Biology 20 – Chapter 5 ***Name:***
Taxonomic Systems – Reading Assignment

1. What are the two main purposes for having a biological classification system? (pg 135)

identifying organisms
recognizing groupings of living things

2. What is taxonomy? (135)

science of classifying organisms

3. a. Who came up with our current system for classifying living organisms? (135)

Carl Linneus

b. What is this system based on? (135)

physical and structural features

4. What is binomial nomenclature? (135)

2 part naming system made up of genus name and species name

5. Why is the latin language used for classification?

common language for all scientists

6. Define genus. (135)

first part of a scientific name

includes many species

7. Define species. (135)

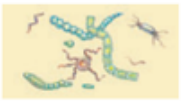
group of organisms that look alike and can interbreed under natural conditions to produce fertile offspring

8. What are the seven levels of classification? (135)

King Phillip Came Over For Good Soup

Scientific classification	
Kingdom:	Animalia
Phylum:	Chordata
Class:	Mammalia
Order:	Carnivora
Family:	Canidae
~~Subfamily:~~	~~Caninae~~
~~Tribe:~~	~~Canini~~
Genus:	*Canis*
Species:	***C. lupus***

Table 2 A Six-Kingdom System of Classification

	Kingdom	General characteristics	Cell wall	Representative organisms
	1. Eubacteria	• simple organisms lacking nuclei (prokaryotic) • either heterotrophs or autotrophs • all can reproduce asexually • live nearly everywhere	often present (contains peptidoglycan)	bacteria, cyanobacteria
	2. Archaebacteria	• prokaryotic • heterotrophs • live in salt lakes, hot springs, animal guts	present (does not contain peptidoglycan)	methanogens, extreme thermophiles, extreme halophiles
	3. Protista	• most are single-celled; some are multicellular organisms; eukaryotic • some are autotrophs, some heterotrophs, some both • reproduce sexually and asexually • live in aquatic or moist habitats	absent	algae, protozoa
	4. Fungi	• most are multicellular • all are heterotrophs • reproduce sexually and asexually • most are terrestrial	present	mushrooms, yeasts, bread moulds
	5. Plantae	• all are multicellular • all are autotrophs • reproduce sexually and asexually • most are terrestrial	present	mosses, ferns, conifers, flowering plants
	6. Animalia	• all are multicellular • all are heterotrophs • most reproduce sexually • live in terrestrial and aquatic habitats	absent	sponges, worms, lobsters, starfish, fish, reptiles, birds, mammals

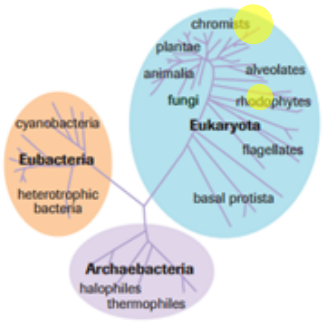


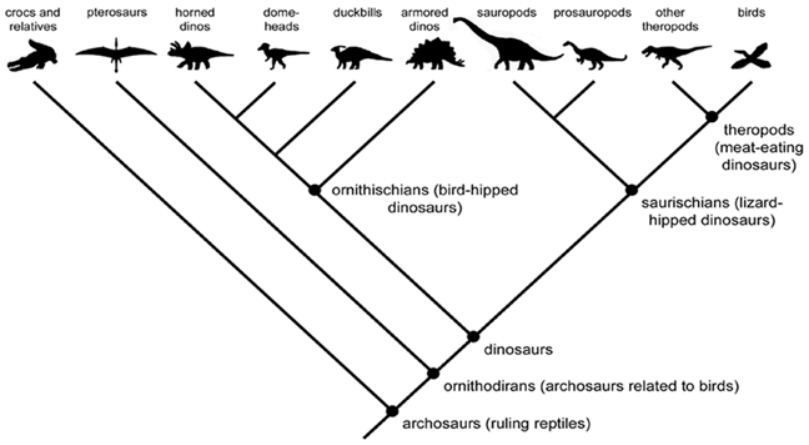
Figure 7 A three-domain system of classification

10.Define phylogeny. (pg 138)

The history of the evolution of a species or a group of species

11.What is a phylogenetic tree? (pg 138)

a branching diagram showing the relationships between groups of organisms



Lesson 1 – Review

1. Describe a situaon in which classificaon affects your life.

2. What is meant by the term binomial nomenclature?

3. Indicate the advantage of using a Lan name over a common (e.g., English) name. Provide at least one example.

4. List, in order, the major levels of classificaon, starng with kingdom.

The major levels of classificaon are kingdom, phylum, class, order, family, genus, and species.

