**Introduction to Evolutionary Theory**

3 theories of evolution

* Evolution
	+ All species have a common origin, and they may have changed with time
* Transformation
	+ Species have separate origins , but they may change
* Separate creation
	+ Species have separate origins and do not change

Evolution explains the history, diversity, adaptation, and complexity of life

* Microevolution
	+ Within populations
* Macroevolution
	+ At or above the species level

Small Scale Evolution in Action

* Schuurman’s HIV experiment
	+ Lamivudine (3TC) is an anti-viral drug
	+ Targets reverse transcriptase (nucleoside inhibitor -nucleotide without the phosphate)
	+ When treated with 3TC, viral load drops precipitously , but within days resistant strains are seen, and shortly becomes the most prevalent population
	+ seen frequently with other antibiotics (MRSA, VRE)
	+ Mutations at positions 184 (intermediate/high level resistance), 151, 69, 65 (low level resistance), 118, T69D and 44 (contributes to resistance) may all contribute, to some degree, to 3TC resistance.
	+ M184V is the most common mutation causing 3TC resistance.
	+ Methionine is changed to one of 3 other amino acids (most commonly valine)

Adaptive evolution

* Process of change
* Driven by reproductive success
* Correlated with heritable variation

Macroevolution

* Speciation
* Phylogenetics
* Phylogeny

Vocabulary of microevolution

* Gene
* Adaptation
* Natural selection
* Heritable variation
* Neutral evolution
* Genetic drift

Artificial selection

* Artificial selection-evolution produced experimentally

Evolution yields insights

* Selection focuses on reproductive success.
* Strong selection produces rapid evolution in large populations.
* Molecular systematics can resolve old mysteries.
* Some evolution is irreversible.
* Organisms are mosaics of parts with different ages.

What is a species?

* The biological species concept defines a species as members of populations that actually or potentially interbreed in nature, not according to similarity of appearance.
* It is not that easy..let’s take a look at two common concepts of species:
	+ Phenotypic similarity
	+ Interbreeding

Species

* Organisms may appear to be alike and be different species.
	+ For example, Western meadowlarks (*Sturnella neglecta*) and Eastern meadowlarks (*Sturnella magna*) look almost identical to one another, yet do not interbreed with each other—thus, they are separate species according to this definition.
* Organisms may look different and yet be the same species?
* You might think that the ants are distantly related species. In fact, they are sisters—two ants of the species *Pheidole barbata*, fulfilling different roles in the same colony.
* The further up the heirarchy-the greater the differences. (two members of the same species are more similar that those of two genuses)

