Chapter 16: Evolution

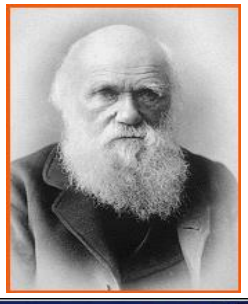
Dr. Bertolotti

Essential Question

How does evolution explain the diversity in life?

What was Charles Darwin's contribution to science?

CHARLES DARWIN

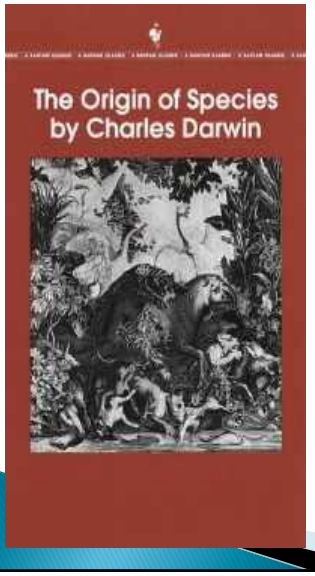


- At 22, sailed on the "HMS Beagle" to the Galapagos Islands.
- Was going to school to be a minister-believed God created each species to match its habitat and they never changed.
- Thought Earth was about 6,000 years old and didn't change.

CHARLES DARWIN

- During journey, he made observations and recorded them in a journal.
- Darwin began to doubt that species remained "constant."

CHARLES DARWIN



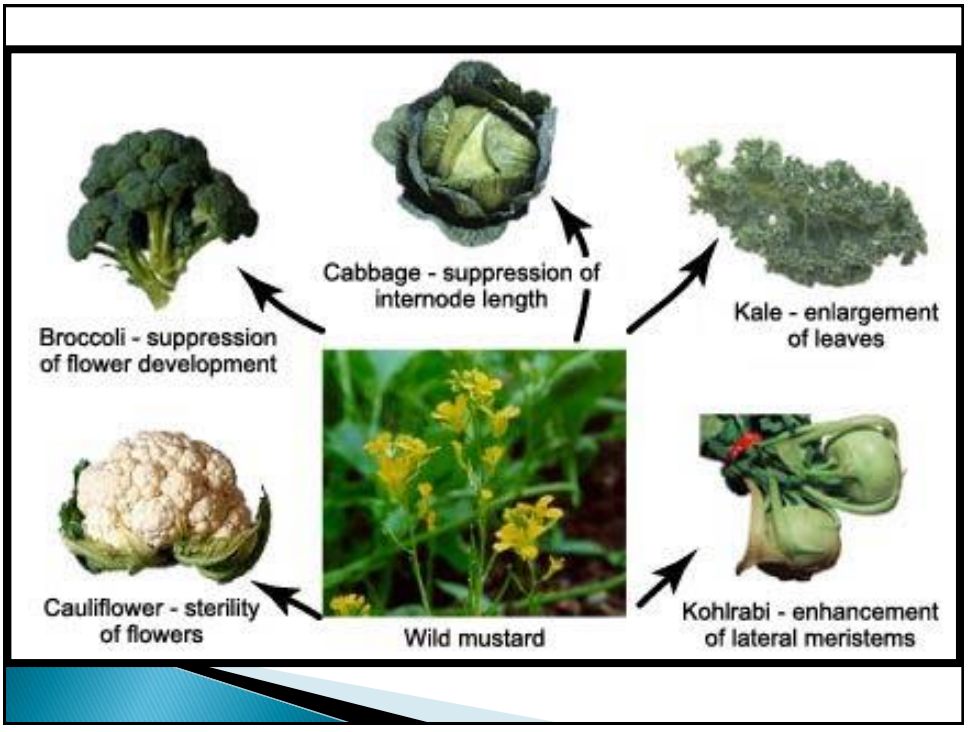
- In 1859, Darwin published "The Origin of Species."
- His book stirred up controversy.
- **Proposed **EVOLUTION OCCURRED BY NATURAL SELECTION**

MAJOR POINTS OF DARWIN'S BOOK:

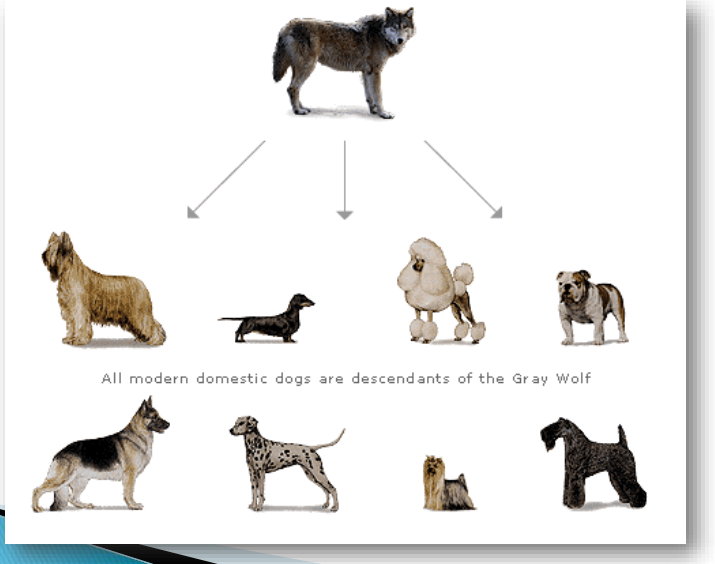
- Organisms have more offspring than can survive.
- Certain individuals are more likely to survive than others (survival of the fittest.)
- Species DO change over time.
- Gradual changes may cause members of one species to eventually evolve into new species.
- African apes are **close genetic relatives** of modern humans.

Darwin's Insights

- 1) **Members of each species vary from one another**
  - **Artificial selection- selection by humans for breeding of useful traits from the natural variation among different organisms**
    - Artificial selection is used to breed animals with the trait of interest
    - In artificial selection, nature provided the variation, and humans selected those variations that they found useful



Artificial Selection



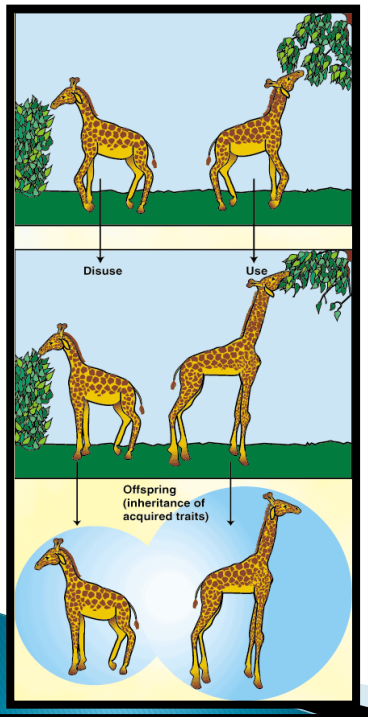
QUESTION AND ANSWER

What was Charles Darwin's contribution to science?

