Biology 1100 Review

Topics:
Ch 13 Meiosis and variation
Ch 14 Mendel and the gene idea
Ch 15 The chromosomal basis of inheritance
Ch 22 Descent with modification
Ch 23 Evolution of populations
Ch 24 The origin of species
Ch 25 Phylogeny and systematics
Ch 26 – the tree of life
Ch 34 Mammals primates humans

1

Overview: Biodiversity seen on the planet today, is the result of the evolution of organisms over vast periods of time, influenced by the environment on earth.

1. DNA is the substrate of evolution, and evolution is the change in allele frequencies over generations. DNA condenses into chromosomes in cells, and go through meiosis and recombination, leading to variation in offspring. (Ch 13/15)
2. Mendel noticed that traits are passed to offspring in certain patterns, leading to the idea of 'factors' – alternative alleles – which could be dominant or recessive. (Ch 14)
3. Darwin postulated that perhaps species could be modified over time, which would explain why extant species are different from fossilized ones. (Ch 22)
4. Evolution occurs at the population level – the mechanisms include natural selection, gene flow, genetic drift, sexual reproduction, and mutation. (Ch 23)
5. The origin of new species is called speciation. (Ch 24)
6. Biodiversity is classified into more and more inclusive groups, reflecting their relatedness. Phylogenetics organizes related groups into 'trees' to indicate when common ancestors must have existed. (Ch 25)
7. The origin of life and geologic events that took place over millions of year give a picture of the sequence of biodiversity over geologic time. (Ch 26)
8. There may be 10 million or more species on earth currently, one of which is humans. Humans belong in the primate group, within the class: mammals. (Ch 34)

2

Selection and speciation won't work unless there is variation in a population. Variation is largely due to chromosome shuffling during meiosis and recombination of chromosomes with fertilization (sexual reproduction).

3

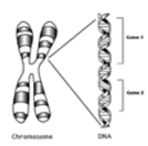
Heredity & variation

1. DNA is the substrate of evolution, and evolution is the change in allele frequencies over generations. DNA condenses into chromosomes in cells, and go through meiosis and recombination, leading to variation in offspring. (Ch 13/15)

- Heredity
  - Is the transmission of traits from one generation to the next
- Variation
  - Shows that offspring differ somewhat in appearance from parents and siblings

4

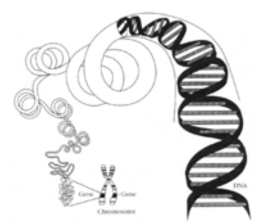
Inheritance of Genes



Genes
- Are the units of heredity
- Are segments of DNA
- Program traits

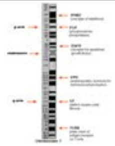
Offspring acquire genes from parents by inheriting chromosomes

5



6

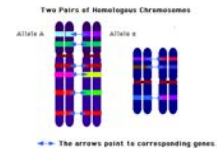
- Each gene in an organism's DNA
  - Has a specific locus on a certain chromosome



- We inherit
  - One set of chromosomes from our mother and one set from our father

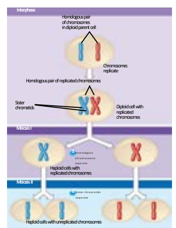
7

- Homologous chromosomes
  - Are two chromosomes composing a pair
  - Have the same characteristics but may have different versions of it



8

The Stages of Meiosis



9

Origins of Genetic Variation Among Offspring

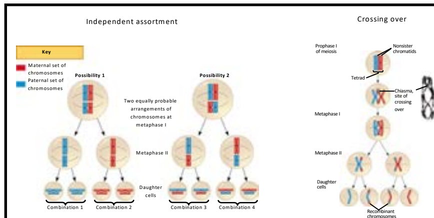
- In species that produce sexually
  - The behavior of chromosomes during meiosis and fertilization is responsible for most of the variation that arises each generation

10

Independent Assortment of Chromosomes and crossing over

- Homologous pairs of chromosomes
  - Orient randomly at metaphase I of meiosis
- Homologous chromosomes
  - End up sorting to different ends of the cell independent of each other
- Homologous chromosomes exchange sections
  - While lined up as tetrads, there is some crossing over

11



12

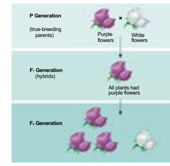
Random Fertilization

- The fusion of gametes
  - Will produce a zygote with any of about 64 trillion diploid combinations

