LS 7B Notes

Lecture Notes

1/8 - Week 1

- Evolution helps us explain differences and similarities between organisms.
- Ecology is the study of the relationships of organisms to one another and to their environment.
- Sexually reproductive organisms pass genetic information to offspring through meiosis.
- **Gene**: Segment of DNA that influences one or more phenotypes.
- **Allele**: Particular form of a gene.
- **Locus**: Stretch of DNA at a particular location on a chromosome.
    - Every gene is a locus, but not vice versa.
- Gametes are produced through meiosis and they are haploids.
- DNA must be replicated in order for the cell to undergo meiosis.
- Homologous chromosomes (paternal and maternal) know how to line up based on the genes that those chromosomes have.
    - The pairing up allows the crossing over to properly happen.
- So at the beginning of meiosis, you have one chromosome from dad and one from mom. We have 23 of these chromosome pairs in total. On each of these chromosomes, there are genes. Since we have two chromosomes in each pair, that means there are two alleles for that gene. These alleles can either be the same or can be different. The chromosomes in the pair are called homologous chromosomes. They're similar because they represent information about the same gene, but they're not identical since one comes from dad and the other comes from mom. When the information from the chromosomes get duplicated, each of the 46 chromosomes arranged so that you have sister chromatids now. So, you still have 46 chromosomes but you have 92 sister chromatids.

1/10 - Week 1

- Missense mutation changes the amino acid. Silent mutation doesn't change the amino acid. Point mutations change one or more nucleotides. Nonsense mutation turns the amino acid into a stop codon.
- Not all alleles will have simple dominance. In some, R1R2 will result in a mixture of R1 and R2, which is incomplete dominance.
    - One doesn't exhibit dominance over another.

1/12 - Week 1

- **Solid**/Striped and **Folded**/Straight

- Segregation of one set of alleles of a gene pair is independent of the segregation of another set of alleles.
- Mendel's independent assortment principle says that the passing on of different traits are independent of each other.
    - Basically says that alleles separate independently.
- A phenotype could be influenced by more than one genotypes.

1/17 - Week 2

- Fragment length tells you how many repeats there are, and that tells you how many different alleles there are.
- We can disprove things using the gel analysis, but cannot really prove anything.
- X-linked genes get passed on on X chromosomes.
    - With a lot of these questions, need to remember that the father has one X chromosome and the mother has two X chromosomes. This means that if you know that the child is a daughter, then you'll have a 2x1 Punnett square.
- X-linked inheritance means that the gene causing the trait or the disorder is located on the X chromosome.

1/19 - Week 2

- Fungi exist as haploid cells, but they also have different mating types.
- Two cells of the same mating type will undergo cell fusion to get a binucleate cell.
- The reproductive cycle for fungi has two rounds of meiosis and an additional round of mitosis.
    - There's also not much of crossing over, because the alignment stays the same.
- Recombination frequency is a function of the distance
    - We can only specify relative distances if we know recombination frequency, we cannot say exact numbers.

1/22 - Week 3

- SNPs, RFLPs, and VNTRs are all places in the genome that can uniquely identify people or act as genetic markers. And thus they can also help us predict whether certain SNPs indicate whether a gene will be mutated.
- Alleles can be used as genetic markers to test for the presence of certain mutated genes.
- The disease gene of interest and the prober don't always match up in terms of predicting whether the gene will be mutated?
- A genetic marker is a gene with a known location on a chromosome that can be used to identify species.
- SNPs aren't necessarily on the particular gene, and thus recombination can occur and that's where even though the SNP may not indicate a mutated allele, there could be recombination and the gene may still be mutated.

- Heritable BRCA1 mutations would mean that all cells (not just your breast cells) would have the mutant copy of BRCA1.

1/24 - Week 3

- Environment plays a huge role in determining the phenotype of organisms, it isn't just the genotype.
- Mutations can happen at the chromosome level, where you could have one extra or one missing chromosome.
    - Can be either a sex chromosome or any autosomal one
- Genetic variation is based on the copy of the allele for that gene. Complex genes are affected by multiple genes.
- Environmental variation is due to differences in the environment.
- You can determine the effect of genes vs environment through experiments where you hold one as your control.
- A slope of 1 on that graph means that the children will be exactly the same height as parents. This is the sole effect of genes on variation of phenotypes. A slope of 0 means that there is no relationship. This is the sole effect of environment on variation of phenotypes.
    - In reality, we see that the slope is in between since there is influence from both the genes and the environment.

1/26 - Week 3

- When parents are below average, then the offspring are taller than the parents but shorter than the average.
- This means that there is some other factor that influences an offspring's traits rather than just the genotype.
- Regression to the mean can be the result of gene by gene interactions and gene by environment interactions.
    - Gene interactions still affect regression to the mean b/c sometimes even if you have parents that are tall, the genes that you get from them may interact with each other in such a way that you end up being shorter.
- Codominance is where phenotypes can be caused by multiple different alleles.
    - An example is Ia (codominant), Ib (codominant), and i (recessive)

1/29 - Week 4

- A unit of evolution is a population, which is a group of individuals of the same species living in the same place at the same time.
- Microevolution is a change of the relative frequencies of alleles or genotypes in a population over time.
- Darwin's main points are that populations have the ability to grow exponentially, they don't though, variation exists within a population, and the variation is heritable.
- The first 2 lead to a struggle for existence and happen because of resource limitation.

- The last 2 leads to some individuals that are better suited for the environment and those favorable traits that the surviving individuals will be passed on.

1/31 - Week 4

- Sexual selection favors traits which increase an individual's mating success.
    - Can cause a situation where most males don't end up reproducing because a select few males have a harem of females.
- Females invest more energy per gamete.
- Sexual dimorphism are the differences in appearance between males and females of the same species.

2/2 - Week 4

- Fitness is about the total amount of genetic information that you get to pass on.
- Relatedness is the percent of the genome shared between two individuals due to inheritance.
- Overall fitness is determined by all the genes you pass to your offspring and those you share with your non offspring relatives - Inclusive fitness
    - Only the genes that you pass to your offspring - Direct fitness
    - Only the genes that you share with your non-offspring relatives - Indirect fitness

2/5 - Week 5

- Microevolution is a change in allele or genotype frequencies in a population over one or more generations.
    - Example is if you had 80% brown eye color one year and then 40% in the next year
- In the HW equation p^2 + 2pq + q^2 = 1, p represents the probability for dominant allele and q represents the probability for recessive.
- Assortative Mating is where individuals only mate with like genotypes.
    - The allele frequencies won't change but the genotype frequencies may change.
    - The heterozygotes frequencies would go to 0.
- Gene flow homogenizes allele frequencies between two populations.
- In smaller population sizes, genetic drift plays a bigger role in determining allele frequencies.
- It is possible for large populations to have low levels of genetic variation.
- Drift and population size (SOMETHING IMPORTANT)
- Natural selection isn't necessarily a stronger force in large populations than smaller populations or vice versa.
    - Natural selection is more effective in large populations because beneficial alleles are less likely to be lost in drift but the strength of selection is not dependent on population size.