5. Why is the classificaon of organisms important?

6. Discuss the importance of the use of scienfic names in the study of biology.

7. Why is phylogeny somemes called the foundaon of taxonomy?

8. Which of the kingdoms is at the boom of a phylogenec tree? Why is it placed there?

The kingdom Archaebacteria is at the boom of a phylogenec tree because bacteria-like fossils are believed to be evidence that bacteria are the oldest forms of life. Archaebacteria are thought to be the organisms from which eubacteria have originated.

9. The following is a list of some Lan (Lat.) and Greek (Gr.) words and their English definions:

• alopekos (Gr.): fox	• alpinous (Lat.): mountain
• felis (Lat.): cat	• lagos (Lat.) or lepus (Gr.): rabbit
• articus (Lat.): arctic	• aquaticus (Lat.): found in water
• pous (Gr.): foot	• mephitis (Lat.): bad odour
• canis (Lat.): dog	• rufus (Lat.): reddish

Match each scienfic name with the correct common name.

(a) *Felis concolor*	(i) arctic shrew
(b) *Sorex arcticus*	(ii) swamp rabbit
(c) *Canis rufus*	(iii) skunk
(d) *Mephitis mephitis*	(iv) red wolf
(e) *Alopex lagopus*	(v) alpine chipmunk
(f) *Eutamias alpinus*	(vi) arctic fox
(g) *Sciurus arizonensis*	(vii) mountain lion
(h) *Sylvilagus aquaticus*	(viii) Arizona grey squirrel

10. Use the informaon in Table 3 to answer the following quesons.

(a) Which of the species are the most closely related? Explain.

The most closely related species are the mink, short-tailed weasel, and ferret because they are all of the same genus.

(b) Is the river oer more closely related to the muskrat or the weasel? Why?

The river oer is more closely related to the muskrat than the weasel as they are of the same family

(c) Is the groundhog more closely related to the chipmunk or the ferret? Why?

The groundhog is more closely related to the chipmunk than the ferret because they are of the same family.

(d) Which of the species is (are) the closest relave (s) of the squirrel? Explain.

The closest relaves of the squirrel are the groundhog and chipmunk as they are of the same family.

Table 3 Names of Some Common Mammals

Common name	Scientific name	Family
red squirrel	*Tamiasciurus hudsonicus*	Sciuridae
shorttail weasel	*Mustela erminea*	Mustelidae
groundhog	*Marmota monax*	Sciuridae
mink	*Mustela vison*	Mustelidae
eastern chipmunk	*Tamias striatus*	Sciuridae
river otter	*Lutra canadensis*	Mustelidae
fisher	*Martes pennanti*	Mustelidae
muskrat	*Ondatra zibethica*	Cricetidae
black-footed ferret	*Mustela nigripes*	Mustelidae

Biology 20 - Chapter 5 - Lesson 2 - Evidence for Evolution

- Today's species that exist have evolved from ancestral ones.

- This theory of evolution is supported by many different types of evidence collected by scientists

1. Evidence from Fossils

- **paleotology** is the study of fossils

- fossils provide scientists with direct physical evidence of past life

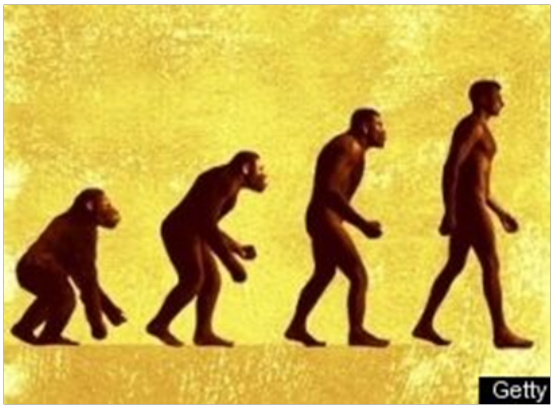
- 3 important patterns are seen when fossils are examined

