How do populations change?

Five requirements for Hardy-Weinberg equilibrium.

The population must have:

1. random mating - all individuals have an equal chance to reproduce - can't choose traits
2. a large population - minimizes genetic drift
3. no movement in or out of the population - alleles cannot be added or lost - no gene flow
4. no mutations - mutations can produce new alleles
5. no natural selection - no alleles can have an advantage

When does this ever happen? Almost never!
- Mendelian segregation and recombination will maintain the allele frequency in a population from generation to generation
- thus, if the frequency changes, something else must be happening
- that something is evolution

$p^2 + 2pq + q^2 = 1$ where,
p = frequency of one allele
q = frequency of the other allele

Where did this equation come from and how can we use it?

Counting Alleles
- assume we have 2 alleles - B, b
- frequency of dominant allele (B) = p
- frequency of recessive allele (b) = q
- frequencies must add to 1 (100%), so:
  $p + q = 1$

Alleles: $p + q = 1$

B b

Counting Individuals
- frequency of homozygous dominant: $p \times p = p^2$
- frequency of homozygous recessive: $q \times q = q^2$
- frequency of heterozygotes: $(p \times q) + (q \times p) = 2pq$
- frequencies of all individuals must add to 1 (100%), so:
  $p^2 + 2pq + q^2 = 1$

Individuals: $p^2 + 2pq + q^2 = 1$

BB Bb bb

Hardy-Weinberg

Imagine a population of 500 wildflower plants with 2 alleles, C^R and C^W which code for flower color. There are 320 plants with red flowers and 160 plants with pink flowers and 20 plants with white flowers. We can use the Hardy-Weinberg Theorem to predict the ratio of the genotypes in the next generation.

500 individuals means there are 1000 alleles in the population. (p + q)

How many C^R alleles are in the population? (p)

320 red flowers (C^RC^R) = 320 x 2 = 640 C^R alleles

160 pink flowers (C^RC^W) = 160 C^R and 160 C^W

So we have 800 C^R alleles out of 1000 alleles p = 0.8

1 - p = q
1 - 0.8 = 0.2

So we have 200 C^W alleles

$p^2 + 2pq + q^2 = 1$ becomes
$(0.8)^2 + 2(0.8)(0.2) + (0.2)^2 = 1$

0.64 + 0.32 + 0.04 = 1

C^RC^R C^RC^W C^WC^W

For a population in Hardy-Weinberg equilibrium, these proportions will not change.

Example

Imagine a population of 100 cats, in which there are 84 black and 16 white.
Predict the number of each genotype?

q^2 (bb): 16/100 = 0.16

q (b): = 0.4

p (B): 1 - 0.4 = 0.6

Assuming H-W equilibrium, we would expect:

$p^2 = 0.36$ $2pq = 0.48$ $q^2 = 0.16$

This is our null hypothesis.

Now imagine we observe the following:
Sample data 1: 74 are homozygous dominant, 10 are heterozygous, and 16 are homozygous recessive

$p^2 = 0.74$

$2pq = 0.10$

$q^2 = 0.16$

Chi-squared = >70
Critical value = 5.991

Null is rejected.

How do we account for this difference? (Note that a chi-squared analysis would be done to make sure there *is* a difference.)

Maybe:
1. Hybrids are in some way weaker.
2. Immigration from an external population that is predominantly homozygous B
3. Non-random mating in which white cats tend to mate with white cats and black cats tend to mate with black cats.

Sample data 2: 20 are homozygous dominant, 64 are heterozygous, and 16 are homozygous recessive

$p^2 = 0.20$

$2pq = 0.64$

$q^2 = 0.16$

Seems like heterozygote advantage.

Examples

Imagine 9% of a population is homozygous dominant for a particular trait.
Find the proportion of each of the other genotypes.

AA = 0.09 = p^2

p = 0.3 and q = 0.7

AA = 9%

Aa = 42%

aa = 49%

Practice

Use the Hardy-Weinberg Theorem to estimate the percentage of the population carrying the allele for PKU, a recessively inherited disorder.
About 1 in 10 000 babies born has the disorder.

q^2 = 1/10 000

q = 0.01

p = 0.99

The carriers are heterozygous, so

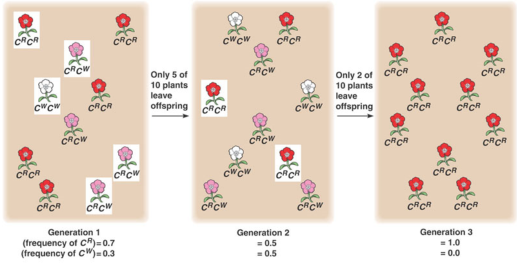
2pq = 2(0.99)(0.01) = 0.0198 or about 2%