13

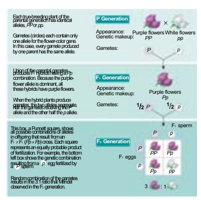
2. Mendel noticed that traits are passed to offspring in certain patterns, leading to the idea of 'factors' – alternative alleles – which could be dominant or recessive. (Ch 14)

- Trait: a variant of a character, such as purple or white flowers
- Homozygous: an organism has identical alleles for a trait
- Heterozygous: an organism has different alleles for a trait
- Phenotype: physical observable traits
- Genotype: contributing alleles to traits



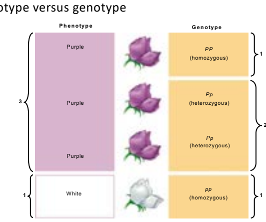
14

- Mendel's law of segregation, probability and the Punnett square



15

- Phenotype versus genotype



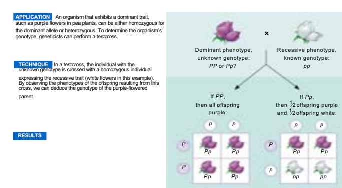
16

The Testcross

- In pea plants with purple flowers
  - The genotype is not immediately obvious
- – A testcross:
  - Allows us to determine the genotype of an organism with the dominant phenotype, but unknown genotype
  - P _ x pp

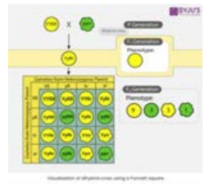
17

- The testcross



18

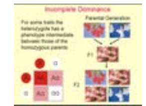
- The dihybrid cross

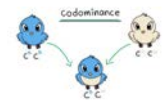


19

Non mendelian inheritance patterns

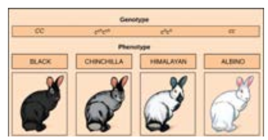
Single gene:
- Complete dominance
- Incomplete dominance
- Co-dominance





20

Multiple alleles contributing to a trait

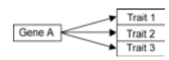


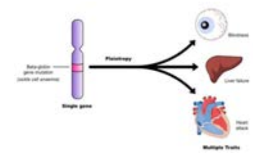
Multiple alleles makes for many possible dominance relationships. In this case, the black C allele is completely dominant to all the others; the chinchilla c^{ch} allele is incompletely dominant to the Himalayan c^{h} and albino c alleles; and the Himalayan c^{h} allele is completely dominant to the albino c allele.

21

Pleiotropy

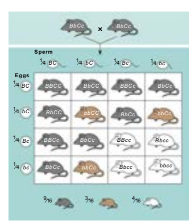
- A gene has multiple phenotypic effects





22

- Epistasis – a gene at one locus alters the phenotypic expression of a gene at a second locus



23

Pedigrees – family tree of traits (analysis)

- Pedigrees can be used to predict the traits of future offspring (genetic disorders)

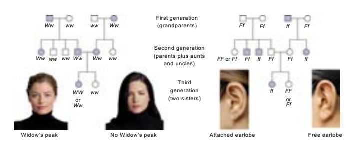


Figure 14.14A, B

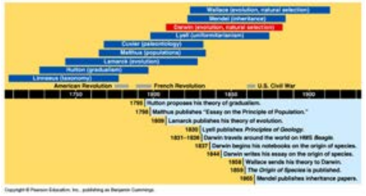
24

3. Darwin postulated that perhaps species could be modified over time, which would explain why extant species are different from fossilized ones. (Ch 22)

Descent with modification: evolution

25

Darwin built his ideas about evolution on a base that was established by others.



26

27

28

<u>Natural selection.</u>

Darwin's theory on evolution by the mechanism of natural selection was based on these observations:

i. All species have the potential to overproduce offspring. If they continued to do so, they would use up all the world's resources.

ii. However, if we look at populations, we see that they are stable, except for seasonal fluctuations or unless changed by man altering the environment.

iii. Thus, environmental resources limit their production.

Inference 1: Conditions lead to a struggle for existence among individuals of a population.

29

Other observations:

iv. Individuals within a population have varying characteristics.

v. Much of the variation is heritable (genetic).

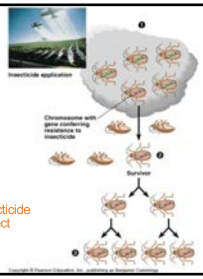
The inferences from these observations:

2. Individuals with traits that allow them to outcompete other individuals will survive and reproduce.

3. These favorable traits are maintained in the future generations, leading to gradual changes in the population.

This is Darwin's Theory of Natural Selection

30



Evolution of insecticide resistance in insect populations.