1. Different species lived on earth at different time in the past

2. The complexity of living organisms has generally increased over time

    - seen by looking at fossils of similar species from different time periods

3. Living species and closely matching fossils are found in the same geographical area



- The age of a fossil can be determined in two ways

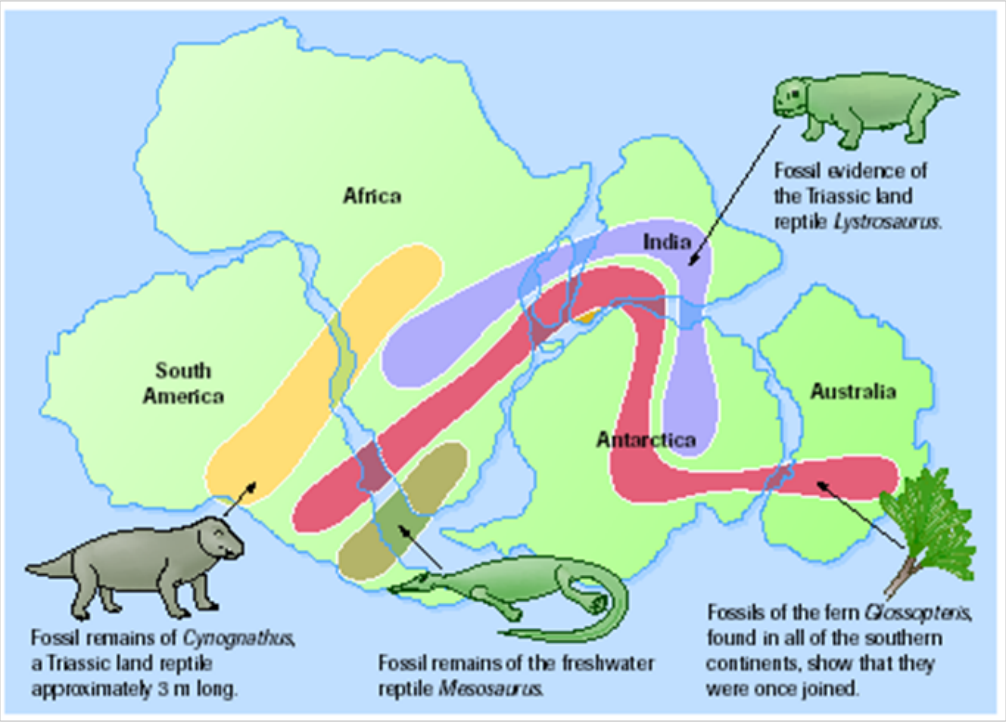
- What layer it is found in relative to other fossils
- By using **radiometric dating** (pg 141-142)

Evidence from Biogeography

- **Biogeography** explores the variation and distribution of life over Earth's surface, both today and in the past.

- 225 million years ago, all earths land existed as one land mass called **Pangea**

- The slow drift of Earth's tectonic plates eventually separated the ancient landmasses into the continents we see today.



- Fossils older than 225 million years are found on many different continents

- Fossils younger than approx 150 million years are only found on one continent

    - This tells us that the species evolved after the break up of the continents

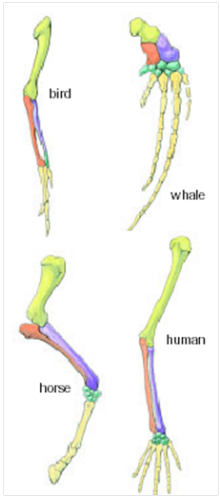
- Remote islands (like Hawaii) show us that many new species have evolved from the first organisms that inhabited the island

    - Hawaii 1729 native species originated from only 272 original species

Evidence from Anatomy

- **homologous** features - similar structure, but not similar function

  - ex. The forelimb of a bird, whale, horse and human
  - suggests that they all evolved from a common ancestor

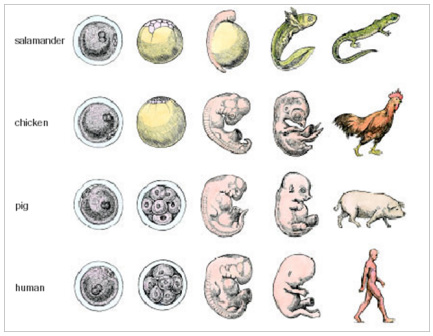


- **analogous** features - similar in appearance and in function, but do not appear to have the same evolutionary origin

  - ex. Birds wing and an insects wing

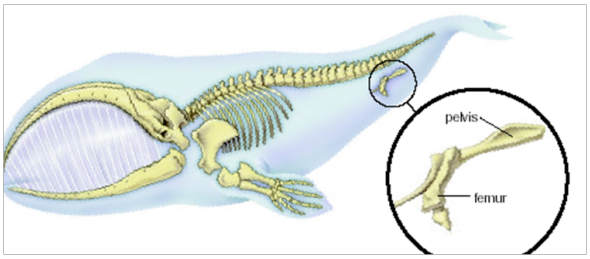
- evolutionary relationship among species is also evidenced in embryonic development

  - In the early weeks of development, human embryos possess a tail and gill slits, similar to those in chicken and fish embryos.
  - embryonic tail serves no function in humans and later forms the tailbone.
  - gill slits become modified in both humans and birds to form various internal structures, including bones of the inner ear.



- **vestigial** features - structures which no useful function

  - ex. modern species of whales and snakes have vestigial hip and leg bones
  - evidence that suggests they evolved from ancestors that walked on four limbs
  - thought that they once served a purpose in ancient ancestors
  - Blind cave salamanders have empty eye sockets, suggesting that they evolved from salamanders with fully functioning eyes.



