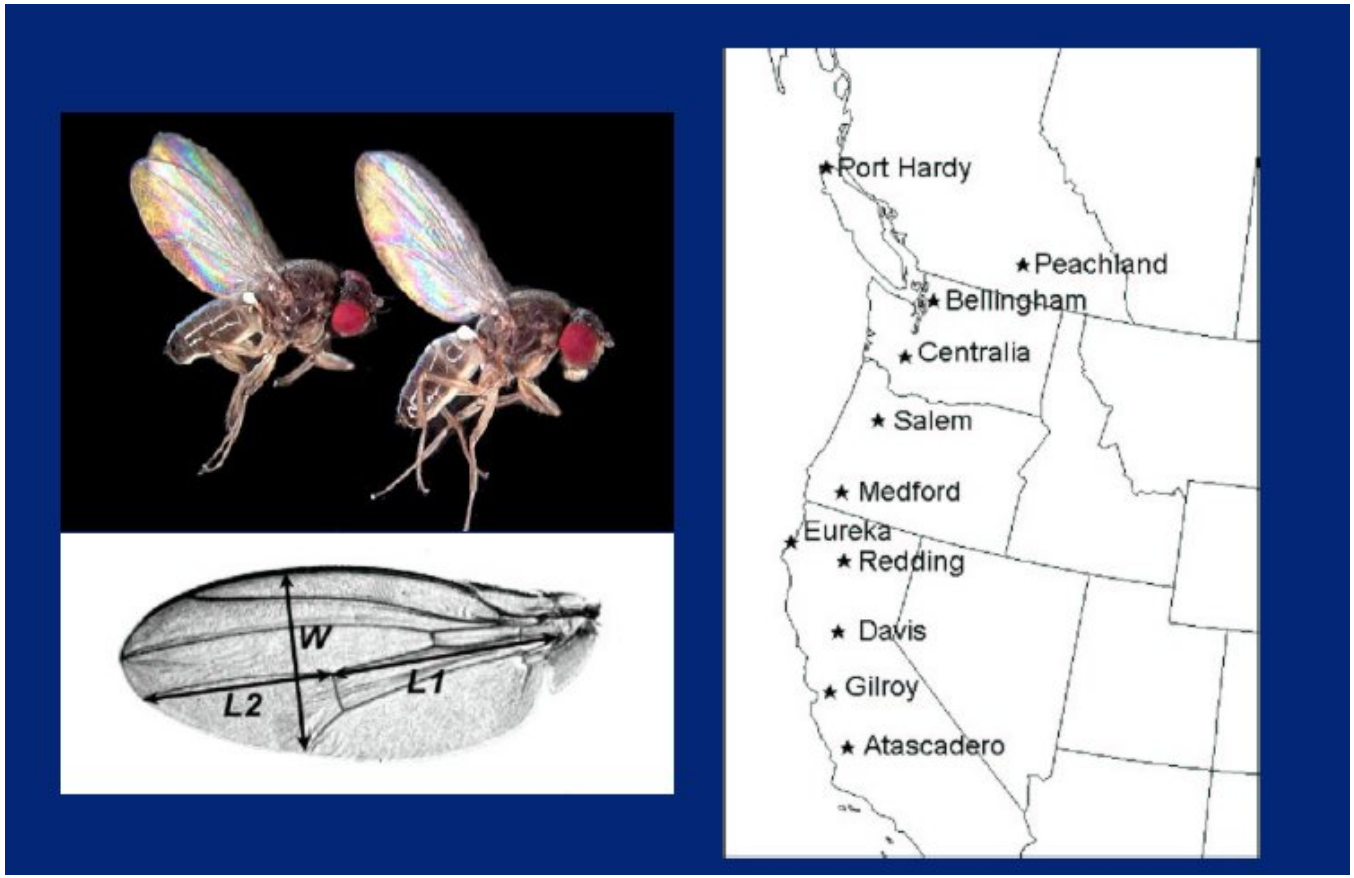
Migration versus selection

- Banded snakes are cryptic (hidden) on the mainland
- Bare limestone on islands favors non-banded snakes
- Non-banded cannot fix on islands due to gene flow
- Gene flow reduces population fitness