31

Artificial selection: diverse vegetables derived from wild mustard

32

Evidence of evolution

Homologous structures: anatomical signs of descent with modification.

Embryological: related embryos have the same features. They change with rates of development.

Molecular evidence: DNA/RNA is a universal genetic code.

Fossil record: we can see similarities in fossils to present-day (extant) species.

Convergent evolution: shows natural selection for adaptations of unrelated organisms with similar traits

33

4. Evolution occurs at the population level – the mechanisms include natural selection, gene flow, genetic drift, sexual reproduction, and mutation. (Ch 23)

- Natural selection works on individuals.
- Evolution occurs at the population level
- Evolution is the change in allele frequencies in a population over generations.

34

Hardy-Weinberg Equilibrium

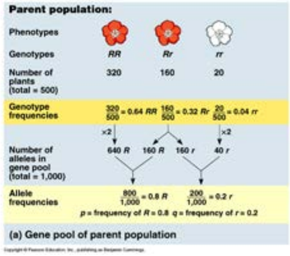
The gene pool of a non-evolving population remains constant over multiple generations; *i.e.*, the allele frequency does not change over generations of time.

The Hardy-Weinberg Equation:

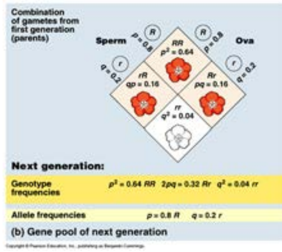
$$1.0 = p^2 + 2pq + q^2$$

where p^2 = frequency of AA genotype; $2pq$ = frequency of Aa plus aA genotype; q^2 = frequency of aa genotype

35



36



37

But we know that evolution does occur within populations.

Evolution within a species/population = microevolution.

Microevolution refers to changes in allele frequencies in a gene pool from generation to generation.

Causes of microevolution:

1) Genetic drift
2) Natural selection
3) Gene flow
4) Mutation

38

1) Genetic drift

Genetic drift = the alteration of the gene pool of a small population due to chance.

Two factors may cause genetic drift:

a) Bottleneck effect may lead to reduced genetic variability following some large disturbance that removes a large portion of the population. The surviving population often does not represent the allele frequency in the original population.

b) Founder effect may lead to reduced variability when a few individuals from a large population colonize an isolated habitat.

39

2) Natural selection

As previously stated, differential success in reproduction based on heritable traits results in selected alleles being passed to relatively more offspring (Darwinian inheritance).

The only agent that results in adaptation to environment.

3) Gene flow

-is genetic exchange due to the migration of fertile individuals or gametes between populations.

40

4) Mutation

Mutation is a change in an organism's DNA and is represented by changing alleles.

Mutations can be transmitted in gametes to offspring, and immediately affect the composition of the gene pool.

The original source of variation.

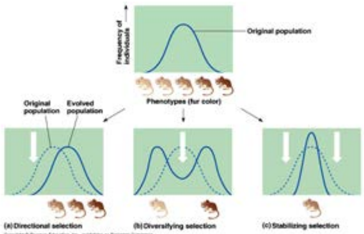
41

Genetic Variation, the Substrate for Natural Selection

Genetic (heritable) variation within and between populations exists both as what we can see (*e.g.*, eye color) and what we cannot see (*e.g.*, blood type).

Not all variation is heritable. For example, environmental variables also can alter an individual's phenotype during its lifetime.

42



43

Sexual selection leads to differences between sexes

Sexual dimorphism is the difference in appearance between males and females of a species.

Intrasexual selection is the direct competition between members of the same sex for mates of the opposite sex.

- This gives rise to males most often having secondary sexual equipment such as antlers that are used in competing for females.

Intersexual selection (mate choice), when one sex is choosy when selecting a mate of the opposite sex.

- This gives rise to often amazingly sophisticated secondary sexual characteristics; *e.g.*, peacock feathers.

44

45

5. The origin of new species is called speciation. (Ch 24)

The origin of new species, or speciation
- Is at the focal point of evolutionary theory, because the appearance of new species is the source of biological diversity

Evolutionary theory
- Must explain how new species originate in addition to how populations evolve

Macroevolution
- Refers to evolutionary change above the species level

46

- Two basic patterns of evolutionary change can be distinguished
  - Anagenesis
  - Cladogenesis (increases diversity)

Figure 24.2 (a) Anagenesis (b) Cladogenesis

47

The Biological Species Concept

- The biological species concept
  - Defines a species as a population or group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring but are unable to produce viable fertile offspring with members of other populations
  - Because members interbreed, the species has a common gene pool.