Evidence from Biochemistry

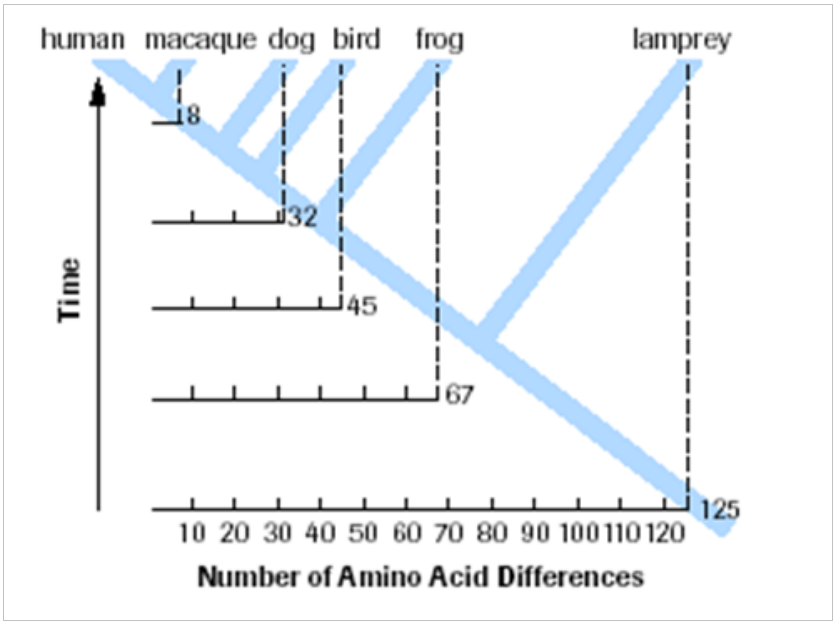
- Evidence for evolution has also been found by comparing biochemical characteristics of different species.

- Over time, similar proteins in different species become increasingly different in terms of their amino acid sequences.

- hemoglobin is an oxygen-carrying **protein** present in all vertebrates.

- Different species have a slightly different sequence of amino acids in the protein molecule

- The differences were greater between species that were less similar overall, such as a macaque and a lamprey



- Geneticists have found large numbers of both homologous and vestigial *genes* in the DNA of virtually all species.

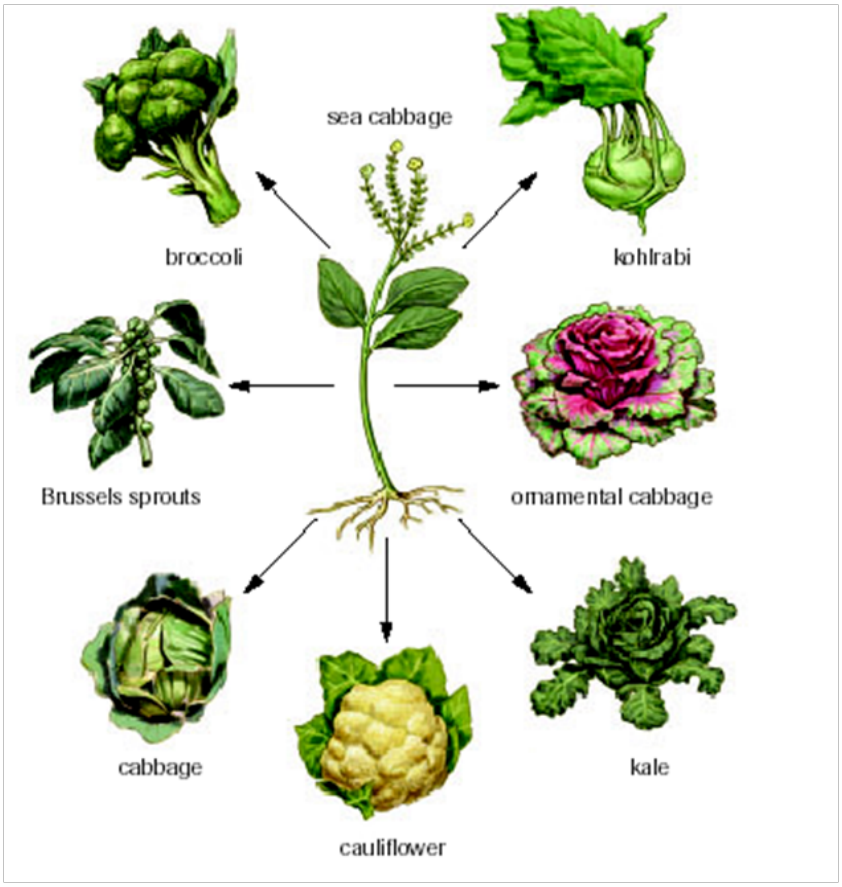
- We have a defective copy of gene that would allow us to create our own vitamin C

Evidence from Artificial Selection

- Artificial selection is another word for plant and animal breeding, in which people breed individuals with desired characteristics in order to get offspring with those same characteristics.