Practice

Evolution of a Soybean Population Activity

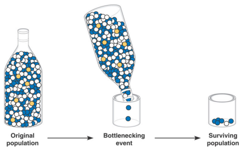
Soybeans

Genetic drift
- allele frequencies change because alleles are lost by random chance
- genetic diversity is decreased



Two causes:

1. Bottleneck effect
- a disaster reduces the size of a population to a few survivors
- alleles could be over-represented, under-represented, or eliminated



2. Founder effect
- individuals become isolated from a larger population
- the gene pool might not reflect the original

Genetic drift

Remember Hardy-Weinberg equilibrium:
1. Extremely large populations - chance fluctuations are smaller

2. No gene flow - alleles do not move between populations

3. No mutations - no alleles are created — The generation to generation change due to mutation is quite small.

4. Random mating - need random mixing of gametes — Can change mix of heterozygotes and homozygotes but does not change allele frequencies

5. No natural selection - no individual can have an advantage

Evolution occurs when these conditions are not met.

Populations change because of:
1. Genetic drift - reduces diversity as alleles are lost

2. Gene flow - reduces diversity because gene pools mix. *e.g.*, inter-racial mating among humans

5. Natural selection

Effect of Predation on Natural Selection of Color Patterns in Guppies Activity

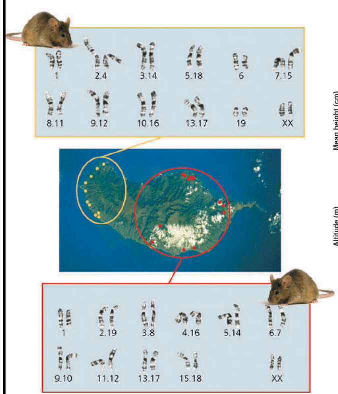
Causes of population change

How do we know natural selection changes populations?

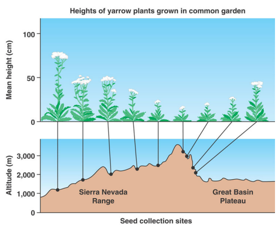
- a population of mice was introduced to the Portuguese island of Madeira in the 15th century.

- in some populations, original chromosomes have become fused (indicated by ".")

- speciation has occured



Yarrow plants from the Sierra Nevada mountains
- seeds were collected from different altitudes and planted
- the height of the plants was correlated to the elevation from which the seeds were collected
- this indicates natural selection of plant height by altitude

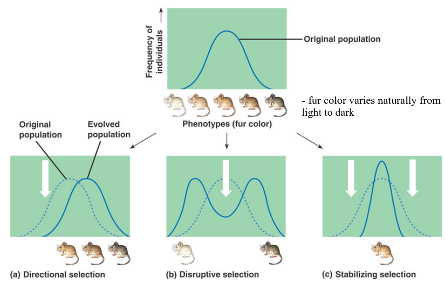


Geographic variation

In what ways do populations change?

- fitness is the contribution that an individual makes to the next generation compared to the contribution of others
- we must also always remember that natural selection acts on phenotype (*i.e.*, the whole organism) and not genotype
- this means that harmful alleles might be maintained if the overall fitness is good
- reproduction is the key! Fitness is measured by your ability to leave offspring

As natural selection occurs, in what ways can the population change?



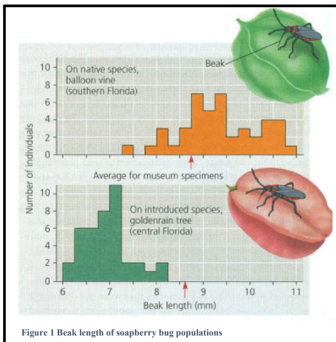
- fur color varies naturally from light to dark

(a) Directional selection
- a phenotype at one extreme is favored
- the terrain becomes darker
- most common when the environment changes or individuals migrate
- the overall makeup is shifted
- *e.g.*, black bears in Europe increased in size during glacial periods and decreased during warmer interglacial periods

(b) Disruptive selection
- phenotypes at both extremes are favored
- the terrain is a patchwork of light and dark rocks
- *e.g.*, finches in Cameroon have small bills for soft seeds or large bills for hard seeds. Intermediate bills suck at both