48

- Prezygotic and postzygotic barriers to inter-species reproduction

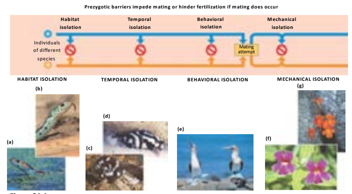
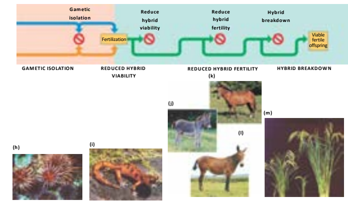


Figure 24.4

49



50

- Speciation can occur via isolation of a group from the parent group.
  - Allopatric speciation (geographic isolation)
  - Sympatric speciation (reproductive or niche isolation, or polyploidy)

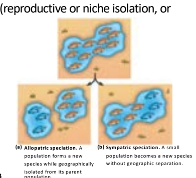


Figure 24.5 A, B

51

- Allopatric speciation. Geographic isolation.
  - One or both populations may undergo evolutionary change, beginning with two different gene pools.

Figure 24.6

52

Habitat Differentiation and Sexual Selection

- Sympatric speciation
  - Results from non-random mating
  - Results from the appearance of new ecological niches
  - Results from polyploidy, where some individuals, through errors in meiosis, have offspring with multiple chromosome sets.

53

- The Hawaiian archipelago
  - Is one of the world's great showcases of adaptive radiation
  - The island chain is relatively young, sprung from volcanoes, and therefore had lots of new ecological opportunities.

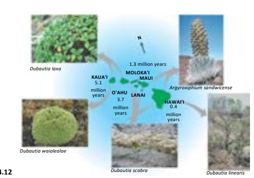


Figure 24.12

54

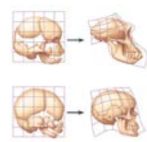
The Tempo of Speciation

- It may be gradual over many 1000's of generations, as genetic changes accumulate.
- It may occur more quickly if new ecological opportunities arise (like the Galapagos Islands)
- Big events like floods, earthquakes and volcanoes can isolate small populations from a parent population.

55

Changes in rate and timing of development may cause significant differences between species

- Heterochrony
  - Is an evolutionary change in the rate or timing of developmental events
  - Can have a significant impact on body shape



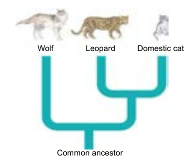
56

6. Biodiversity is classified into more and more inclusive groups, reflecting their relatedness. Phylogenetics organizes related groups into 'trees' to indicate when common ancestors must have existed. (Ch 25)

- Phylogeny:
  - The evolutionary history of a species or group of related species represented in a phylogenetic tree or cladogram
- Gathering data:
  - The fossil record
    - Shows ancestral characteristics that may have been lost over time
  - Morphological, biochemical, and molecular comparisons of extant species
- Systematics
  - An analytical approach to understanding the diversity and relationships of organisms, both present-day and extinct

57

A phylogenetic tree depicting evolutionary history of three extant species.



58

Collecting data to build phylogenetic relationships.

Fossils

Panthera pardus   *Felis catus*

Morphological similarities and differences

59

Molecular comparisons (finding homologies)

- Systematists use computer programs and mathematical tools
  - When analyzing comparable DNA segments from different organisms

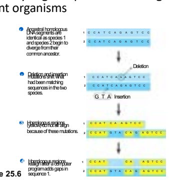


Figure 25.6

Figure 25.7

60

Hierarchical Classification

- Linnaeus developed binomial nomenclature
- Linnaeus introduced a system for grouping species in increasingly broad categories

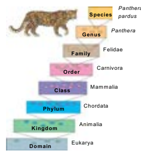


Figure 25.8

61

Linking Classification and Phylogeny

- Systematists depict evolutionary relationships
  - In branching phylogenetic trees

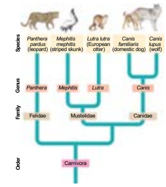


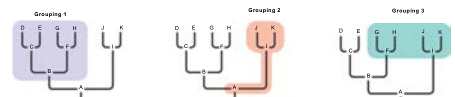
Figure 25.9

62

Phylogenetic systematics

- Construction of phylogenetic trees based on shared characteristics
- A cladogram
  - patterns of shared characteristics among taxa
- A clade within a cladogram
  - A group of species that includes an ancestral species and all its descendants
- Cladistics
  - Is the study of resemblances among clades

63



(a) Monophyletic. In this tree, grouping 1, consisting of the seven species B–H, is a monophyletic group, or clade. A monophyletic group is made up of an ancestral species (species B in this case) and *all* of its descendant species. Only monophyletic groups qualify as legitimate taxa derived from cladistics.