- Cauliflower, broccoli, kale, and cabbage are all the same plant

  - Over the centuries, farmers and plant breeders selected characteristics of a single plant species, the sea cabbage, to produce a range of edible and ornamental varieties



- The fact that humans can use artificial selection to produce such dramatic changes in species over relatively short periods of time provides compelling evidence that similar and even more dramatic changes occur in nature over millions of years and countless generations

Lesson 2 – Review Quesons

Read pgs 140-149

1. Explain how the following paerns of fossils offer compelling evidence for evoluon:

   (a) the relaonship between the age of fossils and the kinds and complexity of fossils

   Older fossils are generally structurally less complex. Also, there generally seem to be fewer species as we go backwards through the fossil record.

   (b) the relaonship between the geographical locaon of both fossils and living species

   Fossils of some species, parcularly older fossils, can be found in many different connents, whereas living species tend to be found in the same geographic region. This is because the fossils were formed before the break-up of the connents.

2. Would you expect to find more unique species on remote islands, such as Iceland, or islands that are close to a large landmass, such as the Queen Charloe Islands? Give reasons for your answer.

Biogeography shows us that isolaon allows for greater diversity in evoluon. An island that is close to the mainland is not isolated. There is sll migraon. The island is sll part of the mainland's gene pool. The remote island has much less gene flow (migraon) with the mainland. It is more isolated and therefore is more likely to result in the evoluon of unique species.

3. Brainstorm a list of living plants and animals that you think might be able to reach the Hawaiian Islands from the coast of Brish Columbia. Be prepared to defend your choices.

Animal species that could reach Hawaii from B.C. should be able to fly (birds, bats, and flying insects) or can survive in the water (crabs, fish, sea mammals). Plants would either have to be water plants, such as kelps and sea grasses, or have spores and seeds that could survive the journey. Many plants have small wind-dispersed seeds or seeds that travel on or in birds. Students may suggest that with current world trade and Hawaii being a busy tourist spot, any species could get to Hawaii by hitchhiking with humans.

4. The shells of crabs and turtles serve a similar purpose. Are they homologous or analogous traits? What evidence did you use to reach your conclusion?

Crab and turtle shells are analogous structures; they evolved from different structures. Crabs and turtles have more differences than similaries. They are not closely related.

5. Would you consider human body hair to be a vesgial feature? Support your answer.

Human hair sll has some funcon; therefore, it is not vesgial. Head hair gives us some protecon from the sun. Facial hair may play a role in sexual selecon. Body and pubic hair does not appear to have a modern funcon.

6. Examine Figure 9. Each of these series of leers represents the paral sequence of amino acids for the same type of protein in each of six different species. Each leer represents a specific kind of amino acid. Highlighted leers show differences in the sequence as compared to that of the chicken. The order and type of each amino acid is coded by inherited genec informaon. Therefore, based on evoluonary theory, we would expect more closely related species to have more similar sequences.

   Based on this evidence, compare each sequence to that of the chicken, and match each species with its most probable sequence.

Species: tuna, turtle, dog, screwworm fly, penguin.

chicken	GDIEKGKKIFVQGKCSQCH
_____	GDVEKGKKIFVQGRCAQCH
_____	GDIEKGKKIFVQGKCSOCH
_____	GDVAKGKKTFVQGKCAQCH
_____	GDVEKGKKIFVQGKCAQCH
_____	GDVEKGKKIFVQGKCAQCH

Figure 9

Chapter 5 - Lesson 3 - The Making of the Theory of Evolution

Lamarck's Theory

- Jean-Baptiste Pierre Antoine de Monet Chevalier de Lamarck

- He presented the first theory of evolution that included a *mechanism* (a way that change occurred)

- he believed that new, very simple species were continually being created by **spontaneous generation**, and then gradually became more complex.

- He believed that organisms had a "force" or "desire" that led them to change for the better

o organisms must be able to produce new parts to satisfy these needs and become better adapted to their environment.

- Lamarck thought that the **use** and **disuse** of certain structures could be passed on to the offspring

- **Inheritance of acquired characteristics** - ***false*** idea that features organisms acquire during their life time would be passed on to their offspring

- Much of Lamarck's work was incorrect but, he did recognize that the environment played a role in driving evolutionary change

Darwin's Theory

- Charles Darwin travelled the world for 5 years (1831-1836) on the HMS Beagle

- From his observations and the observations and ideas from others, Darwin then put together a workable theory of evolution by **natural selection**.