(c) Stabilizing selection
- intermediates are favored so that extremes are eliminated
- the terrain is sandy colored
- *e.g.*, average birth weight for human babies is 3-4 kg; larger and smaller babies have higher mortality

Modes of selection



Soapberry bugs feed most effectively when the length of their "beak" is similar to the depth of the seeds within the fruit. Researchers measured beak lengths in soapberry bug populations feeding on the native balloon vine. They also measured beak lengths in populations feeding on the introduced goldenrain tree. The researchers then compared the measurements with those of museum specimens collected in the two areas before the goldenrain tree was introduced. Their results are summarized in Figure 1.

Figure 1 Beak length of soapberry bug populations

1. a) What can you say about beak length in the two populations?

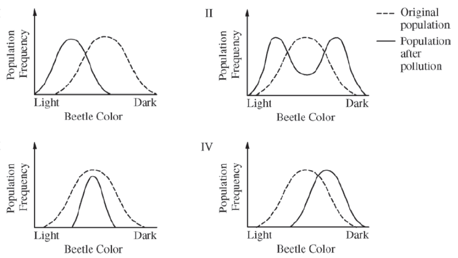
b) Based on what you know about the soapberry bug feeding strategy, suggest a reason for the difference in beak length.

c) Using your suggestion in (b), explain how the difference in beak length occurred?

2. Additional studies took soapberry bug eggs from a population that fed on balloon vine fruits and reared them on goldenrain tree fruits (and *vice versa*). Predict the results you would expect to find. Justify your response.

Soapberry Bugs

In a hypothetical population of beetles, there is a wide variety of color, matching the range of coloration of the tree trunks on which the beetles hide from predators. The graphs below illustrate four possible changes to the beetle population as a result of a change in the environment due to pollution that darkened the tree trunks.



Which of the following includes the most likely change in the coloration of the beetle population after pollution and a correct rationale for the change?

a) The coloration range shifted toward more light-colored beetles, as in diagram I. The pollution helped the predators find the darkened tree trunks.

b) The coloration in the population split into two extremes, as in diagram II. Both the lighter- colored and the darker-colored beetles were able to hide on the darker tree trunks.

c) The coloration range became narrower, as in diagram III. The predators selected beetles at the color extremes.

✓d) The coloration in the population shifted toward more darker-colored beetles, as in diagram IV. The lighter-colored beetles were found more easily by the predators than were the darker-colored beetles.

MC Practice

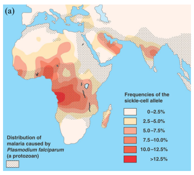
So why doesn't natural selection eliminate all variation?

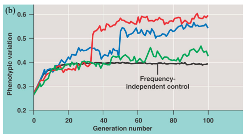
Variation is preserved in three ways:
1. Diploidy
- recessive alleles are hidden from selection
- they could be advantageous under different conditions, becoming favored and more common
- these could allow the population to change if the environment does

2. Balancing selection
- sometimes two or more phenotypes are maintained (balanced polymorphism) for some reason
- this can result from two things:

a) Heterozygote advantage
- if being a heterozygote is an advantage, both alleles will be preserved
- in these cases, the advantage of the mutant allele balances the harm
- *e.g.*, sickle cell allele accounts for 20% of hemoglobin alleles in some tribes
- How many would have the disease?
($q = 0.2$, $q^2 = 0.04$)
- How many heterozygotes would you expect?
($2pq = 2(0.2)(0.8) = 0.32$)

b) Frequency-dependant selection
- one phenotype declines if it becomes too frequent in the population





- birds were trained to pick out virtual moths on a computer screen
- birds were presented with a screen with a speckled background which sometimes included a moth.
- it was rewarded for pecking the moth
- the birds quickly learned how to spot the most common moth
- the computer adjusted the prey to make the common ones rare and the rare ones more common (just like natural selection)
- mutations were also included
- whenever a type of moth became more common, birds quickly learned how to spot them
- thus alleles were preserved because rare moths were always at an advantage while common moths were at a disadvantage because the birds quickly learned how to find them

- in 3 trials (colored lines) the experimental group showed more variation than the control group*

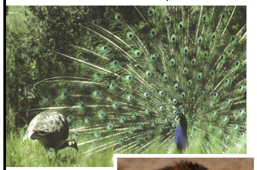
* for the control group, the moth variation did not depend on selection by the jays

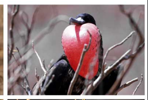
3. Neutral variation
- some variation has little or no impact on reproductive success
- the frequency of such alleles can change due to genetic drift and mutation
- also, some alleles may be neutral in one environment but then advantageous in another

Preserving variation

How does mate choice influence natural selection?