2/7 - Week 5

- Can only use the Hardy Weinberg equation when you know if the population is in HW equilibrium. If you are not sure, you cannot use the equation to determine allele frequencies from genotype frequencies.
    - Given the genotypes and info that the population is in HW equilibrium, you can then find the allele frequencies.
- Fitness curves show us the most fit values for a trait in a given environment.
- Selection favoring one trait may constrain another.
- Species can possibly be smaller if they start on an island because there is less resources and less predators. But they could also grow bigger due to decreased competition.
- Fitness of two interacting traits can be visualized in a 3-D landscape.
- Adaptive landscapes can often have multiple peaks.
- Populations tend to climb the fitness peaks on the landscape.
- A population may become trapped on one peak despite the potential for higher fitness at another peak.
- Speciation happens over many many generations, and species themselves can sometimes be difficult to distinguish.
    - Not all the criteria for determining is something is part of a species can be applied to everything (BSC cannot be applied to organisms that produce asexually)

2/9 - Week 5

- Gene flow often reduces the amount of divergence between two populations.
- Genetic drift is really what causes the divergence between the two populations, and thus it will have a greater effect on divergence than reproductive isolation. The answer to that clicker question wasn't reproductive isolation because we don't have evidence that they are reproductively isolated yet.
- Just because two species are separated by geography, it doesn't mean that they are reproductively isolated. There has to be specific pre-zygotic or post-zygotic factors.
- New species arise when two populations become sufficiently different from one another.
- Increasing genetic divergence correlates with increased values for reproductive isolation.
- While we have the same genes as chimpanzees, we could see chromosomal arrangement changes that cause reproductive isolation. The genetic material is still the same though.
- Dobzhansky Muller model is when a single ancestral population is divided into two, and different genetic changes accumulate in different lineages.
    - All it takes is two changes on different lineages to get reproductive isolation.

2/12 - Week 6

- Previously existing traits are ancestral traits
- Speciation is depicted by phylogenetic trees.
- All trees may not look the same since the branch can either mean nothing or refer to the extent of genetic difference or the extent of evolutionary time.

- Sometimes the geographic distribution does not match the differences in phylogeny.

2/14 - Week 6

- Convergent evolution is likely when there are similar evolution changes in two different places.
- Maximum parsimony is when we find the phylogenetic tree that requires the fewest evolutionary changes.
- We look for parsimonious because it is unlikely that we will have a lot of evolutions.

2/16 - Week 6

- Parsimony makes the assumption that the fewest evolutionary steps is the most likely explanation.
    - But this may not be true if you have incomplete data.
- Molecular phylogenies may be different from the vicariance phylogeny.

2/21 - Week 7

- Biodiversity refers to how many and what kinds of organisms live in a particular place and time.
- Bacteria branched first, and then the Archaea and Eukarya branched (they are sister taxa).
- Cyanobacteria are bacteria that are photosynthetic.
- You have 10x more bacterial cells than human cells. This makes up the human microbiome.
- Eukaryotic heterotrophs need to take in carbon and energy from outside sources and they can do this via phagocytosis, which allows for rapid acquisition of more larger nutrients than in diffusion.
- The significance of the double membrane is that it is evidence for that mitochondria are derived from another organism.
    - They are the product of endosymbiosis
    - We don't really know when the engulfing of the proteobacteria happened.
- A protist is any eukaryote that is not an animal, plant, or fungi. They don't form a monophyletic group.
- Chloroplasts are also surrounded by a double membrane, like mitochondria were.
    - They also evolved from another place, in this case from cyanobacteria.
- Complex multicellularity is something that evolved at a bunch of different places on the tree.
- Land plants underwent a water to land transition. Because plants had to make that transition, they had to undergo some adaptations.
- Lots of reproductive adaptations going from water to land.
    - Different fertilization and dispersal modes.
- There likely was a single transition from water to land for species.
- Mosses especially need water for fertilization.

- Vascular tissue arises which allows for bulk transport of water and nutrients.
- Angiosperms have the most species diversity of any plant group.
- Hyphae part of fungi are able to grow rapidly and they are one cell wide.
- The reason that animals did not colonize land until 100 mya even though they were there 541 mya is because plants had to be there so animals had something to eat. Oxygen is needed for both animals and plants.

2/23 - Week 7

- Sponges are old, don't move around, don't have symmetry or move around. Sponges are sister to all other lineages on the tree of life.
- Cnidarians have radial symmetry and bilaterians have bilateral symmetry.
- Cnidarians have cnidocytes (unique to this phylum) which are stinging cells. They also do asexual reproduction and sexual reproduction through broadcast spawning by releasing the gametes into the water.
- Cephalization is the concentration of sensory organs to one end of the body (such as the head). This arose in bilaterians. It puts the neurons in front, where the animals will encounter new things in the environment.
- Phylum Platyhelminthes are flatworms which have a simple body plan, and exchange gas via diffusion.
- Phylum Mollusca have a mantle and are modified for respiration, locomotion, and shell formation.
    - Cephalopods are one of those subgroups. They are intelligent, are predators, movement (siphon for jet propulsion), predator defense (ink sac), and feeding (powerful bite) and chromatophores that allow for color change.
        - Examples are octopus, squids, etc
    - Gastropods are another type. They have tooth like radula, muscular foot for movement, and gills for gas exchange.
        - One particular example are nudibranchs which have bright coloration warning others of chemical defense.
        - Another is a Sacoglossan which can steal chloroplasts from the things that it eats.
        - Examples are snails and slugs
- Phylum Arthropoda have exoskeleton made of chitin and jointed appendages (enable movement of rigid bodies). The exoskeleton is important because provides armour, structural support for muscle, prevent from desiccation, and grow by molting which is the process of getting bigger through some fluid expansion or some shit.
    - Examples are spiders and insects.
    - Insects are another group and they have desiccant resistant eggs, wings, and do metamorphosis which refers to 2 specialized life stages, one for feeding and one for reproduction.
- Appendage Modification refers to how appendages have evolved into antennae, mouth parts, claws, limbs, legs, feathery structures, etc.

- Phylum Tardigrada are close relatives to the arthropods. They survive extreme conditions in terms of temperatures, pressures, radiation, no need for food/water.
- Phylum Echinodermata are strictly marine as they have never colonized land or freshwater habitats. They also have pentaradial symmetry through >1 different evolutions. They also have a water vascular system with tube feet which help with nutrient transport and locomotion.
    - Similar to how humans have developed.
- Subphylum Vertebrata include fish and tetrapods. The first ones are jawless fish which don't have any appendages.
- Chondrichthyes refer to sharks and rays, which have jaws and skeleton made of cartilage, calcified teeth, and mostly marine.
- Bony fishes are a paraphyletic group and they have endoskeleton with calcified cranium, swim bladder that controls their buoyancy, fins supported by bony rods. They also have lobe fins and are the closest extant relative of the tetrapods.
- Tetrapods include amphibians, mammals, us, etc. They have 4 jointed limbs, neck, absence of gills, and ears.
    - Class Amphibia have weak lungs, and skin absorbs oxygen.
- Water to land transition also correlates to external vs internal fertilization where in the former we can see the eggs, but with internal, all the fertilization happens within the body.
- Amniotic eggs are one of the most important vertebrate adaptations for terrestrial life. This also helped the water to land transition.
- Sauropsids refer to reptiles and birds. They have watertight skin, breathe air through lungs, and have amniotic eggs. Reptiles are ectothermic so that they can modify internal temperature.
- Wings and flight evolved independently in a couple of different lineages. Bats, birds, and something else.