(b) Paraphyletic. Grouping 2 does not meet the cladistic criterion: It is paraphyletic, which means that it consists of an ancestor (A in this case) and *some*, but not all, of that ancestor's descendants. (Grouping 2 includes the descendants I, J, and K, but excludes B–H, which also descended from A.)

(c) Polyphyletic. Grouping 3 also fails the cladistic test. It is polyphyletic, which means that it lacks the common ancestor of (A) the species in the group. Furthermore, a valid taxon that includes the extant species G, H, J, and K would necessarily also contain D and E, which are also descended from A.

64

- The outgroup comparison
  - Enables us to focus on just those characters that were derived at the various branch points in the evolution of a clade

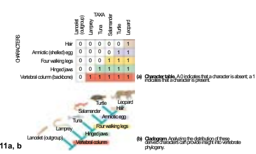
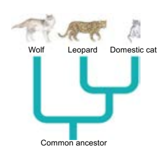


Figure 25.11a, b

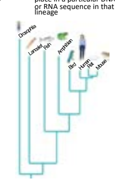
65

Phylogenetic Trees and Timing

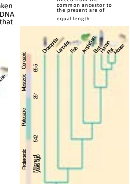
- Chronology represented by the branching pattern
  - Is relative rather than absolute in terms of representing the timing of divergences



- In a phylogram
  - The length of a branch in a cladogram reflects the number of genetic changes that have taken place in a particular DNA or RNA sequence in that lineage



- In an ultrametric tree
  - The branching pattern is the same as in a phylogram, but all the branches that can be traced from the common ancestor to the present are of equal length



66

Maximum Parsimony and Maximum Likelihood

- Systematists
  - Can never be sure of finding the single best tree in a large data set
  - Narrow the possibilities by applying the principles of maximum parsimony and maximum likelihood
  - The most parsimonious tree is the one that requires the fewest evolutionary events to have occurred in the form of shared derived characters
  - Maximum likelihood states that, given certain rules about how DNA changes over time, a tree can be found that reflects the most likely sequence of evolutionary events

67

7. The origin of life and geologic events that took place over millions of year give a picture of the sequence of biodiversity over geologic time. (Ch 26)

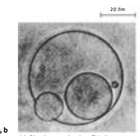
68

- The atmosphere was harsh on earth 4.5 billion years ago and has changed dramatically.
- Instead of forming in the atmosphere
  - The first organic compounds on Earth may have been synthesized near submerged volcanoes and deep-sea vents

Figure 26.3

69

Protobionts – self-assembling and replicating entities – preceded cells.



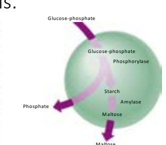


Figure 26.4a, b

(a) **Simple reproduction.** This liposome is "giving birth" to smaller liposomes (LM).

(b) **Simple metabolism.** If enzymes—in this case, phosphorylase and amylase—are included in the solution from which the droplets self-assemble, some liposomes can carry out simple metabolic reactions and export the products.

70

- The first genetic material was likely RNA, preceded DNA
- RNA molecules called ribozymes have been found to catalyze many different reactions, including
  - Self-splicing
  - Making complementary copies of short stretches of their own sequence or other short pieces of RNA

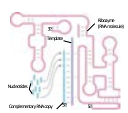


Figure 26.5

71

The First Prokaryotes

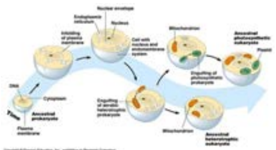
- Prokaryotes were Earth's sole inhabitants
  - From 3.5 to about 2 billion years ago
  - At first did not produce oxygen through photosynthesis.
  - 2.4 billion years ago began to produce oxygen
  - Oxygen-intolerant prokaryotes didn't survive well
  - Oxygen-tolerant species replaced them