- sexual selection can result in sexual dimorphism



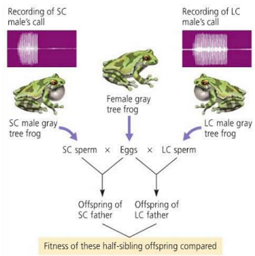


Sexual selection takes two forms
a) Intrasexual
- competition between individuals of the same sex for mates of the opposite sex
- this is usually in males but rare examples exist of females dominating males (as if!)

b) Intersexual (mate choice)
- individuals of one sex choose their mate(s) from the other sex
- this is usually done by females and often results in showy males
- females have fewer mating chances than males so the trick is to choose a male that gives her more fit offspring
- for males, the "showiness" is often maladaptive in itself but might result in more offspring
- when a female chooses a male for some reason, she contributes to the continuation of his alleles
- she also passes on the alleles that made her choose that trait so the preference is continued
- it is not yet clear how these female preferences arose but could be a sign of the male being free of parasites

Sexual selection

Sexual selection



RESULTS

Fitness Measure	1995	1996
Larval growth	NSD	LC better
Larval survival	LC better	NSD
Time to metamorphosis	LC better (shorter)	LC better (shorter)

NSD = no significant difference; LC better = offspring of LC males superior to offspring of SC males.

Female gray tree frogs prefer to mate with males that give long mating calls. Researchers tested whether the genetic makeup of long-calling (LC) males is superior to that of short-calling (SC) males. The researchers fertilized half the eggs of each female with sperm from an LC male and fertilized the remaining eggs with sperm from an SC male. The resulting half-sibling offspring were raised in a common environment and tracked for two years.

The team concluded that the duration of a male's mating call is indicative of the male's overall genetic quality.
1. How do the data support this conclusion?
(Offspring fathered by an LC males had higher fitness than their half-siblings fathered by an SC male.)

2. What forms the basis of the female's mate choice?
(The choice of song length was selected because it represents higher overall genetic quality.)

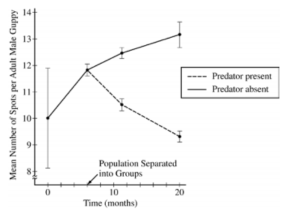
3. Why did the researchers split each female frog's eggs into two batches for fertilization by different males rather than mating each female with a single male frog?
(To compare the effects of the male song (the independent variable), they had to keep the female constant. Different females could have introduced further genetic variation.)

Sexual selection in tree frogs

2014 Q 4 Mean: 1.37

Adult male guppies (*Poecilia reticulata*) exhibit genetically determined spots, while juvenile and adult female guppies lack spots. In a study of selection, male and female guppies from genetically diverse populations were collected from different mountain streams and placed together in an isolated environment containing no predators.

The study population was maintained for several generations in the isolated area before being separated into two groups. One group was moved to an artificial pond containing a fish predator, while a second group was moved to an artificial pond containing no predators. The two groups went through several generations in their new environments. At different times during the experiment, the mean number of spots per adult male guppy was determined as shown in the figure below. Vertical bars in the figure represent two standard errors of the mean (SEM).



(a) **Describe** the change in genetic variation in the population between 0 and 6 months and **provide** reasoning for your description based on the means and SEM.

(b) **Propose** ONE type of mating behavior that could have resulted in the observed change in the number of spots per adult male guppy between 6 and 20 months in the absence of the predator.

(c) **Propose** an evolutionary mechanism that explains the change in average number of spots between 6 and 20 months in the presence of the predator.

Short FR Actual

(a) **Describe** the change in genetic variation in the population between 0 and 6 months and **provide** reasoning for your description based on the means and SEM.
(**2 points maximum**; LO 1.2, 2.24, 4.12, 4.26)

Describe change (**1 point**)	Provide reasoning (**1 point**)
Genetic variation is decreasing	SEM gets smaller

(b) **Propose** ONE type of mating behavior that could have resulted in the observed change in the number of spots per adult male guppy between 6 and 20 months in the absence of the predator.
(**1 point**; LO 1.2, 1.5, 2.40, 3.26, 3.40)
- Sexual selection for individuals with more spots
- Random mating behavior resulted in increased number of spots by chance

(c) **Propose** an evolutionary mechanism that explains the change in average number of spots between 6 and 20 months in the presence of the predator.
(**1 point**; LO 1.2, 3.26, 4.19)
- Directional selection against individuals with large numbers of spots
- Directional selection for individuals with fewer spots
- Natural selection used in context
- Genetic drift resulted in several generations of decreased numbers of spots

Standard

Ok, if natural selection works so well, why do so many things really suck?