Table 1 The Theory of Evolution by Natural Selection

Observation 1	Individuals within any species exhibit many inherited variations.
Observation 2	Every generation produces far more offspring than can survive to reproduce.
Observation 3	Populations of species tend to remain stable in size.
Inference 1	Individuals of the same species are in a constant struggle for survival.
Inference 2	Individuals with more favourable variations are more likely to survive and pass these variations on. Survival is not random. *This* is natural selection.
Inference 3	Since individuals with more favourable variations contribute proportionately more offspring to succeeding generations, their favourable inherited variations will become more common. *This* is evolution.

Natural Selection

- Darwin's theory is based on a very simple set of observations and logical reasoning.

    - He observed that all species exhibited **heritable variations**.

    - He reasoned that, because of those differences, some individuals are better adapte to **survive** and **reproduce** than others are.

    - Over time, the inherited traits that provided the survival advantage would become more common in the population.

    - The population would have evolved.

- This evidence from paleontology, geology, biogeography, anatomy, and artificial selecti is consistent with this idea.

- it was not until the early 1900s that scientists formulated a reasonable explanation, or theory, that could explain *how* such change occurred-the *mechanism* of evolution

Sources of Inherited Variation

- now we will look at how variations in organisms occur, and how they get passed down from generation to generation

- Remember, Darwin's theory of natural selection states that individuals that are better adapted to their environment will contribute more offspring to the next generation.

  - These offspring have traits similar to their parents, and so will in turn be better adapted.

  - Over time, natural selection leads to a change in the traits of the species as a whole (evolvution)

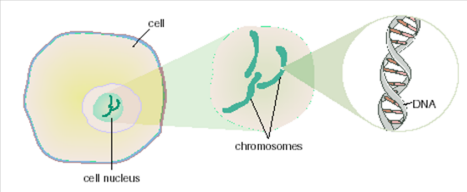
- Variability in a species may arise from two biological processes:

  - mutations

  - sexual reproduction.

Mutations

- DNA is found organized into **chromosomes** in the **nucleus** of a cell



- DNA is composed of long sequences of the four nucleotide bases-adenine (A), thymine (T), cytosine (C), and guanine (G).

- The order that the bases are in are like a code, which, when translated by the cell, gives an organism specific inherited traits.

- Genes are segments of DNA that code for specific traits.

- Mutations are random changes in the DNA itself, and they provide a continuous supply of new genetic information.

- Mutations can be caused environmental factors like radiation or chemicals, or by errors made when cell are reproducing

- Mutations are relatively rare in individuals

- In large populations reproducing over many generations, however, the number of mutations is substantial.

- The effects of a mutation depend on what DNA sequence is altered and how it is affected

  - A neutral mutation has no immediate effect on an individual's reproductive success.

  - A harmful mutation reduces an individual's fitness.

  - A beneficial mutation gives an individual a selective advantage.

  - Most mutations are neutral or harmful in nature.

Table 1 Mutation Misconceptions

Misconception	Accepted Understanding
Mutations occur when "needed," in response to environmental challenges.	Mutations occur at random, with harmful mutations being more common than beneficial mutations. There is no design to it.
Since harmful mutations are more common than beneficial mutations, they can accumulate and the species will steadily degrade.	Harmful mutations are *selected against* and therefore do not accumulate over the generations. The environment favours the fittest organisms. Harmful mutations can reduce or even eliminate the individual's chance of reproductive success.
Since mutations are random or chance events, then evolution is just pure chance.	Although beneficial mutations are rare, they are *selected for* and may accumulate over the generations. Beneficial mutations often give individuals improved survival and reproductive success.

Variation Through Sexual Reproduction

- In sexual reproduction, the offspring are never identical to the parents or to other siblings (except for identical twins).

- Sexually reproducing species therefore have many traits on which natural selection can act.

- Why are sexually-reproducing species so variable? There are three reasons.

1. Sexually-reproducing species have two copies of each gene. Each copy of the gene may be identical or different.

    - there are two parents. Both parents contribute one copy of each gene to the offspring. An offspring therefore inherits one copy of each gene from one parent and one copy from the other parent.

    - The offspring therefore has a different combination of genes than either parent, and therefore will have its own unique set of traits.

2. The assortment of genes that an offspring inherits from either parent is determined randomly.

    - Each sibling therefore has a unique combination of genes, and so siblings from sexual reproduction are not identical to each other. (Identical twins are an exception to this.)

    - Say that a large, black male dog is crossed with a small, brown female dog. A puppy from this cross might inherit any combination of these traits. For example, one puppy might be a large, brown female while another might be a small, black male. (There are other combinations as well.)