2/26 - Week 8

- Ecology is the study of relationships among organisms and to their environment.
- Patterns and processes occur at different ecological scales.
- Births and immigrants increase population size, while deaths and emigration decrease size.
- The per capita growth rate does not change during exponential growth.
    - Number of individuals added increases as the original population increases, but the rate itself does not change.
- When the number of young produced a birth and there are not enough adults to support them, then natural selection occurs because there is a resource limitation, and thus will show that there are a couple traits that will differentiate who lives and who doesn't.
- Populations grow exponentially but resources do not. Growth will be checked by famine, disease, and conflict.

- Abiotic factors refer to non living organisms in the environment while biotic refers to the living ones.
- Density independent factors means that the same proportion of individuals will get affected by a particular event, regardless of density of population.
    - Temperature, flood, and drought are examples.
- Density dependent factors means that the impact of them changes based on if the density is greater.
    - Competition for resources, disease, predation, etc
- Distribution or range gets influenced by abiotic factors and biotic ones.

2/28 - Week 8

- Populations are measured by looking at random areas and then extrapolating.
- Transect quadrat approaches involve splitting the population down one axis, and then placing squares near the line to measure the species that end up inside of the square.
    - Used for populations that are sedentary.
- Mark and recapture are used for those populations that move a lot.
    - Populations are randomly distributed.
    - Capture is random
    - Mark them
    - Capture a bunch again, and look at how many are marked.
- Marked individuals recaptured / total individuals captured on day 2 = marked individuals on day 1 / estimated population size.
- When counting individuals, you can look at size, age, reproductive rate, shelter, and gender.
- Per capita death rate per age class represent the fraction of individuals that are alive at the beginning who die at end of the interval.
    - Per capita death rate = total number of deaths / total number who could die

3/2 - Week 8

- Species that persist are those that maximize fitness.
- Life history is the evolve pattern of resources investment in each stage of that species' lifetime.
- Organisms exhibit trade-offs between reproduction and other physiological functions.
- Fecundity refers to ability to produce offspring. Fecundity and survivorship are often inversely correlated with each other.
- R-strategists are those with many offspring, low parental investment, common with external fertilization, and often are in unstable environments.
- K-strategists are those with few offspring, high parental investment, common with internal fertilization, and often are in stable environments.
- Each members within the same species and the same environments can have different life history plans. Some can be r-strategists and some can be k-strategists.

- Parental investment refers to the activities that increase likelihood for survival for existing offspring, but reduce parens' chances of producing future offspring.
    - Benefit: More offspring survive
    - Cost: Reduced survival chances for themselves and reduced mating opportunities.
- An island is an area of habitat surrounded by a different habitat
    - This can be a body of area surrounded by water.
    - This can also be an area of grasslands in a desert.
    - These are also called habitat patches.
- Island biogeography refers to a graph with the number of species and the rate of both extinction and arrival of the species.
    - Immigration rates can decline if the island is far away.
- Larger islands have more colonists and lower rates of extinction compared to smaller islands.
    - On smaller islands, less resources and thus more competition and greater extinction rate.
- The number of species that are on the island is a function of both the distance (negatively correlated) to the mainland as well as the size of the island (positively correlated).
- A metapopulation is a group of independent populations connected via corridors. They might be living in the same habitat patch, but they are in adjacent patches.
- In a metapopulation, the small populations can sink out, but then the bigger ones can rescue them through recolonization or dispersal to a sink.
- Deforestation can result in habitat loss and fragmentation which reduces quantity, the quality of the habitat can be lowered, the habitat now can support less species, and there is an edge habitat that gets created. This could result in a metapopulation formation where you have a lot of separate populations that may be connected.
- Edge habitats can be different in that they can be exposed to more environmental effects, more human effects, etc.
- Size of the habitat fragment affects the percentage of populations that are affected by the edge conditions.
- Corridors often help preserve species in populations that can be connected to each other.

3/5 - Week 9

- Many microbes of the human microbiota are commensals.
- Parasites takes everything they need from their host.
- Xylem parasites take water instead of sugar from the tree that it lives on.
- Mutualisms are the associations that benefit both species. Mutualisms can be facultative or obligate or on that spectrum.
- The color inside coral is dependent on the algae that grows around it. The relationship is symbiotic.

- There is a fig and wasp mutualism.
- Facultative association means it's not necessary that these species are associated, but it is very helpful.

3/7 - Week 9

- Sugar in a plant will travel along a concentration gradient which means that if a fungus is connected to a tree, then there will be a transfer of sugar.
- Competition is always density dependent and always negatively affects all the species involved.
    - Even the winner of the competition has negative repercussions.
- Ecological niche is the role of the species in the ecosystem, fundamental is the niche a species could occupy, while the realized is the niche it actually occupies. Interspecific competition can reduce the size of the realized niche.

3/9 - Week 9

- Competition determines fundamental niche.
- A spatial solution is that we have different niches within the tree.
- Herbivores are heterotrophs that feed on photoautotrophs (plants)
- Predators are heterotrophs that feed on other heterotrophs
- Some sample chemical defenses of plants are that they damage the nervous system, affect the growth/development of insect and fungi, and reduced digestibility.
    - Animals can have adaptations to get around these defenses.
- Predation can alter species' abundance indirectly if other species are affected by a given species' increase/decrease in population.
- There is coevolution and a kind of arms race for evolution between predators or prey.
- Crypsis (camo) is a way of not getting eaten.
    - Bright colors can be cryptic depending on the right background.
- To avoid being chosen, you can have mechanical defenses or aposematic coloration (which produces toxins)
- Mimicry is selective pressure for similar color patterns. A non-toxic species that wants to looks like it is toxic.
    - It reinforces the signal to the predators
- A community is an assemblage of populations living in an area or habitat at a given time.
- Species diversity includes the number of different species (richness) and the distribution of individuals across species (evenness)
    - If high richness and high evenness, that means you have high diversity.
- Ecosystem = Community (biotic) + Environment (abiotic)
- Carbon cycle is integral to biodiversity of life throughout the biosphere because carbon is transferred from one organisms to another in a food chain.
- Carbon cycles throughout communities via food webs.
- We can break groups into trophic levels, where producers are at the base. 10% of the biomass at one level is passed on to the next higher level.

3/12 - Week 10

- Community complexity promotes resilience.
- Resistance to disturbance increases with increasing species richness.
- Keystone species have a disproportionate role in the community as species may depend on it and effects community over multiple trophic levels.
    - If that species is not there, there are dramatic effects.
- Ecological succession is an environment changing based on external factors.
- Primary succession is when an ecosystem starts from scratch.
- A secondary succession is when there is a disturbance and the ecosystem reverts to an earlier stage of development.
- Immediate disturbance hypothesis says that moderate levels of disturbance enhances biodiversity.
- As air cools, rain and snow form because the air loses its ability to hold water (warm air can hold more moisture than cold air can).

3/14 - Week 10

- Decline in Amphibian populations is caused by habitat loss, pollution, and climate change.
    - Problems are all interconnected.
- Habitat loss is the #1 threat to biodiversity, and it can affect species worldwide because animals (mainly birds) migrate.

3/16 - Week 10

- Through overfishing, we can see a decline in the number of fish, as well as the average size of the fish.
- Shifting baselines refers to the concept that memories tend to be short and we reference conditions as those that we experience in our own lifetime, but it's important to also acknowledge historical data and context.
- Photosynthesis is a short term sink (b/c it's taking away carbon from the atmosphere), and cellular respiration is a short term source.
    - They are short term because it happens quickly and on an individual level.
- Organic burial is a long term sink b/c dead organisms sink to the bottom, and that carbon stays stored in that sediment for a very long time. It's thus a long term removing off carbon from the atmosphere.
- Plants respire at night, and thus the CO_2 levels in that area will increase, while the levels will decrease in the daytime when photosynthesis is happening.
- CO_2 concentrations regularly cycle up and down over the course of the year because of the different seasons which cause changes in amount of photosynthesis that happens..
    - When summer in northern hemisphere, there is more primary production and decreasing the amount of CO_2 in the atmosphere during the summer.
- More greenhouse gas means that there is more heat retention.

