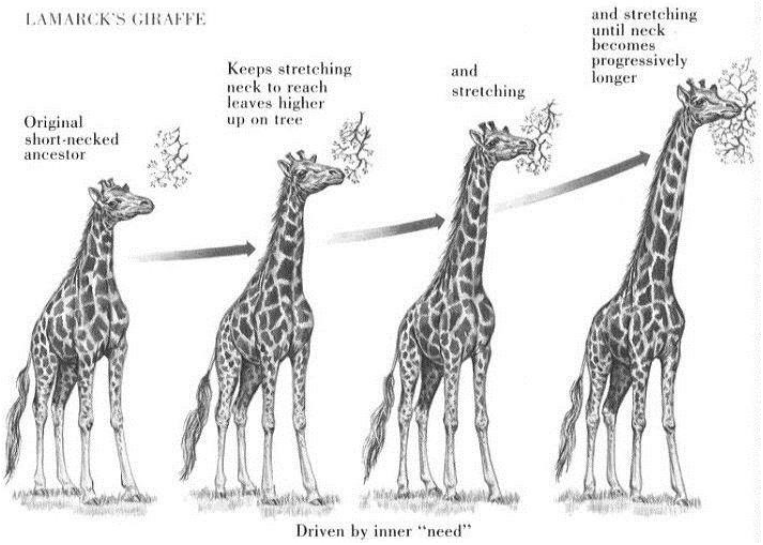
Zoology – EVOLUTION: History and Evidence

I. Origins of Darwinian Evolutionary Theory

A. **Pre-Darwinian Evolutionary Ideas**

1. Before the 18th century, speculation on origin of species was not scientific.
2. _____ portrayed a constant world after a creation event.
3. Early Greek philosophers considered some ideas of evolutionary change.
    a. _____ were recognized as former life destroyed by _____.
    c. Lacking a full evolutionary concept, the idea faded before the rise of _____.
4. Biblical account of creation became a tenet of faith.
    a. Evolutionary views were heretical.
    b. _____ calculated _____ as date of life's creation.
5. French biologist Jean Baptiste de _____ offered first complete explanation in _____.



a. He convincingly argued that fossils were remains of _____ animals.
b. Lamarck's mechanism was **inheritance of** _____.
c. He explained long necks of giraffes to stretching efforts of ancestral giraffes.
d. Lamarck's concept is _____; individuals transform their own traits to evolve.
e. In contrast, Darwin's theory is _____or due to differential survival among offspring.

6. Geologist Sir Charles _____ established the principle of _____.
    a. Uniformitarianism consists of two important principles:
        1) Laws of physics and chemistry remain the same throughout earth's history.
        2) Past geological events occurred by natural processes similar to those observed today.
    b. Natural forces acting over long periods could explain formation of fossil-bearing rocks.
    c. Earth's age must be measured in _____ of years.
        1) It is now accepted that earth is _____ years old.
        2) Life has existed on earth for more than 3.5 billion years.
    d. Geological changes are natural and without direction; both concepts underpinned Darwin.

II. Major revolutions in evolutionary thought occurred in last 150 years.

A. **First revolution - Charles Darwin**, *Origin of Species*, 1859
   1. Evolution by natural selection

B. **Second revolution** - 1930's – an intersection of concepts provides better understanding of the mechanisms of evolution.
   1. Darwinian natural selection
   2. Mendelian genetics
   3. Population genetics