1. Evolution can only work with what it has.
- every species comes from a long history of evolution
- evolution does not invent things, it remodels them
    - *e.g.*, wouldn't it be better for birds to have four legs for running as well as wings for flying?
- they don't because they descended from reptiles that had only two pairs of limbs
- imagination can create Pegasus - evolution cannot

2. Adaptations are compromises
- organisms have to do lots of different things so they are unlikely to be good at all of them
- natural selection acts on the whole organism so you have to take the good with the bad
    - *e.g.*, seals spend time on land so it would be better to have legs, but flippers are better for swimming
    - *e.g.*, having prehensile fingers, an opposable thumb and flexible limbs is awesome but makes us prone to injuries.
    - *e.g.*, walking upright frees our hands to do other tasks but makes us prone to back strain because our skeleton was built to walk on four limbs

3. Chance plays a part
- the bottleneck and founder effects are random - they do not choose the best collection of alleles
- founding populations may not be the best suited for the new environment
    - *e.g.*, an unexpected frost does not kill only the least fit individuals so sometimes superior alleles are lost

4. Natural selection can only act on existing phenotypes
- the "ideal" traits might not exist at a particular time
- new alleles cannot arise simply because they are needed

- "Survival of the Fittest" might describe natural selection from an individual perspective but "Survival of the Barely Better Than" is likely more accurate

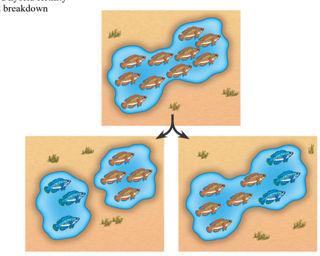
Why aren't things perfect?

What is a species and where does one come from?
- species - a population or group of populations whose members have the ability to interbreed in nature and produce viable, fertile offspring

- species arise when populations become separated
- reproductive isolation prevents members of the two populations from exchanging genetic material
- once separation occurs, the gene pools diverge and speciation can occur

How do populations become isolated?
1. Prezygotic barriers - impede mating
- habitat isolation
- temporal isolation
- behavioral isolation
- mechanical isolation
- gametic isolation

2. Postzygotic barriers - prevent the zygote from developing
- reduced hybrid viability
- reduced hybrid fertility
- hybrid breakdown



(a) Allopatric speciation
- geographic separation isolates a population
- this tends to happen rapidly because the founding populations are usually small

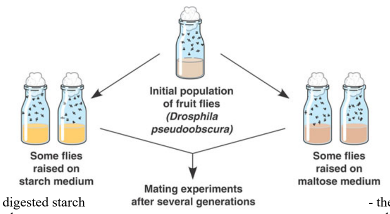
(b) Sympatric speciation
- a small population becomes a new species without separating

Allo/sympatric speciation

A group of people whose ancestors immigrated to North America 200 years ago have certain allele frequencies that differ significantly from those in surrounding populations in Canada. Which of the following is the most likely explanation for the difference in allele frequencies?
a) Mutation
b) Independent assortment
c) Reproductive isolation
d) Allopatric speciation
e) Gametic isolation

MC Practice

Can speciation be shown in the lab?



- these ones digested starch more efficiently
- these ones digested maltose more efficiently

- flies were then mixed to measure their mating preference

		Female Starch	Female Maltose
Male	Starch	22	9
Male	Maltose	8	20

Mating frequencies in experimental group

		Female Same population	Female Different populations
Male	Same population	18	15
Male	Different populations	12	15

Mating frequencies in control group

- the control eliminated the chance that the flies simply didn't like strangers

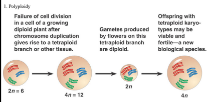
- flies tended to mate with like partners adapted to the same medium
- flies from different populations adapted to the same medium did not show a preference

- notice that separation is not complete (some mating between starch flies and maltose flies occurred) but seems to be underway

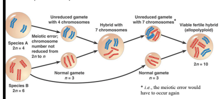
Speciation experiment

How can populations diverge if they are not separated?