    - The greater the number of genes a species has, the larger the number of combinations and the greater the genetic variability of the species as a whole.

3. Sexually reproducing species choose different mates. This process is not always random, but each combination of parents will give rise to different combinations of genes and traits in the next generation.

    - In a small population of 1000 males and 1000 females, there are 1 million different possible mating pairs.

Lesson 3 – Review

Read pgs 150-156

1. Make a two-column chart with the headings “Inherited traits” and “Acquired traits.”

(a) In each column, write examples of your own traits (these can be physical or behavioural).

1. Chart for inherited and acquired traits in humans

Inherited traits	Altered: yes/no and how	Acquired traits	Altered: yes/no and how
Height	Yes, decalcification and osteoporosis can cause older adults to shrink	Knowledge	Yes, I can forget if I don't practice and can add to by further study
Skin colour	Yes, tanning and tattoos	Weight	Yes, I can diet and exercise or not (weight has a genetic component but can be altered by the environment)
Eye colour	No	Hair style	Yes, hair can be cut, dyed, and styled at will
Number of fingers per hand	Yes, can decrease due to amputation but cannot increase	Strength	Yes, lifting weight will increase strength and muscle mass
Startle reflex	No	Endurance	Yes, running regularly will improve endurance, whereas smoking will decrease it
A four-chambered heart	No		

(b) Which, if any, of your inherited traits could be altered during your life? How?

(c) Which, if any, of your acquired traits can be passed on to your offspring? How?

None of the acquired traits can pass on genecally to offspring.

2. Aer returning from his famous voyage, Darwin began to believe that species could change. What steps did he take to gather evidence to support this possibility?

Darwin made extensive observaons at the me of his voyages. When he returned, he connued to ponder his evidence and perform experiments. He also read the current research in the field. Darwin also had correspondence with Alfred Wallace, who independently derived a similar theory of evoluon.

3. Describe the impact that the principles in Malthus’s essay had on Darwin’s thinking.

The paper by Malthus made Darwin realize that there must be compeon between individuals of a populaon to survive and reproduce given limited resources.

4. In some wild deer populaons, selecon by humans favours the survival of smaller males, since large bucks are preferenally hunted.

(a) What would you expect to happen to the genec makeup of this populaon over me?

The arficial selecon of humans has put pressure on large males and favours smaller males. We would expect for the gene pool to show this in future generaons, with fewer and fewer large males being born. The “large” trait could eventually be eliminated from the populaon.

(b) In these populaons, will mutaons for “small size” occur more oen than for “large size”? Explain.

Mutaon rate is unchanged by natural selecon.

5. What key informaon regarding variaon was missing in Darwin’s explanaon of the evoluon of species?

Darwin was unaware of the source of variaon—sexual reproducon and mutaon.

6. Compare and contrast the contribuons of sexual reproducon and mutaon in producing variaon within populaons. Consider both short- and long-term influences.

Short-term variaon is derived from the shuffling of genec combinaons through sexual reproducon. Long-term variaon in a populaon is achieved by the introducon of new genes by mutaon.

7. Following their inial contact with non-indigenous people, many populaons of indigenous peoples suffered devastang losses from previously unknown diseases. How might evoluonary biology account for their low resistance to these diseases?

Indigenous populaons had never been exposed to these diseases, so their populaon did not contain large numbers of people with resistance to these diseases. The disease acts as a selecng agent. Aer several generaons of exposure, indigenous people have evolved a resistance similar to that of the European selers.

Chapter 5 - Lesson 4 - Speciation

- **Speciation** - the formation of a new species

- A species can be thought of as a population of individuals who are reproductively isolated

  - not capable of breeding with individuals of other species

- Most new species are believed to arise by a three-step process called **allopatric** speciation

  - Step 1: A physical barrier separates a single interbreeding population into two or more groups that are isolated from each other.

    - Any mutations that occur in one of these isolated groups are not shared with the other population

  - Step 2: Natural selection works on the separated groups independently, resulting in inherited differences in the two populations.

    - In other words, the populations evolve independently.

    - Differences in selective pressures will be greater if the populations experience pronounced differences in their environments.

  - Step 3: In time, accumulated physical and/or behavioral differences between the populations become so pronounced that the groups, should they be reunited, would no longer be sexually compatible.