- Isotopes of carbon provide evidence for global warming.
- There is also increased CO2 concentrations in the oceans, and this causes lower pH and thus more acidic oceans which can negatively affect organisms.

Textbook Notes

Chapter 14

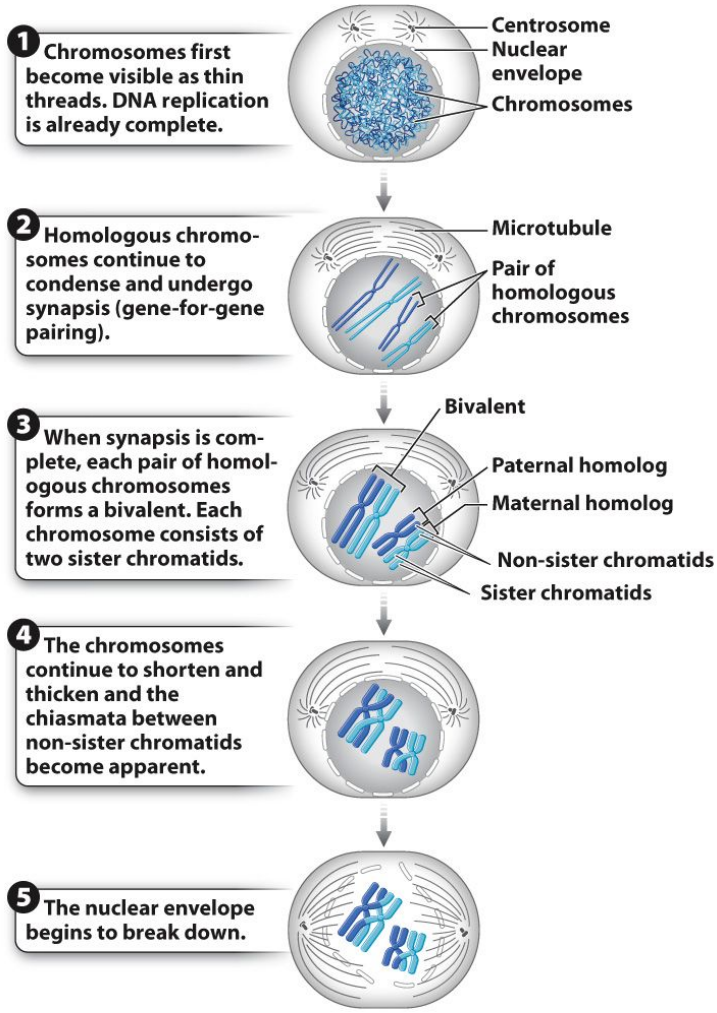
14.1 The Rate and Nature of Mutations

- Mutations result from mistakes in DNA replication or from unrepaired damage to DNA.
    - Can be caused by chemicals in the environment or by radiation.
- Mutations are spontaneous and random.
- Sites in the genome that are especially mutable are called **hotspots**.
- Mutation rates are not related to genome size.
- You can measure mutation based on the rate of mutation per nucleotide per replication or by the rate per genome per generation.
- Mutations in eggs and sperm are called **germline** mutations and those in non reproductive cells are called **somatic** mutations.
    - The former may be transmitted to future generations and uses rate per genome per generation while the latter won't and uses rate of mutation per nucleotide per replication.
- Rate of mutation per nucleotide per replication is greater in somatic cells that in germ cells.
- For cancer to develop, mutations must occur in the same cell lineage.
- Most cancers come from mutations in somatic cells.
- Any mutation that increases the risk of disease in an individual is known as a **genetic risk factor** for that disease.

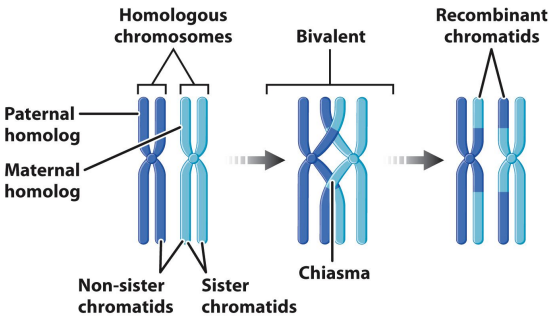
Chapter 11

11.3 Meiotic Cell Division

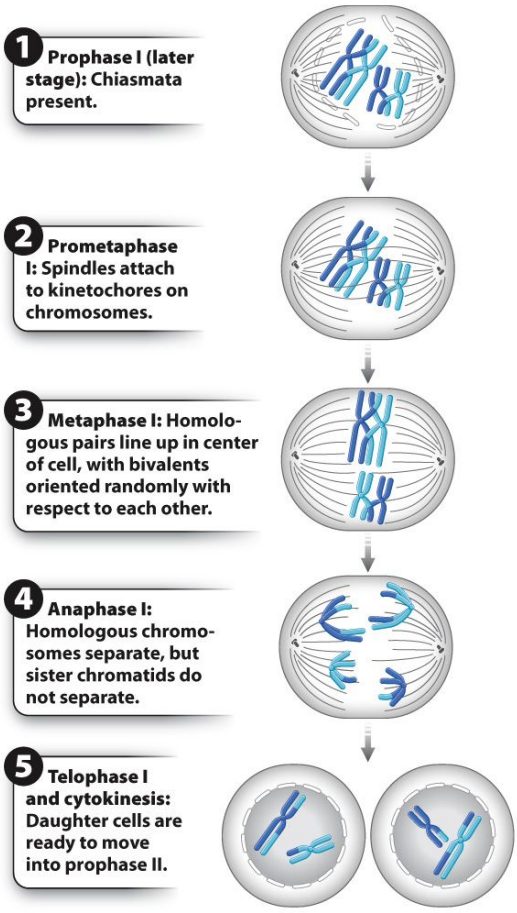
- In sexual reproduction, gametes fuse during fertilization to form a new organism.
- Gametes are produced by meiotic cell division, which has 2 rounds of nuclear division.
    - First round is meiosis I and second is meiosis II
- Meiotic cell division results in 4 daughter cells, with half the number of chromosomes as the two parent cells.