What ideas shaped Darwin's thinking?

Before Darwin

- Hutton and Lyell helped scientists recognize that Earth is many millions of years old, and the processes that changed Earth in the past are the same processes that operate in the present
  - Hutton and Lyell proposed that geological processes have shaped the Earth, ex. Rain



- Lamarck was among the first scientists to recognize that living things have changed over time and that all species were descended from other species.
- Lamarck also proposed that by selective use or disuse of organs, organisms acquired or lost certain traits during their lifetime.
  - These traits could then be passed on to their offspring.
  - Over time, this process led to change in a species.

Before Darwin (cont'd)

- Malthus reasoned that if the human population continued to grow unchecked, sooner or later there would be insufficient living space and food for everyone
- Wallace also summarized similar thoughts of evolutionary change as Darwin which served as an incentive for Darwin to publish his work, *On the origin of Species.*

QUESTION AND ANSWER

What ideas shaped Darwin's thinking?

What is evolution?

What is evolution?

- Can be summarized using the following sentence:
  - "***Life on Earth evolved gradually beginning with one primitive species that lived more than 3.5 billion years ago; it then branched out over time, throwing off many new and diverse species; and the mechanism for most (but not all) of evolutionary change is natural selection.***"

- **Evolution is a scientific theory.**
  - In science, a theory is much more than just a speculation about how things are: it is ***a well-tested explanation that unifies a broad range of observations and hypotheses, and enables scientists to make accurate predictions about new situations.***
    - Examples: Atomic theory and germ theory.
  - For a theory to be considered scientific, it must be ***testable*** and make ***verifiable predictions***.
    - That is, we must be able to make observations about the real world that either support it or disprove it.
  - A theory is accepted as "true" only when its assertions and predictions are tested over and over again, and confirmed repeatedly.

- A theory becomes a fact (or a "truth") when so much evidence has accumulated in its favor- and there is no decisive evidence against it- that virtually all reasonable people will accept it.
- **Evolution is therefore BOTH a fact and a scientific theory**.

QUESTION AND ANSWER

What is evolution?

Explain how the 5 pieces of evidence supports evolution

The evidence

- 1. The fossil record
- 2. Vestigial structures
  - Atavisms
- 3. Embryology and Anatomy
  - Homologous structures
  - Analogous structures
- 4. Geographic distribution (biogeography)
- 5. DNA (Molecular)

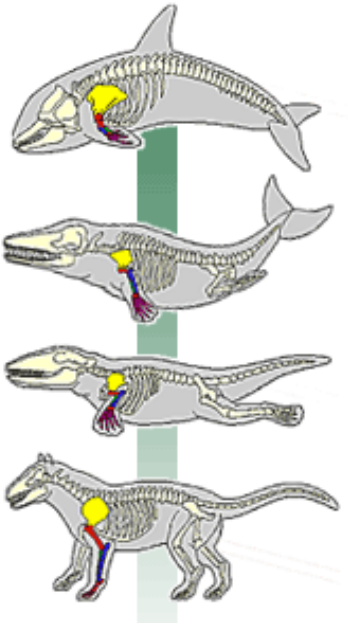
1. The fossil record

- The fossil record:
  - 1. Confirms several predictions of evolutionary theory- gradual change with lineages, splitting of lineages, and the existence of transitional forms/species
    - ***Transitional forms/species****: species that have been found in the fossil record that are intermediates between two other species in the evolutionary process)*
  - 2. When transitional forms are found, they occur in the fossil record where they should.
    - Example: The earliest birds appear after dinosaurs but before modern birds.
  - 3. Evolutionary change nearly always involves remodeling the old into the new.

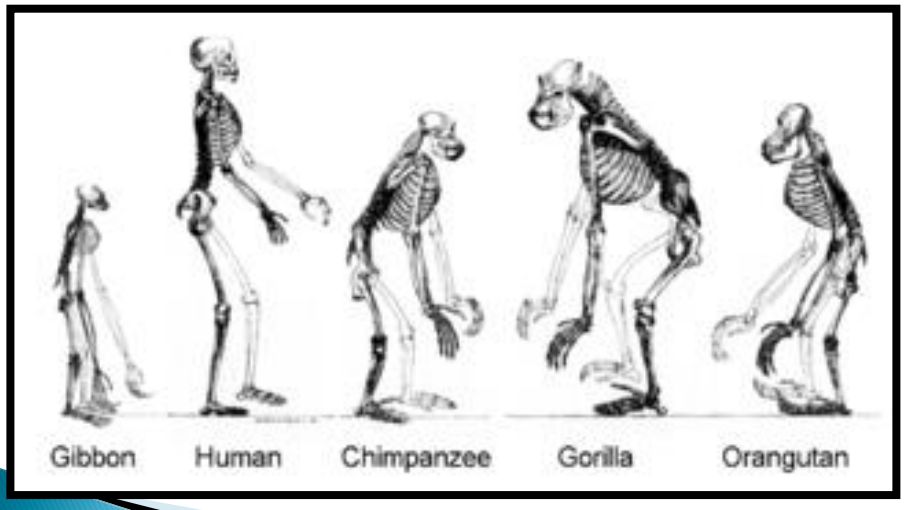
Fossil Evidence

- **Fossils show:**
  - life has been around for millions of years
  - transitional species link older to newer species
    - Darwin proposed the idea of transitional species, though he had no evidence
    - Today we have evidence:
      - Whales--60 million years of evolution
        - descended from 4-legged animals that were also ancestors to cows and horses
        - evidence shows slow loss of legs
        - pelvis still remains with no rear legs

Fossil Evidence



Descent with modification



2. Vestigial structures

- **Vestigial structures** are not considered vestigial because it is functionless , but because ***those structures no longer perform the function for which it evolved***.
  - Example: Wings of an ostrich- which was an adaptation in its ancestors for flight but is now used for other functions such as maintaining balance, mating, and threatening its enemies.
  - These vestigial structures have not disappeared completely because a) it is slowly disappearing and b) some of the structures have assumed new roles and then will be maintained by natural selection.