1. Polyploidy



- 4N plants cannot breed with 2N plants because the offspring would be 3N and, therefore, sterile
- they can self-pollinate or mate with other 4N
- this makes them a new species
- note that this happened in only one generation
- more commonly, polyploidy results from interbreeding between two different species
- the hybrid is sterile because chromosomes from one species cannot pair with those from the other (red and blue in this case)
- in a subsequent generation, the sterile hybrid may become fertile
- the new hybrid can breed with itself but not with either parent
- can also reproduce asexually



* *i.e.*, the meiotic error would have to occur again

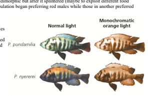
- *e.g.*, goatsbeard
    - three species were introduced to North America from Europe in the early 1900s
    - in the 1950s, two new species were identified in areas where all three European species are found
    - one new species is a tetraploid hybrid of two of the European species
    - the other new one is also an allopolyploid hybrid but of a different combination of two European species
    - note that additional episodes of hybridization are being observed in these species so we know it is not a rare event

- *e.g.*, wheat is an allohexaploid of two sets of chromosomes from three different species

2. Habitat differentiation
- this can happen when a genetic factor allows a subpopulation to exploit a resource unavailable to the parent population
- *e.g.*, apple maggot fly
    - original habitat is the hawthorn tree
    - about 200 years ago, populations colonized apple trees introduced by Europeans
    - apples ripen sooner than hawthorn fruit
    - natural selection is favoring early breeding and rapid development in flies on apple trees
    - speciation is underway

3. Sexual selection
- *e.g.*, cichlids in Lake Victoria
    - the lake has dried and filled several times, most recently about 12,000 years ago
    - 500 cichlid species live there and are so genetically similar they likely arose since the last filling
    - sexual selection seems to have been a factor in this rapid speciation
    - an original population was dimorphic but after it splintered (maybe to exploit different food sources), females of one population began preferring red males while those in another preferred blue

- under normal light, females of each species mated only with males of their own species
- under orange light, females mated with males from both species (and the hybrids were fertile)
- this shows that sexual selection based on color is the primary reproductive barrier
- once the populations separated, sexual selection reinforced the color difference

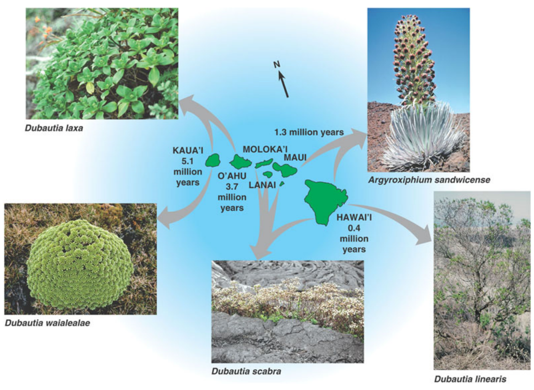


- both species were placed in two tanks
- under normal light, females mated only with males of the same species
- under orange light females mated with males of both species
- the hybrid offspring were viable and fertile
- speciation is underway

Sympatric speciation

- adaptive radiation occurs when new organisms enter new areas or some event causes widespread extinction
- it results in the evolution of diverse species

- each Hawaiian island was created by a hotspot and started as bare lava
- they were colonized by organisms arriving by wind, ocean, or from nearby islands
- most species on the islands are found nowhere else on Earth
- the plants below are all descended from one ancestor that reached the islands about 5 MYA from North America



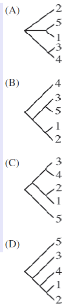
Adaptive radiation

Five new species of bacteria were discovered in Antarctic ice core samples. The nucleotide (base) sequences of rRNA subunits were determined for the new species. The table below shows the number of nucleotide differences between the species.

NUCLEOTIDE DIFFERENCES

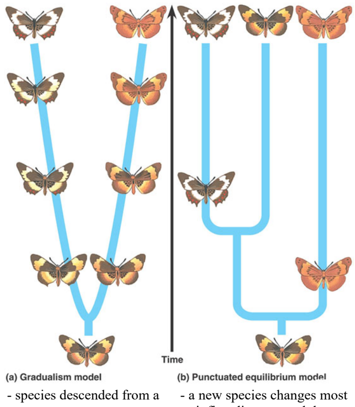
Species	1	2	3	4	5
1	–	3	19	18	27
2		–	19	18	26
3			–	1	27
4				–	27
5					–

Which of the following phylogenetic trees is most consistent with the data?