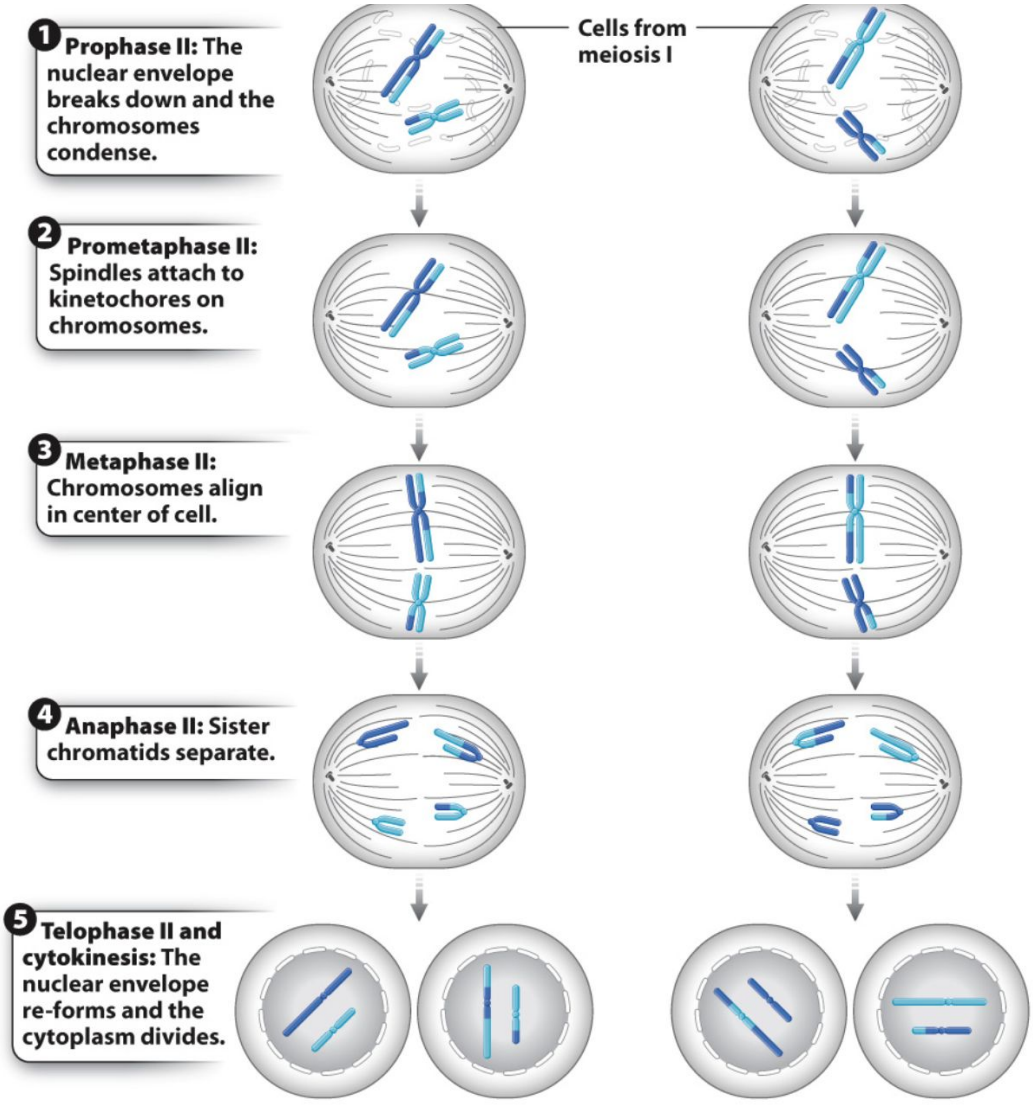
- Prophase I is shown above.
- Then the homologous chromosomes (one from mom and one from dad) pair with each other, and lie side by side in a process known as synapsis. Each pair forms a **bivalent**.
- At the end of prophase, there are 92 chromatids, 46 centromeres, and 23 bivalents.
- Within a bivalent is a **chiasma** which is a crossover, or a breakages and reunion between non sister chromatids.



- Thus, homologous chromosomes of maternal and paternal origin exchange DNA segments.



- The rest of meiosis (explained above) serves to halve the number of chromosomes.
- In metaphase, it's important to know that the homologous pairs, or the bivalents, will line up with independent orientation, meaning that the arrangement is random. Thus, there are 2^n possible arrangements where n is the number of pairs.
    - This and crossing over is what gives us a huge amount of variation in meiosis.
- In anaphase, what's different from mitosis is that the centromeres don't split and the chromatids that make up each chromosome remain together.
- 3 ways in which meiosis I differs from mitosis: Homologous chromosomes pair, undergo crossing over, and segregate from each other.



- In Anaphase II is where the sister chromatids do split.
- Meiosis II is very similar to mitosis because the chromatids split and there's no crossing over.
- Smaller meiotic products that receive small amounts of cytoplasm are called polar bodies.
- A gamete is a haploid cell where it contains a single set of chromosomes.
    - Egg and sperm cells are gametes.
- During fertilization, gametes fuse to form a single cell called a zygote, which is diploid, with chromosomes from both parents.

Chapter 15

15.1 Genotype and Phenotype

- Genetic makeup of a cell or organism constitutes its **genotype**.

- **Polymorphism** is the genetic difference among individuals that is so common that it has be present in a random group of 50 people.
- **Phenotype** is an individual's observable traits and characteristics, like height and weight and eye color.
- Different forms of any gene are called **alleles**, and they correspond to different DNA sequences.
    - Each individual carries 2 alleles of each gene.
- Individual who inherits an allele of the same type from each parent is homozygous, while individuals who inherit different types of alleles from their parents are heterozygous.
- Cigarette smoking affects the enzyme alpha 1 antitrypsin which inhibits another enzyme called elastase, which breaks down elastin. If you reduce the activity of that alpha enzyme, then you'll destroy elastin too quickly.
    - The PiZ allele can increase the odds of having an alpha enzyme with reduced activity.

Chapter 16

16.2 The Foundations of Modern Transmission Genetics

- A genotype-by-environment interaction is where you have a phenotype that is influenced by both the genes and the environment. It also means that different genotypes get affected in different ways to the same environmental variation.
- Reciprocal crosses are where you switch the expressions of the trait in the female and male parents.
- True breeding stock is where an organism is homozygous for every trait.
- F1 generation is the first child generation.

16.3 Segregation: Mendel's Key Discovery

- In the formation of gametes, the two members of a gene pair (AA or Aa or aa) segregate so that half the gametes get one allele and half get the other allele. The union of the two gametes is called the zygote.
- Segregation reflects the separation of homologous chromosomes during anaphase I.
- Incomplete dominance is when no one allele comes through.
- Segregation preserves genetic variation because recessive traits can still come through in future populations.

16.4 Independent Assortment

- Principle of independent assortment states that segregation of one set of alleles is independent of the segregation of another set of alleles.
- Genes that modify the phenotypic expression of other genes are said to show **epistasis**.

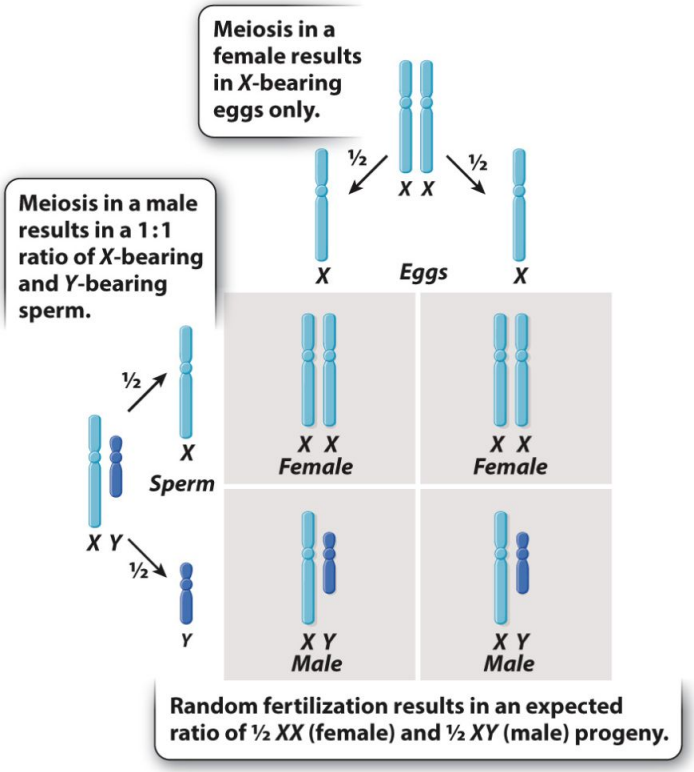
16.5 Patterns of Inheritances Observed in Family Histories