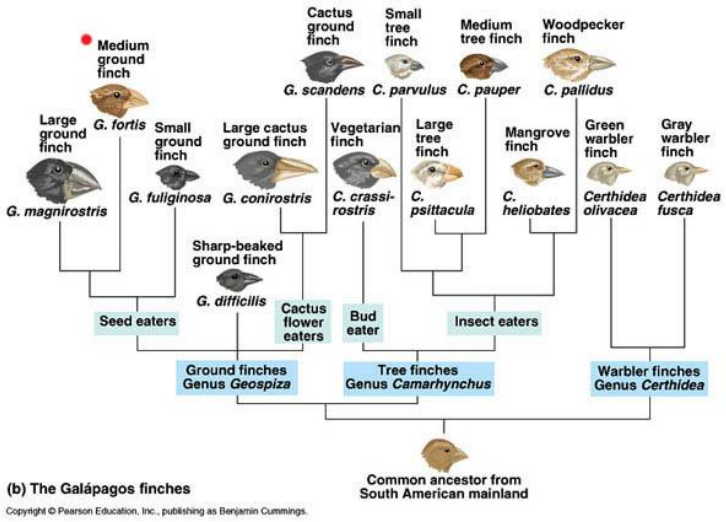
C. **Third revolution** – Now – **The Evolution of Development = "evo-devo"**
   1. Organisms with nearly identical genomes can look very different because different developmental programs created them.
   2. Regulatory genes can act as developmental switches.
   3. **Homeobox genes** (hox genes for short) - Regulatory genes that act as developmental switches. These genes determine the body plan.
      a. The genes of a Chihuahua and a Great Dane are almost identical.
      b. The incredible difference in their body size is actually due to how long the operators (master switch) of the genes controlling bone growth remained active.
   4. Impact of mutations can alter master switches.
   5. There is a similarity of master switches in plants and animals

III. **Darwin's Great Voyage of Discovery** (_____)

A. In 1831, Charles Darwin (almost 23) sailed aboard the small survey ship _____.

B. Darwin made extensive observations in the five-year voyage.
   1. Darwin collected the fauna and flora of _____ and adjacent regions.
   2. He unearthed long extinct fossils and associated fossils of South and North America.
   3. He saw fossil seashells embedded in the Andes rocks at 13,000 feet altitude.
   4. Observing earthquakes and severe erosion confirmed his views of geological ages.

C. The _____ provided unique observations.
   1. These volcanic islands are on the equator 600 miles west of _____.
   2. Each island varied in tortoises, iguanas, mockingbirds and ground finches.
   3. The islands had similar climate but varied vegetation.
   4. Island species therefore originated from South America and were modified under the varying conditions of different islands.



D. Darwin conducted the remainder of his work at home in _____.

1. In 1838, Darwin read an essay on population by Thomas R. _____.
2. Having studied *artificial selection*, a "struggle for existence" because of overpopulation gave him a mechanism for evolution of wild species by *natural selection*.
3. In 1858, he received a manuscript from a young naturalist, _____, summarizing the main points of natural selection.
4. Geologist Lyell and botanist Hooker persuaded Darwin to publish a paper jointly with Wallace's paper.
5. Darwin then rushed to publish a shorter "abstract" version in 1859: _____.
6. 1250 copies sold of first printing in one day.

IV. Darwin's Theory – Evolution Occurs by _____

A. Natural selection gives a natural explanation for origins of adaptation.

B. Darwin's theory of natural selection consists of four observations and three conclusions.

1. **Observation 1:** _____ _____.
   a) If all individuals produced survived, populations would explode exponentially.
   b) Darwin calculated that a single pair of elephants could produce 19 million offspring in 750 years. This is a SLOW breeding species!
      1) Elephant females breed at the earliest at 9 years, and bear one calf every four years until age fifty optimally. It would take a female 40 years to bear 10 calves.
2. **Observation 2:** _____ _____ _____.
   a) **Conclusion 1:** The struggle for food, shelter, and space becomes increasingly severe with overpopulation. There is competition for _____.
      1) In each generation, many individuals must die young, fail to reproduce, produce few offspring, or produce less-fit offspring that fail to survive & reproduce in their turn.
      2) Survivors represent only a small part of those produced each generation.
3. **Observation 3:** _____

_____. Individual members of a population differ from one another in their ability to obtain resources, withstand environmental extremes, escape predators, etc.

a) **Conclusion 2:** The most well-adapted (the "fittest") individuals in one generation will usually leave the most offspring. This is _____ _____: the process by which the environment selects for those individuals whose traits best adapt them to that particular environment.

4. **Observation 4:** _____ _____.

a) Darwin only noted the resemblance of parents and offspring.

b) Gregor Mendel's mechanisms of heredity were applied to evolution many years later.