Ring Species

* One of the most powerful counters to the argument that the theory of evolution doesn't convincingly explain the origin of new species is the rare but fascinating phenomenon known as "ring species."
* This occurs when a single species becomes geographically distributed in a circular pattern over a large area. Immediately adjacent or neighboring populations of the species vary slightly but can interbreed.
* But at the extremes of the distribution -- the opposite ends of the pattern that link to form a circle -- natural variation has produced so much difference between the populations that they function as though they were two separate, non-interbreeding species.
* The various *Ensatina* salamanders of the Pacific coast all descended from a common ancestral population. As the species spread southward from Oregon and Washington, subpopulations adapted to their local environments on either side of the San Joaquin Valley.
* Common ancestor: *Ensatina eschscholtzii picta*
* In Southern California, naturalists have found what look like two distinct species scrabbling across the ground. One is marked with strong, dark blotches in a cryptic pattern that camouflages it well. The other is more uniform and brighter, with bright yellow eyes, apparently in mimicry of the deadly poisonous western newt. These two populations coexist in some areas but do not interbreed -- and evidently cannot do so.
* Moving up the state, the two populations are divided geographically, with the dark, cryptic form occupying the inland mountains and the conspicuous mimic living along the coast. Still farther to the north, in northern California and Oregon, the two populations merge, and only one form is found.
* In this area, it is clear that what looked like two separate species in the south are in fact a single species with several interbreeding subspecies, joined together in one continuous ring.
* The evolutionary story that scientists have deciphered begins in the north, where the single form is found. This is probably the ancestral population. As it expanded south, the population became split by the San Joaquin Valley in central California, forming two different groups. In the Sierra Nevada the salamanders evolved their cryptic coloration. Along the coast they gradually became brighter and brighter.
* The division was not absolute: some members of the sub-populations still find each other and interbreed to produce hybrids. The hybrids look healthy and vigorous, but they are neither well-camouflaged nor good mimics, so they are vulnerable to predators. They also seem to have difficulty finding mates, so the hybrids do not reproduce successfully. These two factors keep the two forms from merging, even though they can interbreed.
* By the time the salamanders reached the southernmost part of California, the separation had caused the two groups to evolve enough differences that they had become reproductively isolated. In some areas the two populations coexist, closing the "ring," but do not interbreed. They are as distinct as though they were two separate species. Yet the entire complex of populations belongs to a single taxonomic species, *Ensatina escholtzii*.
* Why is *Ensatina* so important?
	+ All of the intermediate steps, normally missing, have been preserved, and that is what makes it so fascinating!
* Molecular differences
	+ New tools allowed researchers to study the salamanders' proteins, the chemical building blocks of life. Even though *eschscholtzii* and *klauberi* live in the same places in Southern California, their proteins are quite different from one another and each is more biochemically similar to its northern neighbor.
	+ This is exactly what we'd expect to observe if these two subspecies represent the endpoints of the ring species. Furthermore, populations of *picta* had great variety in their proteins — and that's typically what we observe in populations that have been established for a long time and have had plenty of time to accumulate mutations.
	+ Biologists also used mitochondrial DNA sequences to try to figure out the family tree for all the salamander subspecies. They found that the northern salamander lineages branched off near the base of that family tree — suggesting that they are closely related to the ancestor of the ring. The forms near the eastern and western endpoints of the ring formed distinct clans—just as we'd expect if they each evolved separately from *Ensatina*'s ancestor.
	+ Sequence data from *Ensatina*'s nuclear DNA should show the same patterns as its mitochondrial DNA, with the most diversity in the north and big genetic differences distinguishing the southernmost lineages. Furthermore, the evolutionary tree based on these DNA sequences should be consistent with a northern origin and southward diversification.
	+ But *Ensatina*'s nuclear DNA was a hard nut to crack. No one had yet made a detailed study of it because of its quirks. *Ensatina* has a huge genome — roughly six times bigger than ours! — and it's littered with repetitive DNA — chunks of DNA that probably don't code for anything and that repeat the same, short genetic sequence over and over again. All that makes their DNA extremely difficult to sequence.
	+ Hundreds and hundreds of short genetic sequences, were sequenced, hunting for ones with enough genetic variation to figure out *Ensatina*'s evolutionary history. Different parts of *Ensatina*'s genome have different levels of variation — some are remarkably uniform among all *lineages,* and some vary more from population to population.
	+ This is because different parts of the genome evolve at different rates. Since *Ensatina* has diversified into subspecies relatively recently, the parts of its genome that evolve more slowly haven't had time to accumulate mutations that would carry information about how the lineages are related to one another.
	+ On the other hand, the parts of its genome that evolve more quickly, have accumulated more mutations and now vary among populations. These stretches of DNA can be used to figure out which lineages are most and least closely related.
* Why doesn't *Ensatina*'s ring join up fully? In the 1960s, Charles W. Brown, discovered a few locations in Southern California where the muted western form (*eschscholtzii*) and the blotchy eastern form (*klauberi*) live together and actually do interbreed, producing blurrily blotched hybrids.
* Evidence for Evolution
	+ Need evidence for:
		- Descent with modification
		- All species share a common ancestor
* Biochemistry
	+ If you compare the chemicals (e.g. DNA, hemoglobin, ATP) found in different animals and plants, the degree of similarity between these organisms can be measured.
	+ There is a 1% difference between the DNA of humans and chimps.