- Record of ancestral relationships is summarized in a family history diagram called a pedigree.
- If a dominant trait is rare, then the parent will almost always be Aa instead of AA.
- Recessive traits have the tendency to skip one generation.
- Some genes have multiple alleles, but an individual can only inherit 2 (one from mother and one from father) for each gene.
    - A gene for which at least 2 alleles exist is said to be polymorphic.
- **Incomplete penetrance** is where individuals with a genotype corresponding to a trait don't actually show the phenotype.
    - On/Off switch
- **Variable expressivity** is where a phenotype is expressed to different degrees in different people.
    - Temperature dial
- Genetic test is a method of identifying the genotype of an individual.

Chapter 17

17.1 The X and Y Sex Chromosomes

- Reciprocal crosses yield the same types of progeny in the same proportions. Basically if you have a male that has a trait crossed with a female that doesn't have that trait (both homozygous), then that result should be the same as when a female with that trait crosses with a male that doesn't have that trait.
    - But for the X and Y sex chromosomes, the reciprocal crosses are not equivalent. This is the indication that the is an impact of parental sex on the inheritance of a trait.
- Meiosis in human males results in half the sperm with an X chromosome and half with a Y chromosome. But with human females, both chromosomes will be X.



- Primary sex ratio is the sex ratio at the time of conception while secondary sex ratio is the ratio at the time of birth.
- Homologous chromosomes are not identical but they have the same genes along their length, and every person has one chromosome from mom and one from dad.
- Sex of an individual is determined by a distinctive pair of unmatched chromosomes known as sex chromosomes.
    - Chromosomes other than sex chromosomes are called **autosomes**.
- Except for small region near the top, the gene contents of the chromosomes are different from each other.
    - The regions of similarity are what allow the chromosomes to pair during meiosis.
        - The crossover during the pairing is what allows them to align properly and then for the X and Y chromosomes to separate and go to different poles.
    - X has more than 1000 genes while the Y chromosome only has 50 protein coding genes.
- Size and gene content of X and Y chromosomes differ greatly among species.

17.2 The Inheritance of Genes in the X Chromosome

- Genes located along the X chromosome are called X-linked genes.
- Most common phenotype in a population is called the wild type.
- For X-linked recessive traits, affected males need one copy of the mutant gene to be affected while females need 2. Immediate offspring of an affected male are not affected because males only give their X chromosome to their daughter. A female whose father is

affected can have affected sons since a female must be a heterozygous carrier of the recessive allele. Also, when a male is affected, you know that the mother must have been heterozygous for that recessive allele (since she cannot have been homozygous).

- A heterozygous female that has a mutant X-linked allele is a carrier for that trait even though she is not necessarily affected by it.
- When homologous chromosomes fail to separate during meiosis I, it's called **nondisjunction**.
- Males can still develop in the absence of the Y chromosome (they'd have XO instead where O indicates no chromosome) and females can still develop with XXY.
- XXX and OY species cannot survive though so we don't see anyone with that genotype.
- Difference between X linked dominant and recessive is that in dominant, even just one mutation on one of the X chromosomes in a female is enough to cause a change in phenotype, while in X linked recessive, the female needs mutations on both chromosomes to see the changes.
- X linked genes show criss cross inheritance because males get their X chromosome from their mother and they pass their X chromosome to their daughters.

15.2 Genetic Variation and Individual Uniqueness

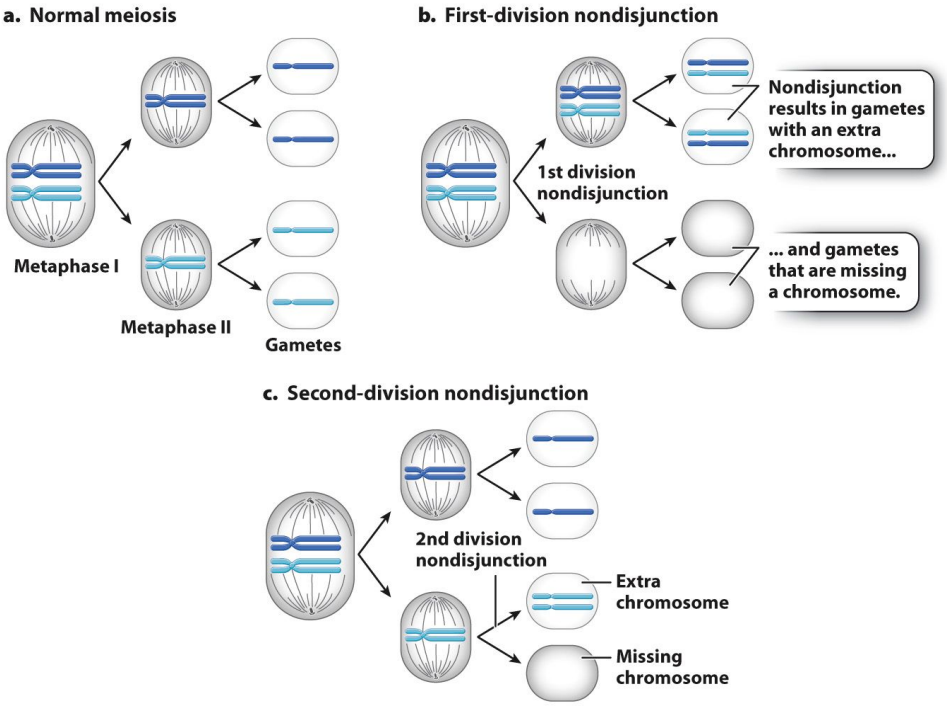
- Most genetic variation in populations is neutral or has no obvious effects because the variation comes through in noncoding DNA.
- Different numbers of a repeated sequence at a particular location is called a variable number tandem repeat.
    - Each individual has two copies of the VNTRs, just like they have 2 copies of each gene.
    - Differing number of repeats is analogous to having different alleles.
- Differences in VNTRs are the basis of DNA typing, which is the analysis of a small quantity of data.
- Because each VNTR in the genome is flanked by a unique sequence used to design PCR primers, it will only amplify one and only one VNTR.
- At a crime scene, we can prove a suspect is not the source of that sample while a DNA match doesn't necessarily prove that the suspect is the source.
    - Any mismatch with any of the polymorphic sites means that we've ruled it out.
- DNA from different individuals can differ in the distance between restriction sites or in presence/absence of a restriction site and this polymorphism is called a restriction fragment length polymorphism. Mutations that destroy or create a cleavage site are the source of these RFLPs.
    - Any individual can carry at most 2 different alleles of a restriction fragment length polymorphism.
- In a VNTR, the restriction fragments are different lengths because of a variable number of repeats between restriction sites (one, two, three, four, or more). In a RFLP, the restriction fragments are different lengths because a restriction site is removed in one DNA sequence and not in another, making the distances between restriction sites different.