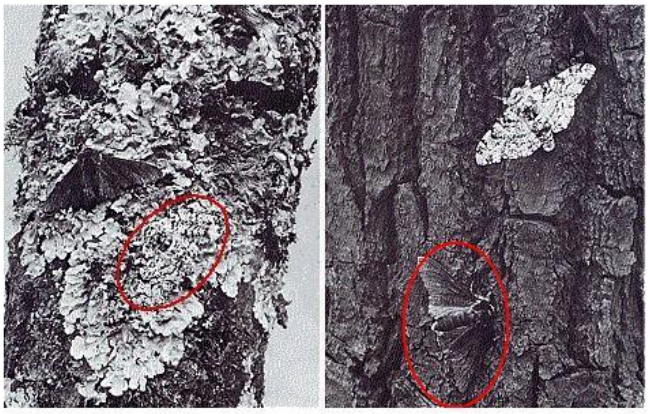
c) **Conclusion 3:** Over many generations, differential, or unequal, reproduction among individuals with different genetic makeup changes the overall genetic composition of the population. This generates new adaptations and new species.

C. Natural selection can be viewed as a two-part process: random and non-random.

1. Production of variation among organisms is random; mutation does not generate traits preferentially.
2. The nonrandom component is the survival of different traits.

D. **Microevolution** - the changes in allele frequencies from generation to generation that may accumulate over long time periods to produce new types of organisms.

Peppered Moths come in light and dark colors.



Birds eat the pepperd moths that they can see.
In areas of little pollution (to the left) trees are covered with light-colored lichens, which hides the light-colored moths. In those populations, the light color becomes more frequent in the population.
In areas of heavy pollution, the trees have no lichens. Thus, it is the dark color that is selected for.

1. We can literally see that evolution through natural selection is occurring around us today

2. Peppered moths of England & the Industrial Revolution

3. 1990's Florida's cockroaches –Combat used corn syrup (glucose) as the bait for its poison. A rare mutation, in which cockroaches won't eat glucose, became widespread after Combat was used.

4. Any pesticide, herbicide, or antibiotic & resistance is an example.

5. **Artificial selection** demonstrates that organisms may be modified by controlled breeding.

a. In a few hundred to at most a few thousand years, man has bred radically different dog breeds, from Chihuahua to Great Dane, from the wolf by selecting qualities that were found desirable & selectively breeding for them.

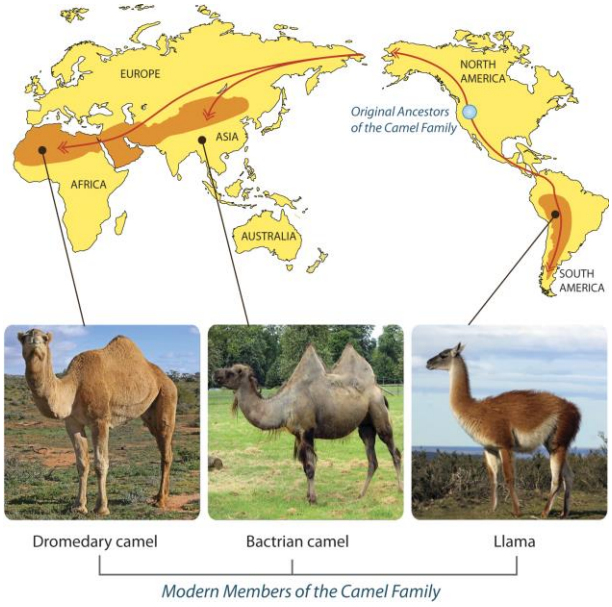
b. What man can do, cannot nature do by selecting for those individuals best adapted to that environment

E. **Macroevolution** - the larger scale changes that result in extinction and formation of new species.

V. Evidence for Macroevolution

A. **Biogeography** – the study of the distribution of organisms in space and time, can yield important information about evolutionary processes.

1. The patterns of species distribution across geographical areas can usually be explained through a combination of historical factors such as speciation, extinction, and continental drift.
2. Islands are typically geographically isolated from mainlands. This isolation can result in speciation. (e.g. The birds of the Galapagos Islands)
    a. Species on a given island may more closely resemble species on a nearby mainland, rather than species on a distantly located island with similar environmental conditions.
3. Continental drift - connections between continents dictate what species are geographically isolated or united (e.g. members of the camel family)



B. **Paleontology** - the fossil record provides evidence of evolutionary change over time. We can see how fossil forms differ from modern forms, evidence of successive change across the strata of different ages, and what organisms have become extinct.