72

Eukaryotes

- Eukaryotic cells arose from symbioses and genetic exchanges between prokaryotes
- Endosymbiosis explains how complex eukaryotic cells may have evolved from simpler prokaryotic cells

The oldest fossils of eukarytoic cells date back 2.1 billion years



73

The Earliest Multicellular Eukaryotes

- Molecular clocks
  - Date the common ancestor of multicellular eukaryotes to 1.5 billion years
- The oldest known fossils of eukaryotes
  - Are of relatively small algae that lived about 1.2 billion years ago

Colonies preceded true multicellularity

Colony

Some cells in the colonies became specialized for different functions

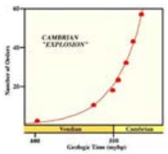
Sponge

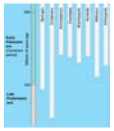
Sponges are probably the first multicellular animals

74

The "Cambrian Explosion"

- Most of the known major phyla of animals
  - Appear in the fossil record that was laid down during the first 20 million years of the Cambrian period





Cnidaria and Porifera somewhat older

75

- Molecular evidence
  - Suggests that many animal phyla originated and began to diverge much earlier, between 1 billion and 700 million years ago
- Plants, fungi, and animals
  - Colonized land about 500 million years ago
- Symbiotic relationships between plants and fungi
  - Are common today and date from this time

76

The earth has not been static, but the continents formed and have been shifting on large plates

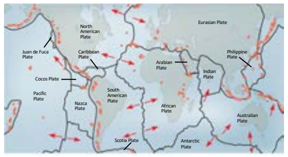


Figure 26.18

77

Supercontinent Pangaea starting breaking up 250 million years ago.

Subduction, volcanic activity, sea level rise and fall, climate changes have all contributed to the evolution of life on earth

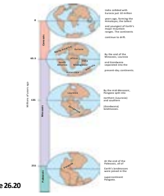
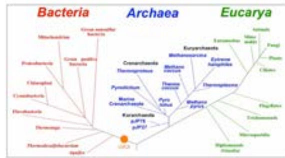


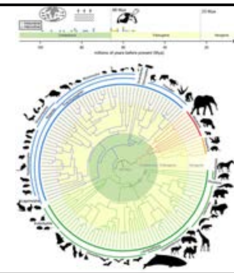
Figure 26.20

78

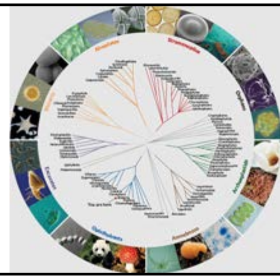


The universal phylogenetic tree of life as defined by comparative rRNA gene sequencing. The three domains of life-Bacteria, Archaea and Eukarya are shown, along with a number of important representative groups. LUCA-Last universal common ancestor. (Madigan et al., 2012).

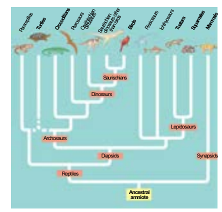
79



80



81



8. There may be 10 million or more species on earth currently, one of which is humans. Humans belong in the primate group, within the class: mammals. (Ch 34)

82

An amniotic egg allowed animals to reproduce on land

- The extraembryonic membranes
  - Have various functions

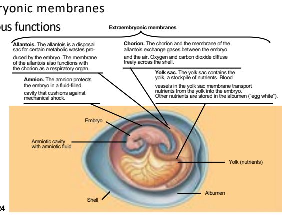


Figure 34.24

83

84

- The major eutherian orders

Figure 34.36

85

- New World and Old World monkeys
  - Underwent separate adaptive radiations during their many millions of years of separation

Figure 34.39a, b

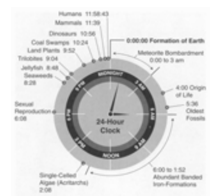
86

- In addition to monkeys, anthropoids include the hominoids - primates informally called apes

Figure 34.40a–e

87

- Humans are bipedal hominoids with a large brain
- *Homo sapiens* is about 160,000 years old
  - Which is very young considering that life has existed on Earth for at least 3.5 billion years



88

- These species are known as hominids

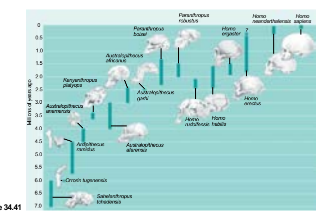


Figure 34.41

89