MC Practice

So how fast is speciation?



(a) Gradualism model
- species descended from a common ancestor gradually diverge more and more as they acquire unique traits

(b) Punctuated equilibrium model
- a new species changes most as it first diverges and then changes little the rest of its life

- fossil record shows that many species appear suddenly, persist unchanged, and then disappear
- this is called punctuated equilibrium
- does this contradict gradual change through descent with modification?

- imagine a species exists for 5 million years
- maybe most of its changes occurred during the first 50,000 years
- this is 1% of its lifetime and would likely not be captured in the fossil record

- also, many changes cannot be recorded by fossils
- while the fossils appear to be static, a species may be changing in color, behaviour, biochemistry, physiology, *etc.*

- the nature of fossil formation would make gradual changes seem to be sudden and drastic

Pace of speciation

But how do big changes occur?
- fish of different colors or flies choosing one food over another are one thing but changing into really diverse species is totally different

- species arise from differences between populations - sometimes tiny differences

- these changes are in a single gene pool and are sometimes called microevolution

- sometimes larger changes occur above the species level and are called macroevolution

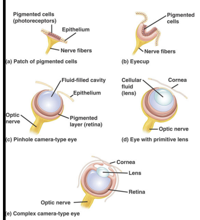
- in most cases, large changes occurred in tiny increments as the effects of small changes accumulate

- remember Hox genes? It's not as big a deal as you might think to dramatically change a body plan

These occur by:
1. Evolutionary novelties
2. Differences in development
3. Changes in spatial pattern

Macroevolution

e.g., the human eye
- how could something so complex have evolved if it needs all its parts to function?
- this argument assumes that only complicated eyes are useful



(a) Patch of pigmented cells
(b) Eyecup
(c) Pinhole camera-type eye
(d) Eye with primitive lens
(e) Complex camera-type eye

a) sense light and dark but no lens to focus
- the limpet clings more tightly to a rock when a shadow passes over it

b) limited directional detection to determine where motion is coming from

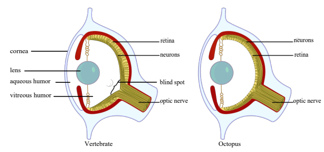
c) better directional detection and some image formation

d) focuses light

e) better focus

- we know that complex eyes in molluscs and vertebrates evolved independently but from a common ancestor because the genes that control eye development are similar

Is the human eye really perfect?
- it seems to be built upside down and backwards



Vertebrate   Octopus

- *e.g.*, honeycombed bones of birds could not have developed in anticipation of flight
- fossils of bird ancestors in China could not fly but were able to climb trees and perch
- light bones may have helped
- wings and feathers may have developed for some other purpose (warmth, courtship, camouflage, *etc.*), but were also useful in flight
- the first flights were likely short glides which favored the further development of feathers and honeycomb bones

- basically, we're saying that novel features might arise by being modified from some other purpose

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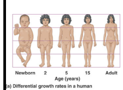
Evolutionary novelties

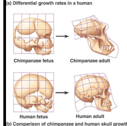
- genes that program development control the rate, timing, and spatial pattern of changes during development
- changes in the expression of these genes can result in different body forms

Heterochrony - if the development of a structure in one species starts earlier or ends later than in another species but proceeds at the same rate, they will have different sizes



(a) Differential growth rates in a human

- arms and legs lengthen more than the trunk and head
- changing the rate of growth can change the adult form substantially



(b) Comparison of chimpanzee and human skull growth

- the fetal skulls of humans and chimps are similar in size and shape

- the rounded skull and vertical face of the newborn chimp is transformed into the elongated skull and sloping face of the adult

- the same growth happens in humans but with a less accelerated growth of the jaw relative to the rest of the skull

- in chimps, brain and head growth starts at about the same developmental stage and proceeds at a similar rate as humans, but end soon after birth

- humans, on the contrary, continue their brain and head growth several years after birth

- *i.e.*, big differences are made by making small changes to the expression of common genes

(a) Ground-dwelling salamander

(b) Tree-dwelling salamander

- the feet of tree climbing salamanders are shorter and have more webbing

- a mutation in a gene that controls foot size may have resulted in this change by switching off sooner
- stunted foot would be favored in a tree-dwelling species

- again, a small genetic change results in a larger morphological change

- paedomorphosis
- juvenile features are retained into adulthood
- this results in animals that look quite different from their ancestors
- again, from a small genetic change