15.3 Genomewide Studies of Genetic Variation

- Genetic variation can come from variation of individual nucleotides and variation in the copy number of regions of DNA that can include one or more genes.
- A single nucleotide polymorphism is a site in the genome where either of two different nucleotide pairs can occur.
    - Differences among two alleles can be because of SNPs. The difference at just one nucleotide site is what causes the change in allele.
    - An example of an SNP is when you have the C-G base pair in one allele and the A-T in the other allele.
- Difference between point mutation and a SNP is that a point mutation is a change in a single nucleotide in a single cell while an SNP results from a point mutation that occurred in the past, so now there could be some descendants with a C at a particular position and some with a G at that position.
- Approximately 3 million SNPs that distinguish any one human genome from another.
- SNPs can help us determine genetic risk factors.
- For a given SNP to be associated with a disease, it means that individuals with one of the alleles of that SNP are more likely to develop the disease than the others who carry the other allele.
    - SNP won't alone cause the disease but will create a greater risk for it.
- Copy number variation refers to differences among individuals in the the number of copies of a region of the genome.
    - These are similar to VNTRs but the regions in CNVs are large and include one or more genes.
- To detect SNPs, we need to create microarrays which contain short DNA sequences called oligonucleotides that match the sequence of a known SNP site in the genome. One pair will match the C-G allele and one will match the A-T allele.
    - The main purpose is to reveal the genotype of an individual with respect to a particular SNP in the genome.
    - Millions of SNPs can be detected using a single microarray.

15.4 Genetic Variation in Chromosomes

- CNV usually involves a small number of genes and thus differences can be indetectable.
- Nondisjunction is the failure of a pair of chromosomes to separate during anaphase of cell division which means that one daughter cell gets an extra chromosome, while the other doesn't get a copy.

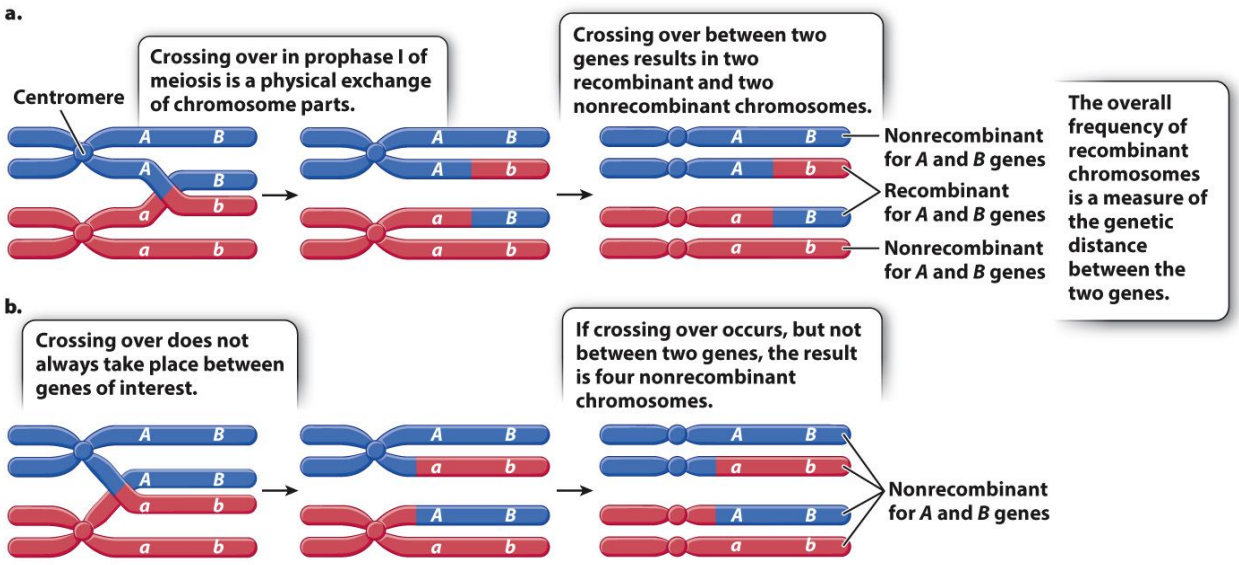


- Different types of nondisjunction above. First division is more common.
- Down syndrome comes from an extra copy of chromosome 21.
- Chromosome layout is called a karyotype.
- XXY males don't show any detectable phenotypic effects mainly because Y only contains a few functional genes. XXX females, however, don't show any effects mainly because all but one of the X chromosomes is active, just like in normal XX females.
- Both *Y* chromosomes in the *XYY* baby must come from the father, so nondisjunction took place in the father. In normal meiosis, the first meiotic division separates the *X* chromosome from the *Y* chromosome, and the second meiotic division separates the sister chromatids of the *X* chromosome and the sister chromatids of the *Y* chromosome. For the *Y* chromosomes to remain together and be included in the same sperm, nondisjunction must take place in the second meiotic division
    - Individuals who are XYY have Klinefelter syndrome.
- Individuals who are just X have Turner syndrome.
- Nondisjunctions can cause spontaneous abortions.
- Some fetuses that undergo this abortion are triploid meaning they have 3 sets of chromosomes or tetraploid where you have 4 sets of chromosomes.
- With nondisjunction in the first meiotic division, you could have two copies of a chromosome that air heterozygous, while you cannot have that if there is nondisjunction in the second division.

17.3 Genetic Linkage and Recombination

- Genes that are close enough on the same chromosome are said to be linked, and thus they tend to be transmitted together and don't sort independently of each other.

- Non Recombinants are where alleles are present in the same combination as that in the parent. Recombinants result from a crossover, which refers to the exchange between parts of homologous chromosomes. During a crossover, no genetic material is gained or lost, it is just transferred a little from one non-sister chromatid to another.
    - One example is if the mom has 2 chromosomes, one with w+c+ and one with w-c-. The non recombinants would get either w+c+ or w-c- from mom, but the recombinants would get w+c- or w-c+.
- Crossing over between two genes results in two recombinants and two non recombinant chromosomes.



- Even when we have crossing over, that still isn't a guarantee that we will see recombinant configuration, as shown in the bottom of the above picture.
- With situations where genes are on the same chromosome, we could still see independent assortment if genes are located very far apart from one another or that they're extremely close together. In the latter case, we don't see crossing over and thus only have non recombinant chromosomes.
    - Genes that are closer together show less recombination than genes that are far apart.
- When crossing over happens, half the cells created in meiosis are non recombinant and the other half are recombinant.
- The closer the genes are along a chromosome, the less likely it is that a crossover will take place in the interval between them.
    - Genes that are close together in the same chromosome tend to be transmitted together during the process of gamete formation.
- The proportion of recombinant chromosomes is called the frequency of recombination and it is a measure of genetic distance between the genes along a chromosome.
    - The greater the distance between two genes, the higher the frequency of recombination
- Frequency of recombination always ranges from 0-50%.

    - Only 50% because there can only be 2 strands that are recombinant and 2 that are non recombinant.
- Genetic map is a diagram showing the relative position of the genes along a chromosome.
    - Map unit is the distance between genes that results in a 1% recombination.
- For genes that show independent assortment, the frequency of recombination is 50%.
- Researchers try to find single nucleotide polymorphisms where one of the nucleotide pairs is a G-C base pair in some chromosomes and an A-T in others. Sometimes, this is directly influenced by whether there is a mutant or non mutant gene next to that SNP. If there is an association found, then that can help us locate the location of the gene, but if not, it just means that the SNP is not closely linked to that particular disease gene.
- Recombination is important because it allows any pair of parental genomes to form a limitless number of possible recombinant (different) gametes depending on where that crossover occurs.