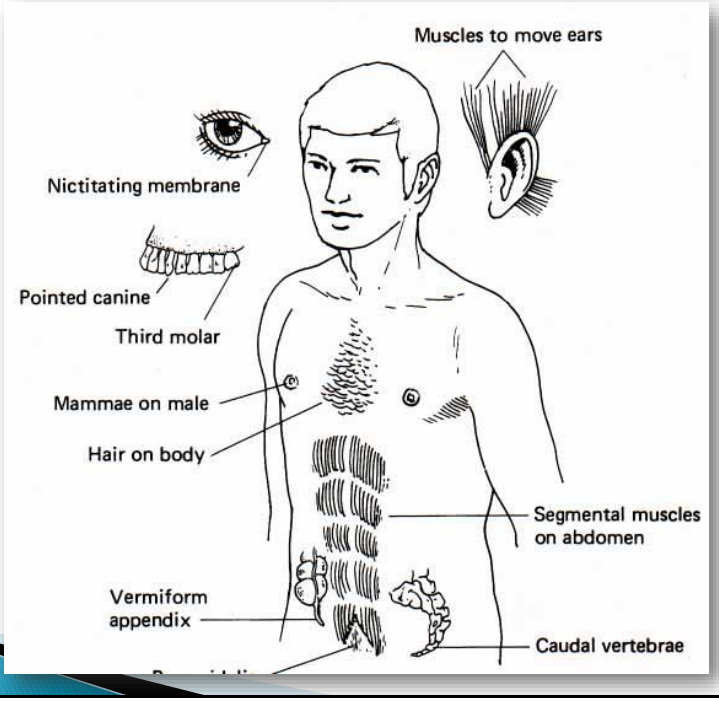
2. Vestigial structures

- In humans, vestigial structures/ traits include: appendix, *arrector pili,* the ability to wiggle your ears, a vestigial tail or coccyx, and pseudogenes.
  - The appendix is a remnant of an organ that was important in our leaf-eating ancestors to break down leaves to sugar.
  - The *arrector pili* are tiny muscles that attach to the base of body hair and gives us "goose bumps" when cold. In other mammals, it raises fur for insulation and makes the animal appear larger when it's making or receiving threats.

2. Vestigial structures (cont'd)

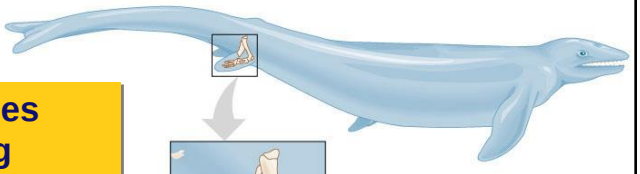
- The useless human ability to wiggle your ears is due to 3 muscles under your scalp that is attached to the ear. In other animals such as cats and horses, it is used to help them localize sound and thus help detect predators, and locate their young.
- The vestigial tail or coccyx is made of fused bones that served as a useful tail of our ancestors.
  - It still serves some secondary functions, such as being an attachment point for muscles, which explains why it has not degraded further.
- The human genome contains more than 2,000 **pseudogenes-** genes that are inactive.

Human Vestigial Structures

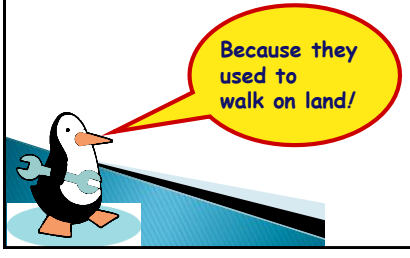


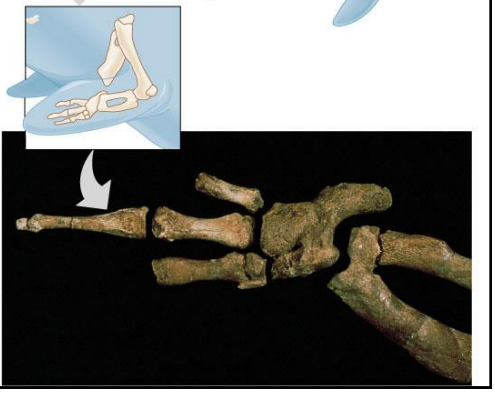
Vestigial organs

- Hind leg bones on whale fossils

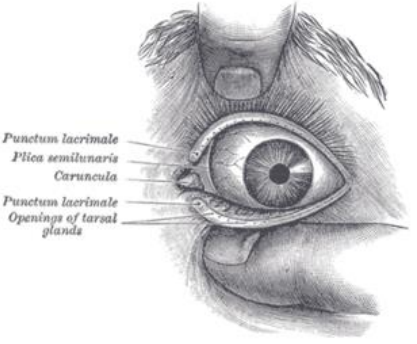


Why would whales have pelvis & leg bones if they were always sea creatures?





Nictitating membrane



2. Vestigial structures

- ***Atavisms* are sporadically expressed remnants of ancestral features**. They differ from vestigial structures because they occur only occasionally rather than in every individual.
- True atavisms must recapitulate an ancestral trait, and in fairly exact way. They occur due the re-expression of genes that were functional in ancestors but were silenced by natural selection when they were no longer needed.

Atavisms

- Example: The “Coccygeal projection” or the human tail.
  - Normally during the 7th week of human embryo development, the tail is reabsorbed by the body. However in some, a tail is present.
- Example 2: The development of teeth in some birds when a crucial protein that is normally missing is replaced.
  - Although birds lost their teeth more than 60 million years ago, they still carry the genes for making them.