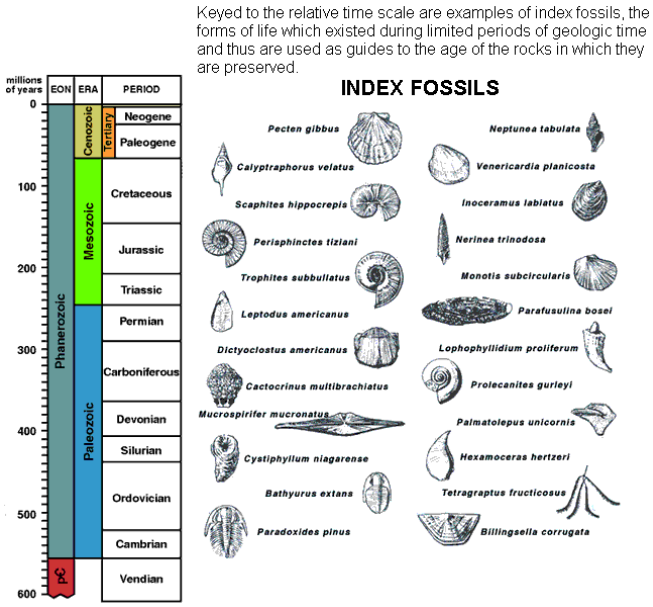
1. The living world is constantly changing in form and diversity. Change in animal life is directly seen in the 600-700 million-year animal fossil history.

Watch this fun video about the geologic time scale of earth: http://youtu.be/7PQURsc2SYs

2. A **fossil** is a remnant of past life.
    a. Insects in amber and frozen mammoths are actual remains.
    b. Teeth and bones can petrify or become infiltrated with silica and other minerals.
    c. Molds, casts, impressions and fossil excrement are also fossils.
3. Most organisms leave no fossils; the record is always incomplete and requires interpretation.
    a. The fossil record is biased because preservation is selective.
    b. Vertebrate skeletons and invertebrates with shells provide more records.
    c. Soft-bodied animals leave fossils only in exceptional conditions such as the Burgess Shale.
4. Fossils occur in stratified layers; new deposits are on top of older material.
    a. The **law of stratigraphy** dates oldest layers at the bottom and youngest at the top.

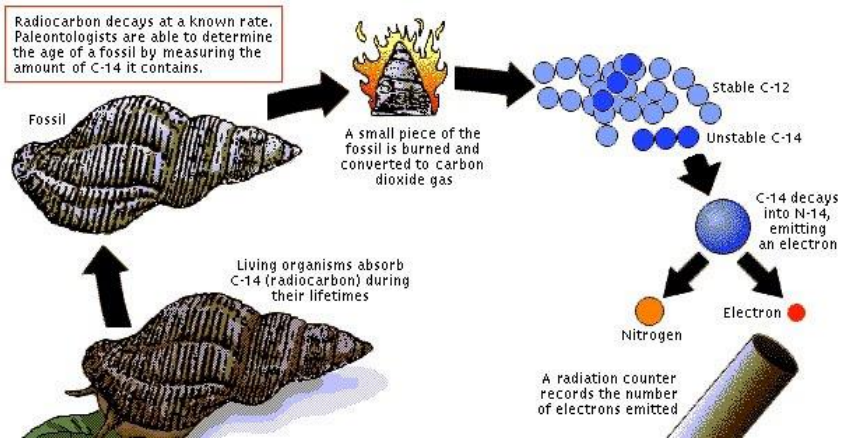
Watch this video on stratigraphy: http://youtu.be/VLBzMvsiYq8

    b. **"Index" or "guide" fossils** are "indicators" of specific geological periods.



5. Another way to determine the age of a fossil is **radiometric dating.**
    a. In the late 1940s, this dating method was developed that determines age of fossils.
    b. **Radiocarbon dating** (sometimes simply known as **carbon dating**) is a method that estimates the age of carbon-bearing materials **up to about 58,000 to 62,000 years.** Carbon dating works because most C (carbon) in the atmosphere is stable C-12. However, a small (but measurable) proportion of atmospheric C is unstable, C-14. The **half-life of carbon-14 is 5,730 ± 40 years.** That means that 5,730 years after death, half of the C-14 in your fossil will have decayed into stable N-14
        1) Carbon is incorporated into plants when they use CO_2 to make sugar. During its lifetime, an animal will incorporate this C (carbon) in its body from eating plants. Once the animal dies, it no longer adds C to its body.
        2) The unstable C-14 begins to steadily break down into stable N-14. The amount of C-14 remaining in the fossil tells us how long the animal has been dead with an extreme degree of accuracy.