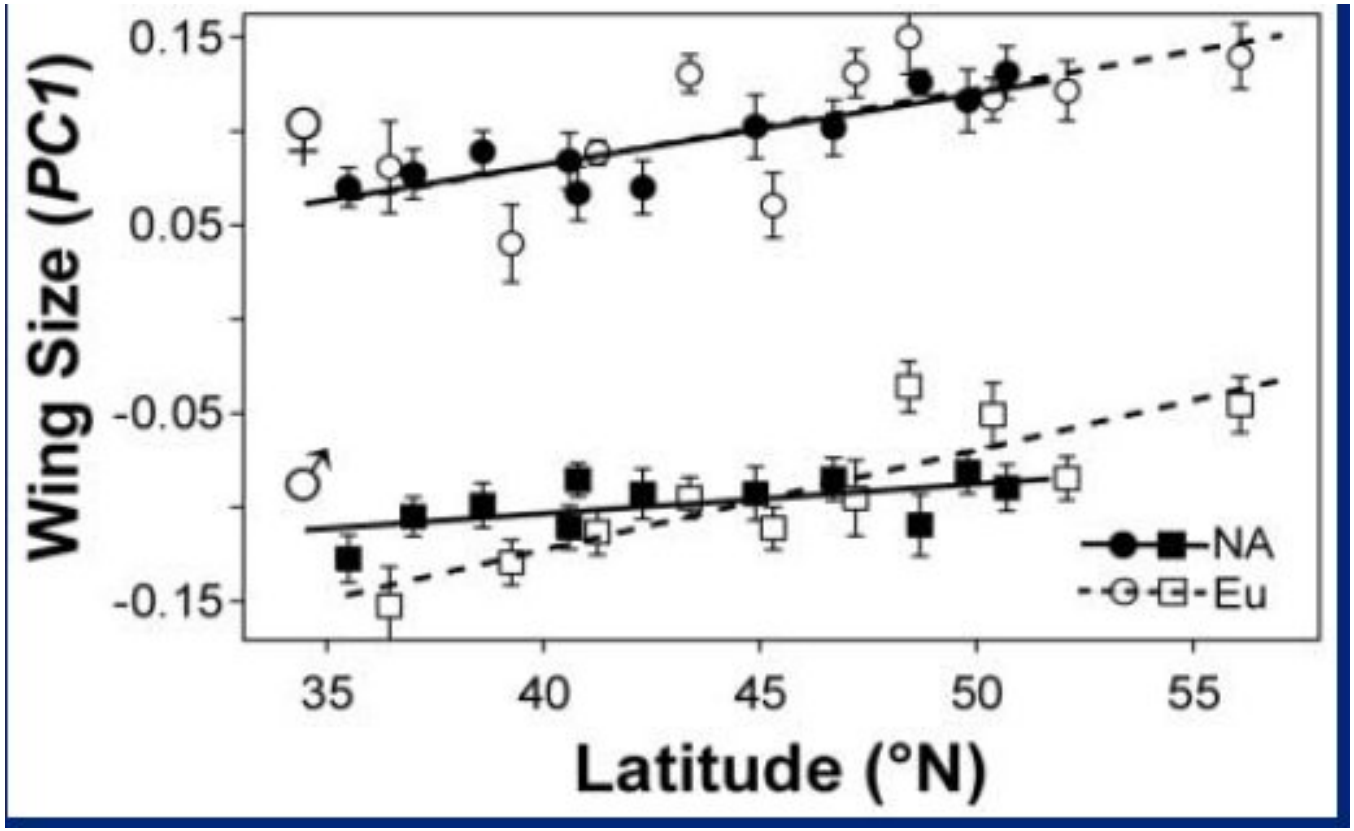
Clines

- A cline is a gradual change in allele frequencies with distance
- It can reflect either drift or (more usually) selection
- Stronger migration means wider cline
- Stronger selection means narrower cline
- If selection changes slowly, cline will be wider