Coccygeal projection” or the human tail

Coccygeal projection" or the human tail

3. Embryology and Anatomy

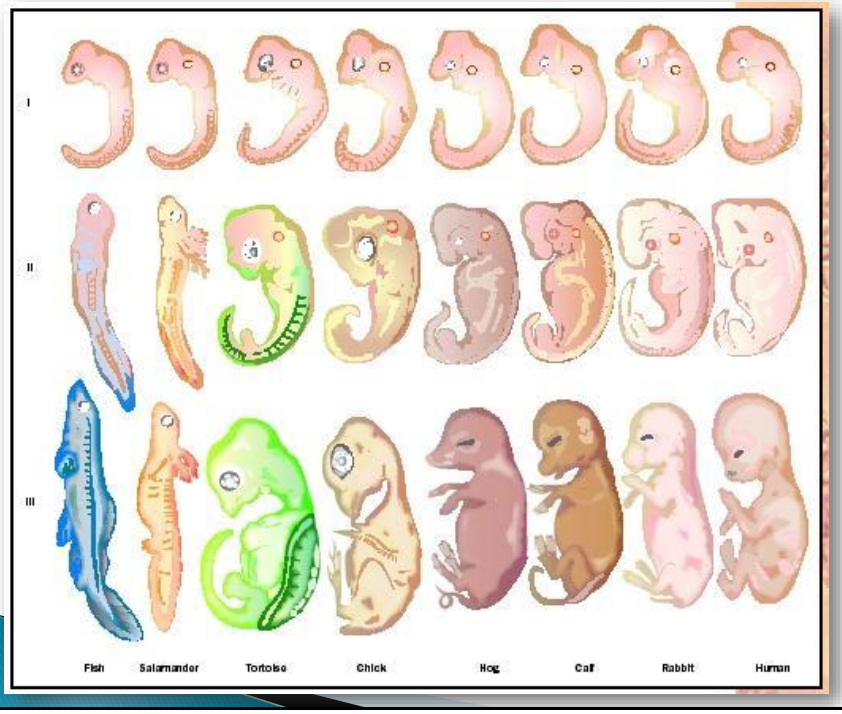
- The developmental sequence is the same for the majority of multicellular and complex organisms- and happens to follow the evolutionary sequence of its ancestors.
- Fish -> amphibian -> reptile -> mammal.
- As one species evolves into another, the descendant inherits the developmental program of its ancestors: that is, all the genes that form ancestral structures.

3. Embryology

- "**Ontogeny recapitulates phylogeny**"- means that the development of an organism simply replays its evolutionary history.
- Embryonic stages don't look like the adult forms of their ancestors but like the embryonic forms of ancestors.
  - Human fetuses never resemble adult fish but they do resemble embryonic fish and reptiles.
  - The recapitulation is neither strict nor inevitable: not every feature of an ancestor's embryo appears in its descendants, nor do all stages of development unfold in a strict evolutionary order.
  - Embryos still show a form of recapitulation: features that arose earlier in evolution often appear earlier in development.

3. Embryology

- The human fetus is furry- around 6th months after conception, we become completely covered with a fine, downy coat of hair called ***lanugo***.
  - *Lanugo* is usually shed about a month before birth and is a remnant of our primate ancestry: fetal monkeys also develop a coat of hair at about the same stage of development.
  - Fetal whales also have lanugo.

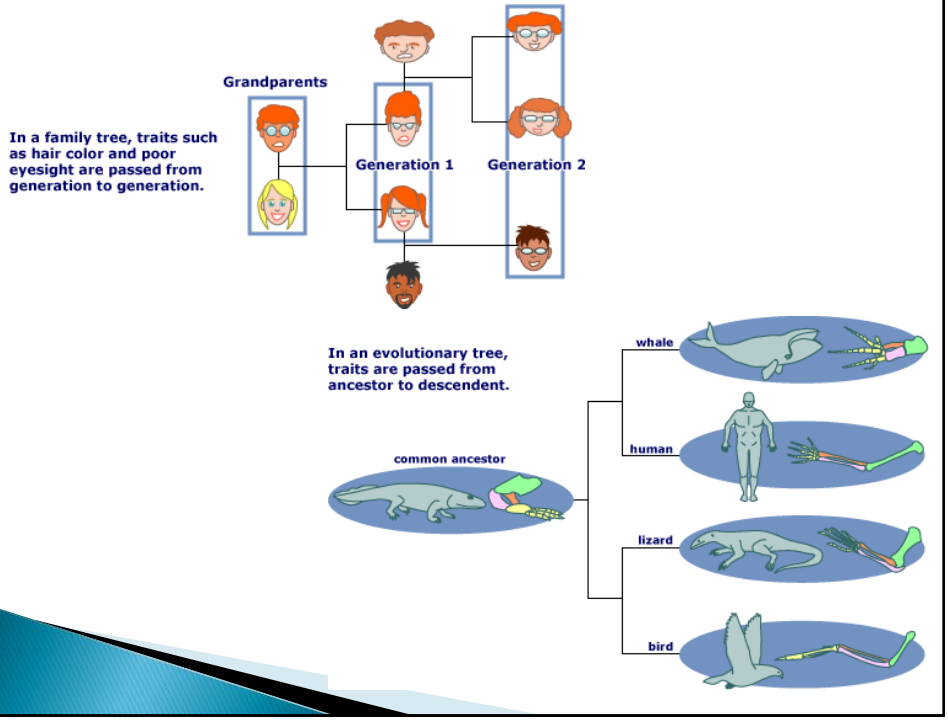


Structural Evidence

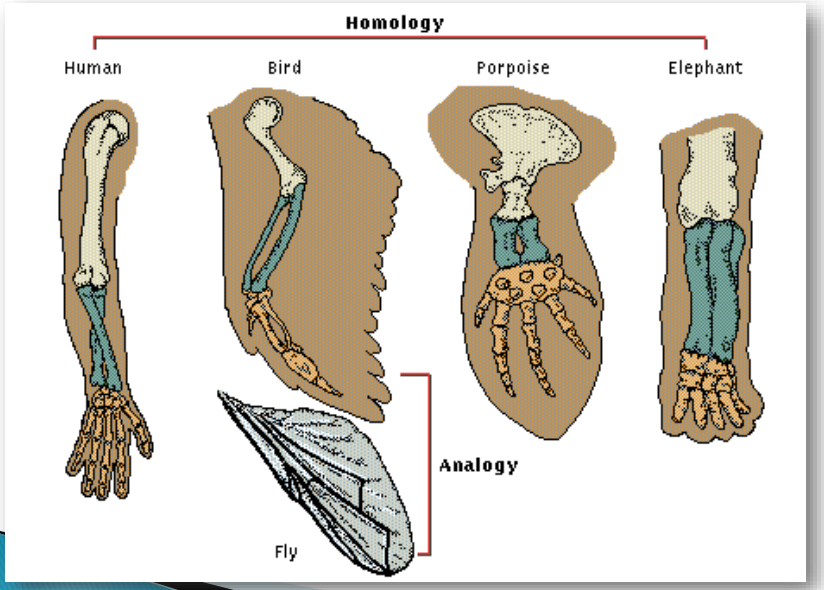
- **Homologous structures: Bone structure is the same (homo) but not its function**
  - Modified structures from a common ancestor
    - Bird wing, dolphin fin, and a human arm
    - Modified structures that share a common ancestry
  - Show these species are related and evolved from a common ancestor