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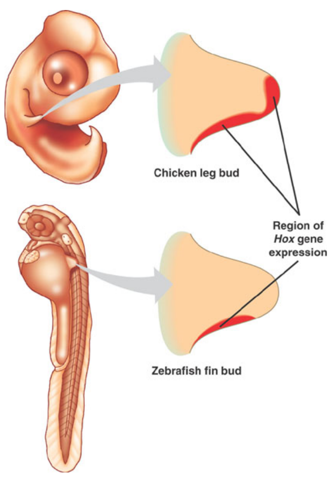
Heterochrony

- changes in homeotic genes can result in large morphological differences



- in tetrapod evolution from fishes, four fish fins developed into limbs
- in tetrapods, skeletal structures extend to the tip of the limb

- in fish, a Hox gene is expressed along the fin bud which results in fin development

- in tetrapod embryos . . . guess what?
- the same gene is expressed at the limb bud, resulting in the development of a limb
- at the tip of the bud the same gene causes the growth of the skeleton into the tip of the limb

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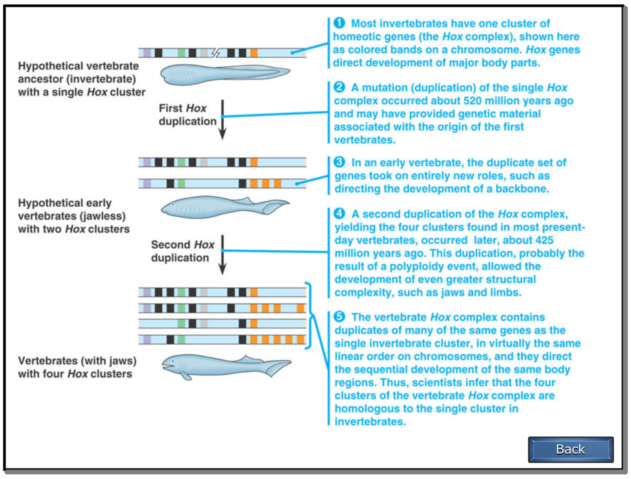
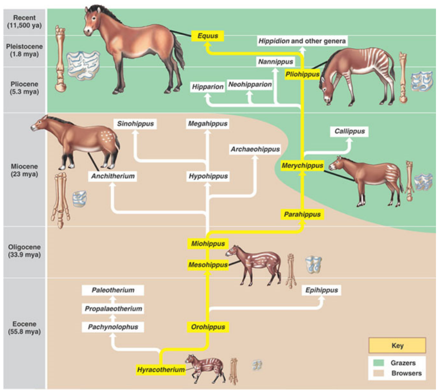
Spatial pattern



Spatial patterns

- horse evolution had no goal
- it shows a few episodes of adaptive radiation



- the yellow line shows that we can make a direct connection between the oldest ancestor and the modern horse
- when we look at all known horse fossils, the trend disappears
- not all branches led to the modern horse

- species are like organisms
- they arise by speciation (birth)
- they become extinct (death)
- new species diverge from them (offspring)

- just like individuals undergo natural selection, species undergo species selection
- those that last the longest give rise to the most new species direct the major trends of evolution

There is no goal

A group of students summarized information on five great extinction events.

Mass Extinction	Time of Extinction	Organisms Greatly Reduced or Made Extinct
End of the Ordovician period	443 million years ago	Trilobites, brachiopods, echinoderms, and corals
End of the Devonian period	354 million years ago	Marine families on tropical reefs, corals, brachiopods, and bivalves
End of the Permian period	248 million years ago	Trilobites, mollusks, brachiopods, and many vertebrates
End of the Triassic period	206 million years ago	Mollusks, sponges, marine vertebrates, and large amphibians
End of the Cretaceous period	65 million years ago	Ammonites, dinosaurs, brachiopods, bivalves, and echinoderms

The students are sampling a site in search of fossils from the Devonian period. Based on the chart, which of the following would be the most reasonable plan for the students to follow?

a) Searching horizontal rock layers in any class of rock and try to find those that contain the greatest number of fossils

b) Collecting fossils from rock layers deposited prior to the Permian period that contain some early vertebrate bones

c) Looking in sedimentary layers next to bodies of water in order to find marine fossils of bivalves and trilobites

d) Using relative dating techniques to determine the geological ages of the fossils found so they can calculate the rate of speciation of early organisms

MC Practice

Attachments

POPULATION GENETICS MODELING.xlsx