* Fossils or organisms that show the intermediate states between an ancestral form and that of its descendants are referred to as transitional forms. There are numerous examples of transitional forms in the fossil record, providing an abundance of evidence for change over time.
	+ *Pakicetus* is described as an early ancestor to modern whales. Although pakicetids were land mammals, it is clear that they are related to whales and dolphins based on a number of specializations of the ear, relating to hearing. The skull shown here displays nostrils at the front of the skull.
	+ A skull of the gray whale that roams the seas today has its nostrils placed at the top of its skull. It would appear from these two specimens that the position of the nostril has changed over time and thus we would expect to see intermediate forms.
	+ Note that the nostril placement in *Aetiocetus* is intermediate between the ancestral form *Pakicetus* and the modern gray whale — an excellent example of a transitional form in the fossil record!
	+ Organisms that are closely related to one another share many anatomical similarities. Sometimes the similarities are conspicuous, as between crocodiles and alligators, but in other cases considerable study is needed for a full appreciation of relationships.
	+ Whales and hummingbirds have tetrapod skeletons inherited from a common ancestor. Their bodies have been modified and parts have been lost through natural selection, resulting in adaptation to their respective lifestyles over millions of years.
	+ On the surface, these animals look very different, but the relationship between them is easy to demonstrate. Except for those bones that have been lost over time, nearly every bone in each corresponds to an equivalent bone in the other.
	+ Frogs, birds, rabbits and lizards all have different forelimbs, reflecting their different lifestyles. But those different forelimbs all share the same set of bones - the humerus, the radius, and the ulna. These are the same bones seen in fossils of the extinct transitional animal, *Eusthenopteron*, which demonstrates their common ancestry
	+ In 2006, a team of scientists unveiled the discovery of *Tiktaalik roseae*, a fossil fish known as the 'fishapod‘is a 375 million year old fossil fish which was discovered in the Canadian Arctic in 2004. Its discovery sheds light on a pivotal point in the history of life on Earth: when the very first fish ventured out onto land.
	+ *Tiktaalik* has a mix of fish and amphibian traits
	+ *Tiktaalik* looks like a cross between the primitive fish it lived amongst and the first four-legged animals (a group called "tetrapods" from tetra-, meaning four, and -pod, meaning foot. Actually, all animals that descended from these pioneer amphibians, including us, can be called tetrapods).
	+ *Tiktaalik* lived about 12 million years before the first tetrapods (which are approximately 363 million years old). So, the existence of tetrapod features in a fish like *Tiktaalik* is significant because it marks the earliest appearance of these novel features in the fossil record.
* Vestigial features
	+ Several animals, including pigs, cattle, deer, and dogs have reduced, nonfunctional digits, referred to as dewclaws. The foot of the pig has lost digit 1 completely, digits 2 and 5 have been greatly reduced, and only digits 3 and 4 support the body. Evolution best explains such vestigial features. They are the remnants of ancestors with a larger number of functional digits.
* Things humans no longer need…
* Goose bumps
	+ The pilomotor reflex, to give them one of their technical names, occurs when the tiny muscle at the base of a hair follicle contracts, pulling the hair upright. In birds or mammals with feathers, fur or spines, this creates a layer of insulating warm air in a cold snap, or a reason for a predator to think twice before attacking.
* Darwin’s point
	+ Six swellings of tissue called the hillocks of Hiss arise around the area that will form the ear canal. These eventually coalesce to form the outer ear. Darwin's point, or tubercle, is a minor malformation of the junction of the fourth and fifth hillocks of Hiss.
	+ It is found in a substantial minority of people and takes the form of a cartilaginous node or bump on the rim of their outer ear, which is thought to be the vestige of a joint that allowed the top part of the ancestral ear to swivel or flop down over the opening to the ear.
* Tail bone
	+ A structure that is the object of reduced evolutionary pressure can, within limits, take on different forms. As a result, one of the telltale signs of a vestige is variability. A good example is the human coccyx, a vestige of the mammalian tail, which has taken on a modified function, notably as an anchor point for the muscles that hold the anus in place
	+ The human coccyx is normally composed of four rudimentary vertebrae fused into a single bone.
	+ Whereas babies born with six fingers or toes are rare, the coccyx can and often does consist of anything from three to five bony segments. What's more, there are more than 100 medical reports of babies born with tails.
* Wisdom teeth
	+ Most primates have wisdom teeth (the third molars) but a few species, including marmosets and tamarins, have none. These are probably evolutionary dwarfs.
	+ It is suggested that when the body size of mammals reduces rapidly their jaws become too small to house all their teeth, and overcrowding eventually results in selection for fewer or smaller teeth
* Appendix
	+ The vermiform appendix is a vestige of the cecum, an organ that would have been used to digest cellulose by humans' herbivorous ancestors. Analogous organs in other animals similar to humans continue to perform that function, whereas other meat-eating animals may have similarly diminished appendices. In line with the possibility of vestigial organs developing new functions, some research suggests that the appendix may guard against the loss of symbiotic bacteria that aid in digestion
* There are also vestigial molecular structures in humans, which are no longer in use but may indicate common ancestry with other species. One example of this is L-gulonolactone oxidase, a gene that is functional in most other mammals and produces an enzyme that synthesizes Vitamin C.
* In humans, a mutation disabled the gene and made it unable to produce the enzyme. However, the remains of the gene are still present in the human genome as a vestigial genetic sequence called a pseudogene.
* People (and apes) have chests that are broader than they are deep, with the shoulder blades flat in back. This is because we, like apes, are descended from an ancestor who was able to suspend itself using the upper limbs. On the other hand, monkeys and other quadrupeds have a different form of locomotion. Quadrupeds have narrow, deep chests with shoulder blades on the sides.
* Hoatzin chicks have claws on their wings, as do some chickens and ostriches. This reflects the fact that bird ancestors had clawed hands.
* Ignoring the reality of evolution is dangerous.