Homologous structures

- Structures that come from the same origin
  - homo- = same
  - -logous = information
- Forelimbs of human, cats, whales, & bats
  - same structure
    - on the inside
  - same development in embryo
  - different functions
    - on the outside
  - evidence of common ancestor



Evidence for Evolution



Structural Evidence

- **Analogous structures: Bone structure is different but they serve the same function.**
  - Flight: Butterfly wing, bat wing, bird wing
  - **Structure is not the same**!
  - Show different species evolved structures with similar function through different evolutionary pathways.
  - EVOLUTION IS NOT RANDOM. Only the mutations that play a role in evolution are.

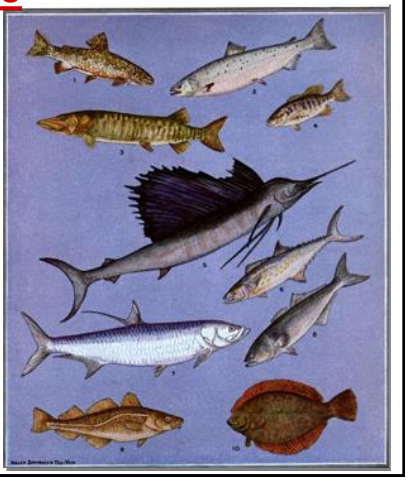
But don't be fooled by these…

- **Analogous structures**
  - look similar
    - on the outside
  - same function
  - different structure & development
    - on the inside
  - different origin
  - no close evolutionary relationship

Solving a similar problem with a similar solution

Analogous structures

- **Dolphins: aquatic mammal**
- **Fish: aquatic vertebrate**
  - both adapted to life in the sea
  - not closely related



4. Geographic distribution (Biogeography)

- Only evolution can explain the diversity of life on continents and islands.
- Many cases of similar species that live in similar habitats but on different continents
- Mammals, amphibians, freshwater fish, and reptiles are often lacking on oceanic islands. They are however present on continental islands.

5. DNA (Molecular)

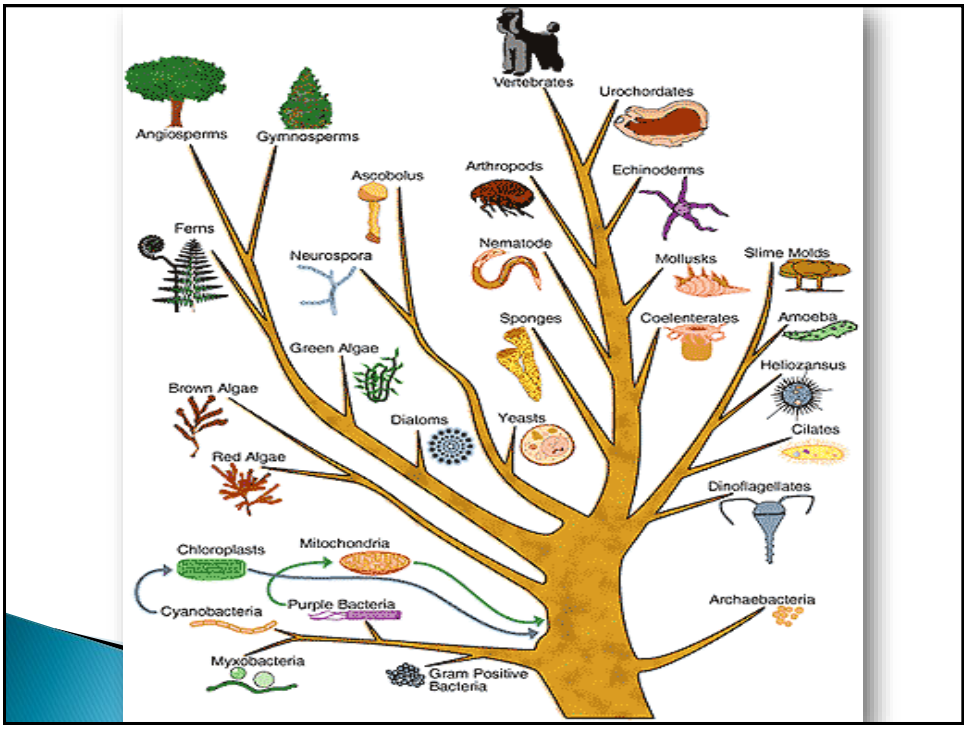
- DNA and proteins
  - DNA is the ultimate tool for scientists studying evolution → DNA controls traits
  - Same genetic basis for <u>all</u> organisms: A, C, T, and G shows we are all related
  - Similar organisms= similar DNA and proteins!!!
  - Species with more similar DNA are more closely related on the evolutionary tree—less time to accumulate mutations (and, therefore, differences)

5. DNA (Molecular)

- Approximately 3-8% of the human genome is comprised of sections of viral DNA.
  - These and other parasitic, self-replicating pieces of nucleic acids have evolved with us over millions of years after being inserted into our DNA by the viruses that infected our ancestors.
  - During the course of a viral infection, some viruses insert their DNA into the host's genome (provirus) and direct the host's cellular machinery to make the proteins and genetic material needed to make more viruses.
  - If this process of gene insertion takes place in a cell that is destined to become an egg or a sperm, the host's offspring will have a copy of the virus in every single cell.
  - Example: a remnant of a retrovirus that invaded primate genome approximately 40 million years ago and have rise to what is known as W family of ERVs.

5. DNA (Molecular)

Animal	Sequence of Bases in Section of *Hoxc8*
Mouse	C A G A A A T G C C A C T T T T A T G G C C C T G T T T G T C T C C C T G C T C
Baleen whale	C **C** G A A A T G C C **T** C T T T T A T G G C **G** C T G T T T G T C T C C C T G C **G** C
Chicken	**A** A **A** A A A T G C C **G** C T T T T A **C** **A** G C **T** C T G T T T G T C T C **T** C T G C T **A**



QUESTION AND ANSWER

Explain how the 5 pieces of evidence supports evolution

What is evolution NOT ?