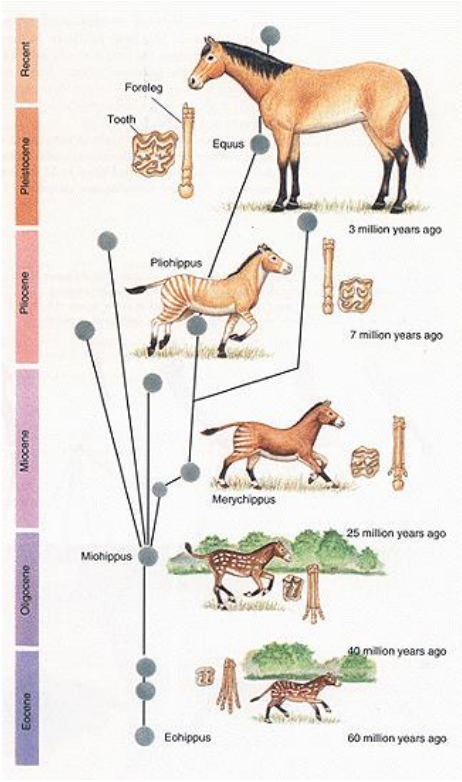
Watch this video demonstrating carbon dating: http://youtu.be/udkQwW6aLik



    c. Radioactive decay of naturally occurring elements is independent of heat and pressure.
    d. Potassium-Argon Dating – to date even older fossils
        1) Potassium-40 (40K) decays to argon-40 (40Ar) and Calcium-40 (40Ca).

2) Half-life of potassium-40 is 1.3 billion years; half of remainder will be gone at end of next 1.3 billion years, etc.
3) Calculating the ratio of remaining potassium-40 to amount originally there provides mathematically close estimate of age of deposit.

6. Evolutionary Trends - Fossil record allows observation of evolutionary change over broad periods of time.
    a. Animals species arise and go extinct repeatedly.
    b. Animal species typically survive 1-10 million years; there is much variability.
    c. **Horse Evolution Shows Clear Trends**
        1) From Eocene to Recent periods, genera and species of horses were replaced.
        2) Earlier horses had smaller sized and fewer grinding teeth, and more toes.
        3) Reduction in toes and increase in size and numbers of grinding teeth correlate with environmental changes.



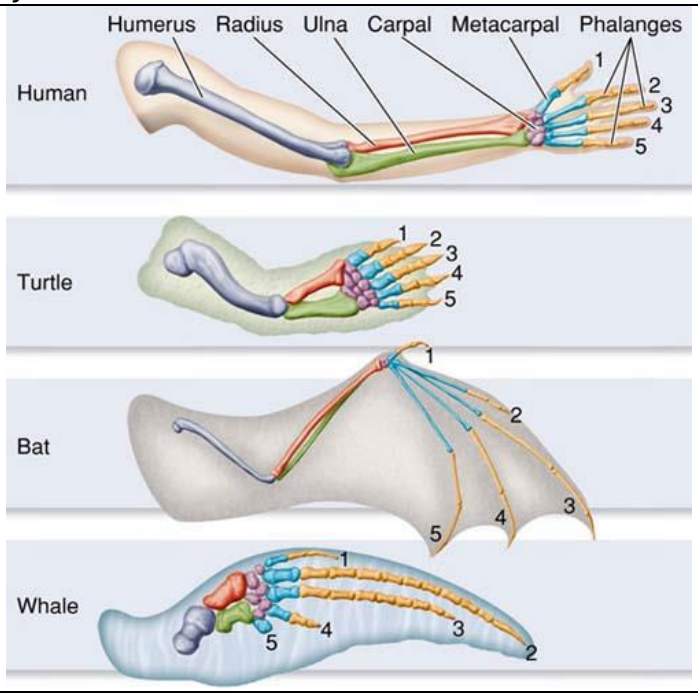
c. Comparative Anatomy –

1. All plants and animals descending from a common ancestor is **divergent evolution**.
    a. **Homologous structures** – structures that may differ in function but **t**hat have similar anatomy due to descent from a common ancestor.