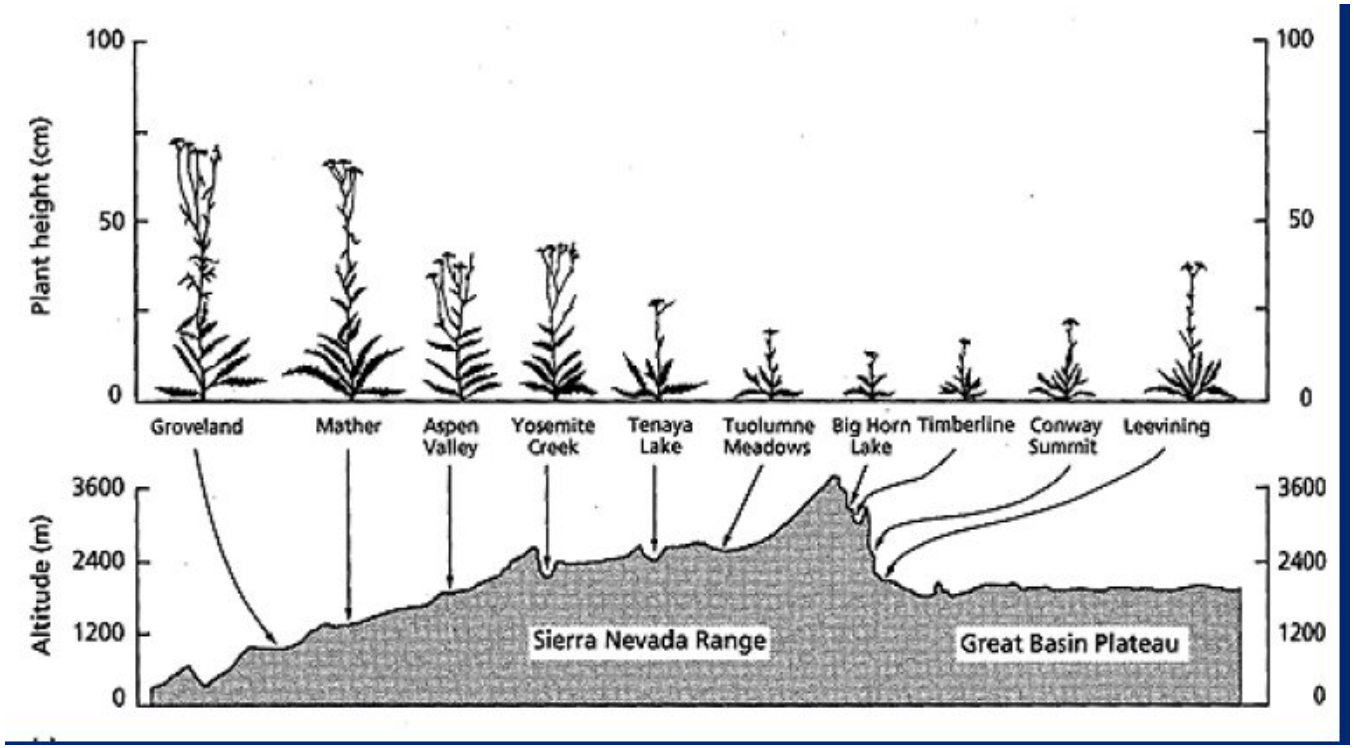
Drosophila subobscura



Drosophila subobscura cline



A common garden experiment



Short-range cline around a zinc mine

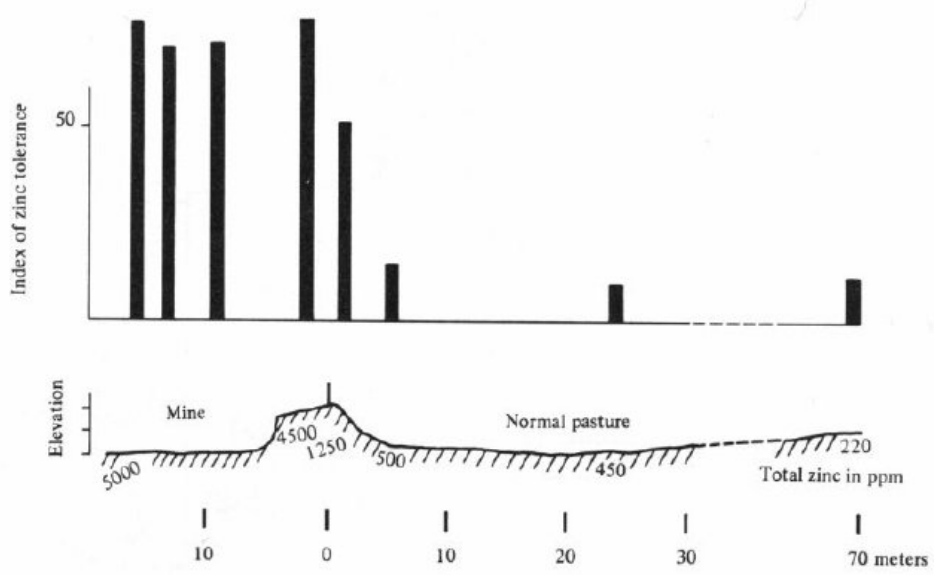


FIGURE 0.5. *The evolution of zinc resistance in grasses over a very fine spatial scale. The top graph illustrates the degree of zinc tolerance exhibited by plants collected from several places along a transect of approximately* 100 *meters in length. The lower graph illustrates the amount of zinc in the soil along the transect. Note the abrupt drop in zinc concentration at the boundary between the mine and the pasture.* [From S. K. Jain and A. D. Bradshaw (1966), Evolutionary divergence among adjacent plant populations I, *Heredity* **21**: 407–441.]

Clines and speciation

- The zinc cline is potentially costly
- Mating with nearby non-resistant plants can be disastrous
- How can the plants avoid this?
  - Self-fertilization
  - Mating with nearby plants (less mobile seeds/pollen?)
  - Asexual reproduction (runners)
  - Mating only with one's own kind
- This could be a first step to speciation

One-minute responses

- Tear off a half-sheet of paper
- Write one line about the lecture:
  - Was anything unclear?
  - Did anything work particularly well?
  - What could be better?
- Leave at the back on your way out