What evolution IS NOT

Biological Evolution...

- is NOT an educated guess, it is a THEORY
- is NOT something one should *believe* in... (it's based on science, not faith).
- is NOT concerned with the origin of life... (it deals only with the origin of *species*).
- is NOT just concerned with the origin of humans...(no more than any other species).
- was NOT discovered or first explained by Charles Darwin...
- is NOT the same thing as natural selection
- is NOT something that happened only in the past...
- is NOT something that happens to individuals...(it happens to POPULATIONS).
- is NOT an accidental
- does NOT have any evidence against it

What evolution IS NOT

- was NOT contrived to undermine religion...(we tried to make sense of observations of life in a testable way).
- does NOT deny the existence of God, it is neutral; God is neither required nor eliminated. For all we know, evolution could be part of God's creation, but science cannot determine that.
- does NOT conflict with any religion, since it is only another way of trying to make sense of the natural world, based on scientific observation and critical analysis.
- Most religions have no problem with evolution, and those that do base their objections on an inaccurate view of science and evolution.
- **If these popular misconceptions about evolution are all wrong, then what IS evolution?**

QUESTION AND ANSWER

What is evolution NOT ?

What is evolution?

What evolution IS

Biological Evolution is...

- the idea that populations of species change over time.
- the idea that new species develop from earlier species by accumulated genetic mutations → descent with modification.
  - life comes from life
  - speciation proceeds with time, increasing the number of species that become increasingly different.
  - all species we see today are like the growing tips of a branching tree: close clusters of tips have most recently evolved.
- Has been **directly observed** in some species, and inferred in many others from clear independent evidence mainly in anatomy, embryology, paleontology, geology, and molecular biology.

What evolution IS

- The mechanism for **HOW** evolution happens is largely explained by natural selection.
- Natural selection is observed constantly, and its role as the main driving force of evolution (as Charles Darwin proposed) has been observed, tested and challenged many times and in many ways, and has survived largely intact.
- There's **NO** observed evidence against this as a mechanism for evolution. The Theory of Evolution by Natural Selection holds the high status of near certainty: it's a scientific theory
- The scientific Theory of Evolution by Natural Selection is so well documented by the evidence that it is as close to a scientific fact as any explanation can be.
- There are no observations of life, living or extinct, that evolution cannot explain.

QUESTION AND ANSWER

What is evolution?

Describe the 6 components of evolution

The 6 components of evolution

1. Evolution
2. Gradualism
3. Speciation
4. Common ancestry
5. Natural selection
6. Nonselective mechanisms of evolutionary change

1. Evolution

- Evolution means that a species undergoes genetic change over time as a result of mutations.
- All living organisms are descended from those that lived earlier.
- Evolution does not occur at the same rate due to the differences in evolutionary pressures experienced.
  - Example: Humans and whales have evolved rapidly but other organisms look almost identical to ancestors that lived millions of years ago.

2. Gradualism

- **Gradualism** refers to the process that is responsible in producing substantial evolutionary change over many generations (or gradually).
- This process occurs over thousands or even millions of generations.
  - Example: The evolution of teeth that occurred over thousands of generations.
- Gradualism does not imply that species evolve at a constant rate- when natural selection is strong, evolutionary change can be fast but will slow down when a species becomes well adapted to a stable habitat.

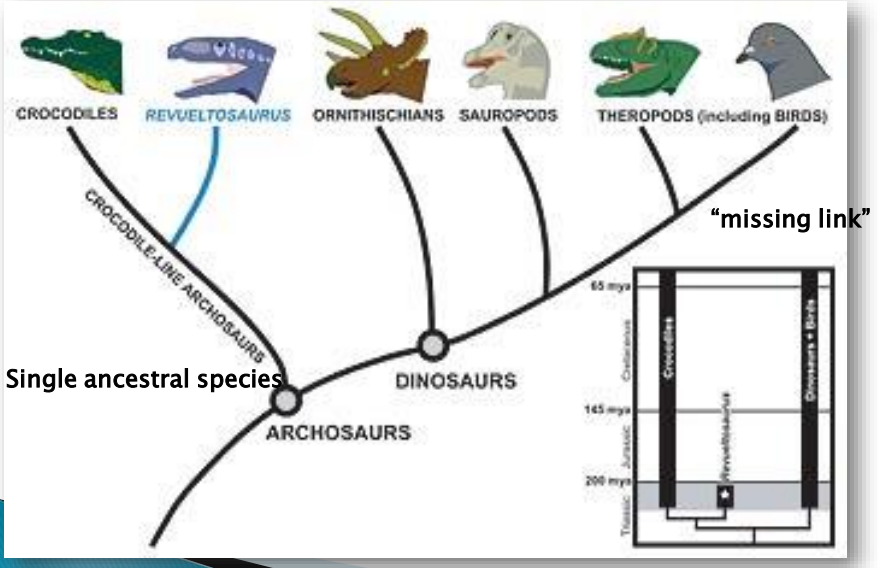
3. Speciation

- **Speciation** means that the evolution of different groups that can't interbreed- that is, groups that can't exchange genes.
- Therefore one ancestor split into two populations probably living in different places, beginning to evolve slight differences from each other.
  - Over a long time, these differences gradually grew larger. Eventually these 2 populations would have evolved sufficient genetic difference that members of the different populations could not interbreed.

Speciation (cont'd)

- Species don't have to split, in fact it doesn't happen very often.
  - Whether they do depends, on whether circumstances allow populations to evolve enough differences that they are no longer able to interbreed.
  - The vast majority of species- 99% of them- go extinct without leaving any descendents.

Phylogenetic Tree



4. Common ancestry

- This simply means that we can always look back in time and find descendants of an ancestor.
- Creatures with recent common ancestors share many traits, while those whose common ancestors lay in the distant past are more dissimilar.
- A **phylogeny (evolutionary tree)** shows the relationship of organisms to each other and a common ancestor.