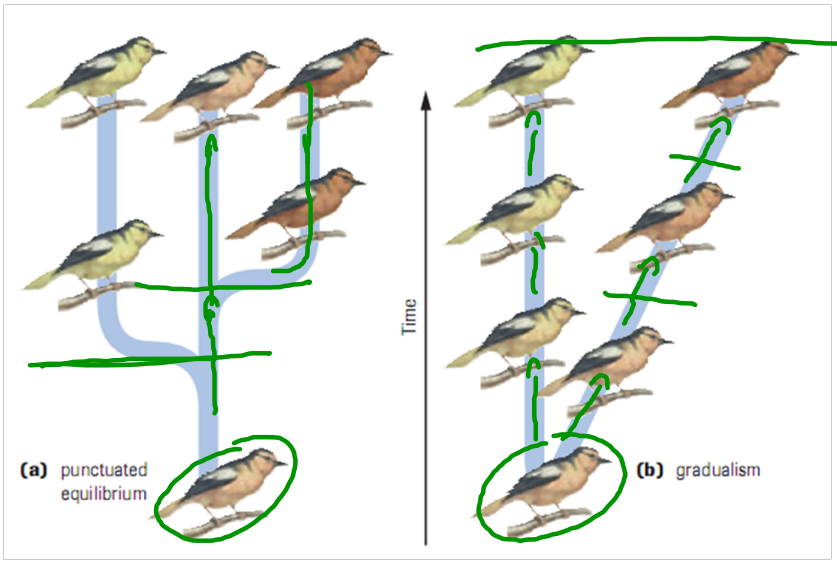
    - At this point, they have formed two or more distinct species

- Physical barriers range in size from entire mountain ranges, glaciers and oceans to river channels and canyons

- **<u>theory of punctuated equilibrium</u>** - the idea that species evolve rapidly, followed by a period of little or no change

  - This theory has three main assertions:

    - many species evolve very rapidly in evolutionary time
    - speciation usually occurs in small isolated populations, so intermediate fossils are very rare
    - after an initial burst of evolution, species are well adapted to their environment and so do not change significantly over long periods of time



Convergent evolution - the development of similar traits or adaptations in unrelated species

- can be the result of occupying similar niches
- these are called **<u>analogous</u>** traits
- ex. wings, antifreeze proteins, eyes to see in the dark, large ears

Divergent evolution - occurs when members of the same species form different traits in response to different environments

- neanderthals and modern humans (same ancestor, different environments)
- red fox and the kit fox

http://www.nelson.com/ABbio20-30/teacher/protect/otr/Bio2030OTR/attachments/i_AnimationSimulation/geological_time.html

http://www.nelson.com/ABbio20-30/teacher/protect/otr/Bio2030OTR/attachments/i_AnimationSimulation/archipelago.html

http://www.nelson.com/ABbio20-30/teacher/protect/otr/Bio2030OTR/attachments/i_AnimationSimulation/evolutionary_tree.html

Lesson 4 – Review

Read pgs 157-161

1. Outline the steps involved in allopatric speciation.

First, a physical barrier separates a single interbreeding population into two or more groups that are reproductively isolated from each other. Any mutations that occur in these isolated groups are not shared with the entire population.

Second, natural selection works on the separated groups independently, resulting in inherited differences in the two populations. In other words, the populations evolve independently. Differences in selective pressures will be greater if the populations experience pronounced differences in their environments.
Finally,over time, accumulated physical and/or behavioural differences between the populations become so pronounced that the groups, should they be reunited, would no longer be sexually compatible. At this point, they have formed two or more distinct species.

2. Living in the same region, the almost identical species of tree frog, Hyla veriscolor (Figure 7 (a)) and Hyla chrysoscelis (Figure 7 (b)) are distinguished only by their vocal calls and their DNA. H. veriscolor has exactly twice the number of chromosomes as H. chrysoscelis. How might H. versicolor have evolved?

Figure 7

Since H. versicolor has twice the number of chromosomes as H. chrysoscelis, it is likely that a mutation resulted in the production of individuals with double the normal number of chromosomes. This would cause the sudden formation of a new species, which is sympatric speciation.

3. Construction of a canal through Panama has affected marine and terrestrial species. Consult an atlas to see the extent of the canal.

(a) Comment on effects on the evolution and speciation of Atlantic and Pacific marine organisms in the vicinity of the Panama Canal.

The canal may permit gene flow among closely related marine species on either side of the isthmus. This may result in the formation of one species from two via crossbreeding. Although it is unlikely that many marine fish would or could actually pass through the lengthy canal, many species (especially invertebrates) might be carried on the outer surface of ships or as stowaways in bilge water.

(b) How might the construction of the Panama Canal have influenced the evolution of terrestrial species?

By forming a physical barrier to the movement of some, especially small, terrestrial animals, the canal may cause allopatric speciation to occur in many species.

4. What aspect of the fossil record suggests that evolution may occur rapidly?

According to the theory of gradualism, we would expect to find many fossils that show small changes in species over time. Instead, distinct species often appear abruptly in the fossil record, and then little further change is seen over very long periods of time.