1) For example, vertebrate limbs show the same basic structures (one upper arm bone, two forelimb bones, wrist bones, and finger bones) modified for different functions (swimming in penguins & whales, flight in bats & birds, running in dogs & sheep, grasping in humans & shrews)

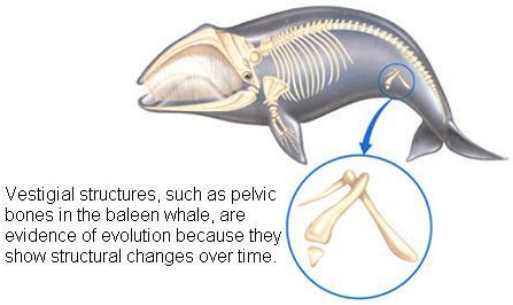
2) Darwin saw homology as major evidence for common descent.

3) It is inconceivable that nearly the same bone arrangements could be ideal for such different functions, as would be expected if each animal were created separately. **This is exactly what we would expect if the forelimbs of these animals evolved from a common ancestor.**



b. **Vestigial structures** – structures that serve no apparent purpose in modern animals. "Evolutionary baggage" inherited from an ancestor.

Vestigial Structures



Vestigial structures, such as pelvic bones in the baleen whale, are evidence of evolution because they show structural changes over time.

1) For example, vampire bats have molar teeth even though they live on a diet of blood & therefore don't chew their food.

2) Pelvic bones exist in whales and certain snakes.

3) The appendix is a vestigial structure in humans

2. Through **convergent evolution**, natural selection has shaped unrelated organisms into similar forms in similar environments.

1) Natural selection predicts that, given similar environmental demands, unrelated organisms might independently evolve superficially similar structures.
2) Such outwardly similar body parts in unrelated organism, called **analogous structures**, often have completely different internal anatomy because they are not derived from a common ancestor.
3) For example: wings of flies & birds; also fat-insulated, streamlined shapes of seals (mammals) & penguins (birds)

Convergent Evolution: Analogous Structures

The shark (a fish), dolphin (a mammal), and ichtyosaur (a reptile) all have a similar torpedo shapes to slice through water. These analogous shapes evolved independently as similar solutions to a shared environemental challenge.

D. **Molecular Biology** – We can look in modern animals for common sequences of DNA that have been inherited from a shared ancestor. This helps us determine patterns of relatedness.

1. The amino acid sequences of proteins are remarkably similar across a huge spectrum of species.
2. The chromosomes of chimpanzees & humans are extremely similar, showing that these species are closely related.

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ARMADILLO      ----------------TGCTACTAATAT-----T-
COW            GCCTCTCTTT-----------CTGCCCTGCAGGC-
HORSE          GTCACAATTTAGGAAGTGCCACTGGCCT-----C-
CAT            GTCACAGTTTAGGGGGTACTACTGGCAT-----C-
DOG            GTCACAATTTGGGGGATACTACTGGCAT-----C-
HEDGEHOG       GTCATAGTTT----GATTATATGGGCTT-----CT
MOUSE          GTCACAGTTTGGAGGATGTTACTGACAT-----C-
RAT            GTCACAATTTGGAGGATGTTACTGGCAT-----C-
RABBIT         ATCACAATTTGGGGAACACCACTGGCAT-----C-
LEMUR          ATCACAA-TTGGGGG-TGCCACGGTCCT-----C-
MOUSE-LEMUR    ATCACAG-TTGGGGGATGCCACTGGCCT-----C-
VERVET         GTCAGAATTTGGGGGATGCTTCTGGCTC-----T-
MACAQUE        GTCAGAATTTGGGGGATGCTTCTGGCTC-----T-
BABOON         GTCAGAATTTGGGGGATGCTTCTGGCTC-----T-
ORANGUTAN      GTCACGATTTGGGAGATGCTTCTGGCTC-----G-
GORILLA        GTCACGATTTGGGGGATGCTTCTGGCTC-----A-
CHIMP          GTCACGATTTGGGGGATGCTTCTGGCTC-----A-
HUMAN          GTCACGATTTGGGGGATGCTTCTGGCTC-----A-
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E. Developmental Patterns – shared embryological stages are indicative of a shared evolutionary ancestry.