5. Natural selection

- **Natural selection is the process by which organisms with variations most suited to their local environment survive and leave more offspring.**
- If individuals within a species differ genetically from one another, and some of those differences affect an individual's ability to survive and reproduce in its environment, then in the next generation the "good" genes that lead to higher survival and reproduction will have relatively more copies than the "not so good" genes.
- Over time, the population will gradually become more and more suited to its environment as helpful mutations arise and spread through the population, while deleterious one are weeded out.
- Ultimately, this process produces organisms that are well adapted to their habitats and way of life.

Natural selection (cont'd)

- Natural selection does not produce the absolute perfection achievable by a designer starting from scratch, but merely the best it can do with what it has to work with.
  - Example: Male testicles begin development in the abdomen, a developmental program that is based on our fishlike ancestors whose gonads developed, and remained completely in the abdomen. However, when the fetus is 6/7 months old, it migrates south.
- Organisms are constrained by their development and evolutionary history as evolution must build new species starting with the design of its ancestors.

Natural selection (cont'd)

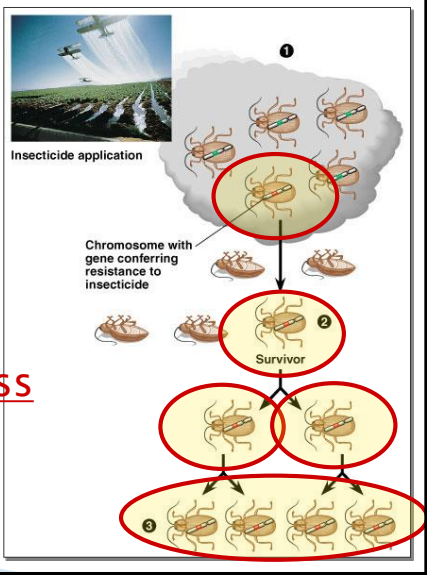
- Natural selection does not yield perfection- only improvements over what came before. It produces ***fitter***, not the *fittest*.
- The idea that natural selection acts "for the good of the species" is misguided as evolution can produce features that, while helping an individual, harm the species as a whole.
  - Example: When a group of male lions displaces the resident males of a pride, which is often followed by a gruesome slaughter of unweaned cubs.

Natural selection in a nutshell

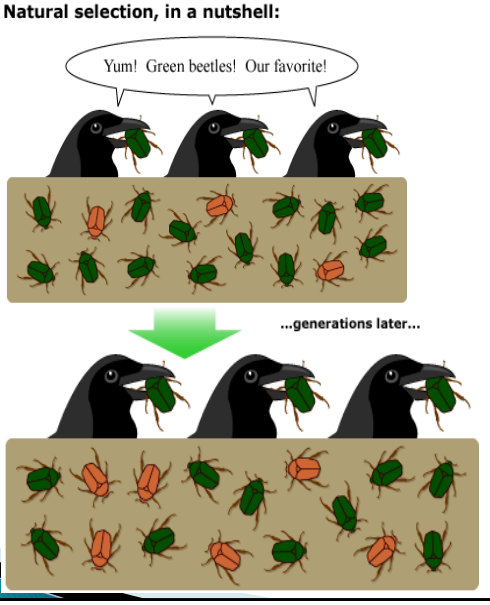
- 1. There is a diversity of genotypes and phenotypes in the environment
- 2. Organisms compete for food, living space, water, and other limited necessities of life.
- 3. Some organisms have variations that make them better suited to life in their environment (beneficial adaptations). **Adaptations is a heritable characteristic that increases an organism's ability to survive and reproduce in its environment.**
- Therefore they have adaptations that make them more fit **(fitness: how well an organism can survive and reproduce)**
- 4. Those that are more fit survive and reproduce. Those less fit eventually die (along with their genes)

Insecticide resistance

- Spray the field, but…
  - insecticide didn't kill all individuals
    - variation
  - resistant survivors reproduce
  - resistance is inherited
  - insecticide becomes less & less effective



Example of natural selection



Natural Selection

- This hypothetical population of grasshoppers changes over time as a result of natural selection.
- Grasshoppers can lay more than 200 eggs at a time, but only a small fraction of these offspring survive to reproduce.

1 The Struggle for Existence

Natural Selection

- Certain variations, called adaptations, increase an individual's chances of surviving and reproducing.
- In this population of grasshoppers, heritable variation includes yellow and green body color.
- Green color is an adaptation: The green grasshoppers blend into their environment and so are less visible to predators.

2 Variation and Adaptation

Natural Selection

- Because their color serves as a camouflage adaptation, green grasshoppers have higher fitness and so survive and reproduce more often than yellow grasshoppers do.

3 Survival of the Fittest

Natural Selection

- Green grasshoppers become more common than yellow grasshoppers in this population over time because more grasshoppers are born than can survive, individuals vary in color and color is a heritable trait, and green grasshoppers have higher fitness in this particular environment

4 Natural Selection

6. Nonselective mechanisms of evolutionary change

- Genetic drift in addition to natural selection produces evolutionary change.
- Genetic drift (which occurs in **small** populations only), may account for some non-adaptive features.

QUESTION AND ANSWER

Describe the 6 components of evolution

Explain how the changes in the peppered moth population is an example of evolution

Natural Selection Example

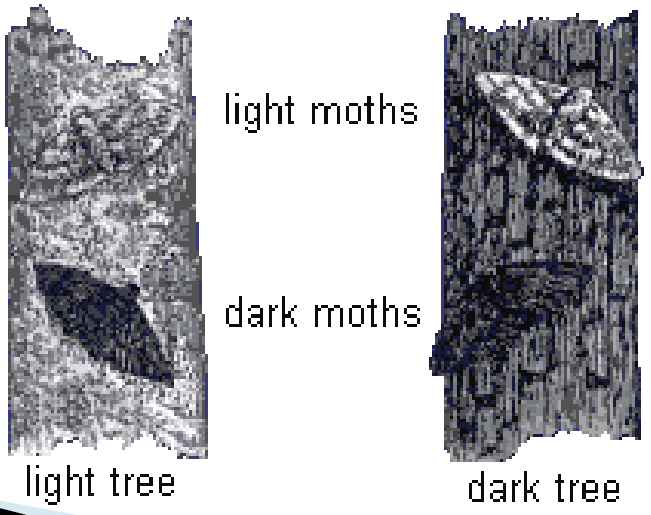
The industrial revolution

- In England in the early 1800's industry boomed
- Factories, trains, smoke and smog
- Peppered moths were dark or light colored, and the dark ones that were once rare became more common.
- Hypothesis?

The Peppered Moth

- Kettlewell tested this hypothesis
  - Released equal numbers of moths in polluted AND clean forests.
  - In industrialized areas, dark gray moth was better camouflaged.
  - They survived, had more offspring
- The population ***as a whole*** evolved to be better suited to the environment→ more gray and camouflaged→ADAPTATION!
- This is an example of microevolution

The Peppered Moth



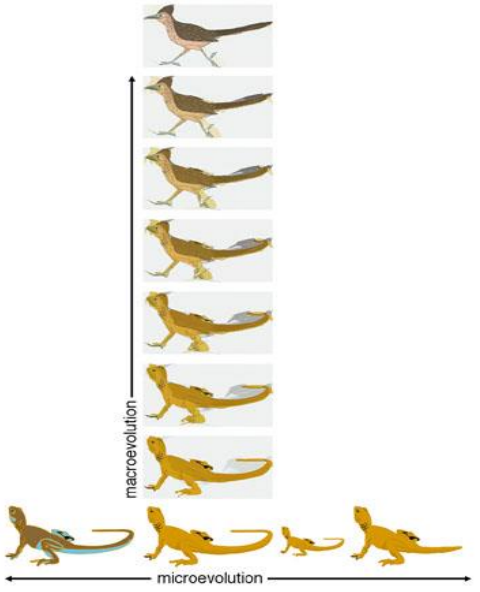
QUESTION AND ANSWER

Explain how the changes in the peppered moth population is an example of evolution

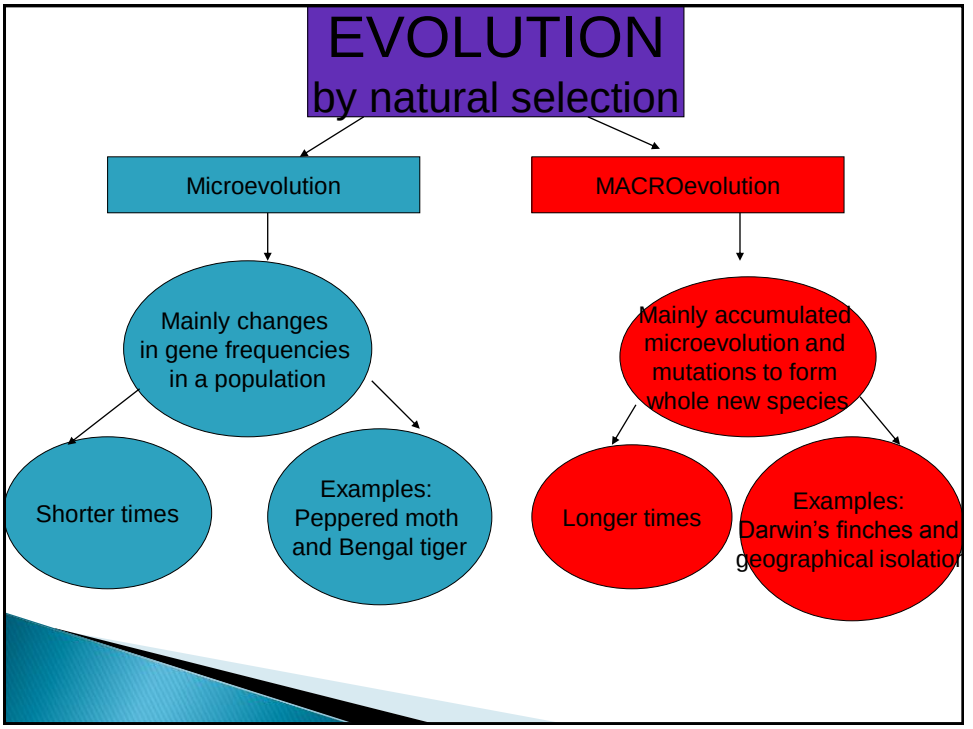
How are the types of evolution different?

Types of Evolution

- **MACROevolution:**
  - Accumulated microevolution and mutations lead to new species--speciation
  - Usually **long** time for noticeable changes to occur.
- **microevolution:**
  - Small genetic changes of a population
  - Can occur in shorter amount of time



EVOLUTION
by natural selection



QUESTION AND ANSWER

How are the types of evolution different?

How can sexual selection explain the presence of certain maladaptive traits?

How sex drives evolution

- **Sexual selection is simply selection that increases an individual's chance of getting a mate**
- The 2 forms of sexual selection:
  - **1. Direct competition between males for access to females**
    - Selection will favor any trait that promotes such victories so long as the increased chance of getting mates more than offsets any reduced survival.
    - This kind of selection produces armaments: stronger weapons, larger body size, or anything that helps win physical contests.
    - Example: The clashing antlers of deer, bloody battles of elephant seals- all of which win access to females by driving off competitors

- **2. Female choosiness among possible mates**
  - To female eyes, not all males are the same- they find some male traits and behaviors more attractive than others, so genes that produce those features accumulate in populations.
  - There is also an element of competition between males- but it is indirect: winning males have the loudest voices, the brightest colors. The winner is decided by the females.
  - Features such as bright colors, ornaments, bowers, and mating displays.
- The evolutionary difference between males and females is a matter of differential investment- investment in expensive eggs versus cheap sperm, investment in pregnancy, investment in parental care (where females alone raise the young). For males, mating is cheap; for females it's expensive.

What do females gain by choosing a particular male?

- **1. She can benefit directly-** picking a male who will help her produce more or healthier young *during the act of child care*.
  - Offspring that is better nourished, survive better, and reproduce more offspring are possible benefits.
  - Also, avoiding diseased parasites through visual cues
- **2. She can benefit indirectly-** by choosing a male who has better genes than those of other males (genes that will give her offspring a leg up in the next generation)
  - Pass on genes that make them more resistant to diseases, healthier- genetically well endowed

- **Traits that differ between males and females of a species- such as color, songs- are called *sexual dimorphism***
  - These sexually dimorphic traits in males seem to violate evolutionary theory as they waste time an energy and reduce survival.
  - It occurs because it is a novel visual stimulant, indicates the health of the male

Video:
Fly Courtship

QUESTION AND ANSWER

How can sexual selection explain the presence of certain maladaptive traits?

Essential Question

How does evolution explain the diversity in life?