17.4 Inheritance of Genes in the Y Chromosome

- SRY is a gene in the Y chromosome that encodes a protein that is the trigger for male development.
    - In the absence of SRY, the female structures continue their development.
- Genes that are present in the unique region of the Y chromosome are Y-linked genes.
    - Not as many Y-linked genes as X-linked genes.
- Males are affected with the traits, females never inherit or transmit the trait, and all sons of affected males are affected. This is all because the Y chromosome is always transmitted from father to son, and never transmitted to daughters.
- Every unique combination of nucleotides along a Y chromosome constitutes a Y-chromosome haplotype, or a haploid genotype.
    - Each geographically distinct population came to have somewhat different set of Y-chromosome haplotypes.
    - Haplotype of your Y chromosome contains genetic information about its origin.
- The tips of the arms of the X and Y chromosomes share small regions of homology, and thus the genes in these regions are inherited in the same manner as those found in non-sex chromosomes, which are called autosomes.

17.5 Inheritance of Mitochondrial and Chloroplast DNA

- Mitochondria and chloroplasts have their own genomes that contain genes for many of the enzymes that carry out the organelles' functions. Genes in these genomes move independent of the segregation of chromosomes in the nucleus.
- Organelles are partitioned to the gametes and their mode of inheritance depends on how the gametes are formed.
- Maternal inheritance is where the organelles in the offspring cells derive from those in the mother.
- Paternal inheritance is where the organelles in the offspring cells derive from those in the father.

- Biparental inheritance is where the organelles in the offspring cells derive from those in both parents.
- Transmission of chloroplasts in one species can be strictly paternal and can be strictly maternal for another species.
- Most animals show maternal transmission of the mitochondria.
- Traits encoded by a mitochondrial genome transmitted through maternal inheritance are where both males and females can show the trait, all offspring of an affected female show the trait, and males don't transmit the trait to their offspring.

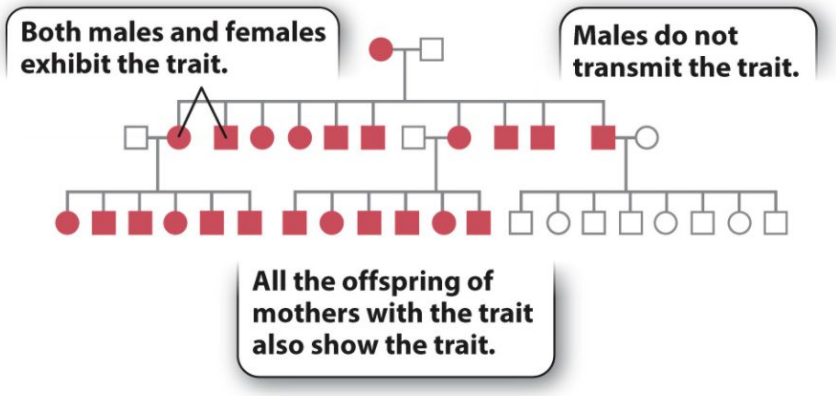


FIG. 17.16 **Maternal inheritance.** Human mitochondrial DNA is transmitted from a mother to all of her offspring.

- No recombination between mitochondrial genomes takes place and thus we can use it to trace ancestry.
- There is more genetic variation in mitochondrial sequences than in Y chromosomes.
- A mutation with an effect on a protein encoded by a mitochondrial gene will be maternally inherited.

Chapter 18

18.1 Heredity and Environment

- Quantitative traits are those that are measured on a continuum.
- Expression of these complex traits is susceptible to lifestyle choices and environmental factors.
    - Also, complex traits are affected by many genes. Thus, the effects of individual genes get obscured.
    - The number of genes affecting complex traits is so large that different genotypes can have very similar phenotypes.
    - Phenotypes of many complex traits actually follow a normal distribution.
- An environmental risk factor is a characteristic in a person's surroundings that increases the likelihood of developing a particular disease.
- The norm of reaction shows how for any genotype, the x axis will represent changes in the environment and then the y axis shows the effect on the phenotype.

- Variation in the effects of the environment on different genotypes is known as genotype by environment interaction.
    - Effect of a genotype can't be specified without knowing the environment, and vice versa.

18.2 Resemblance Among Relatives

- Regression toward the mean is when the offspring exhibits an average phenotype that is closer to the population mean that the phenotype of the parents.
- The slope of the line that relates the average phenotype of parents to the average phenotype of their offspring is a measure of the heritability of a trait.
    - If the slope is .6, then the heritability is 60%.
    - When heritability is 100, then the average phenotype of offspring will equal the average phenotype of the parents.
        - Means that the variation in an environment does not contribute to differences among individuals in a population.
        - You would have a slope of 1.
    - When it is 0, then the average of the offspring will just be the population mean.
        - Means that differences in genotype cannot affect the trait. Genes play no role in the variation in the trait among individuals.
        - You would have a slope of 0.
- The real meaning of heritability is the relative magnitude of variation in a trait among individuals that can be attributed to differences in the genotype of to differences in the environment. A high heritability means that genetic differences account for relatively more variation in the trait than environmental differences. In this case, the 90% heritability means that only 10% of the variation in fingerprint ridge count can be attributed to environment; 90% of the variation is due to differences in genotype.
- A trait with high heritability responds rapidly to selection where a trait with low heritability responds slowly or not at all.

Natural Selection Video

- Evolution by natural selection requires variation, heritability, struggle for existence (whereas populations grow, resources become limited, thus only some survive), and natural selection.
- Traits preserved through natural selection are called adaptations.
- Drift and migration are alternatives to natural selection.

Chapter 21

21.1 Genetic Variation

- A phenotype is an observable trait and is a function of genotype and the environment.
- Any 2 humans differ from one another on average by one DNA base pair per thousand, which means two genomes are 99.9% identical.

- A species consists of individuals that can exchange genetic material through interbreeding.
    - Refers to individuals that can share alleles with each other through reproduction.
- Gene pool is all the alleles present in all individuals in the species.
- Population genetics is the study of genetic variation in natural populations, which are interbreeding groups of organisms of the same species living in the same area.
- Genetic variation can come from mutation or recombination followed by the separation of homologous chromosomes during cell division.
- Somatic mutations occur in the body's tissues while germ-line mutations occur in reproductive cells and are passed on.
    - Germ-line mutations occur in every cell of an individual derived from the fertilization involving the mutation bearing gamete.
- Neutral mutations have little or no effect on the organism.

21.2 Measuring Genetic Variation

- Allele frequencies are the rates of occurence of alleles in populations.
    - Allele frequency x = # x's present in population / total # of alleles
- When a population exhibits only one allele at a particular gene, the population is fixed for that allele.
- Genotype frequency is the proportion in a population of each genotype at a particular gene or set of genes.
- To measure genotype and allele frequencies, you can use observable traits, gel electrophoresis, and DNA sequencing.

21.3 Evolution and the Hardy-Weinberg Equilibrium

- Evolution is simply a change in the frequency of an allele or genotype from one generation to the next.
    - Allele frequencies may not change, but the frequencies of different genotypes can. Called evolution without allele frequency change.
- Hardy Weinberg equilibrium describes the situation in which evolution does not occur. In the absence of evolutionary forces, allele and genotype frequencies do not change.
- Assumptions of HW equilibrium
    - A population in Hardy Weinberg equilibrium sees no differences in the survival and reproductive success of individuals
    - Sees no population added to or subtracted from by migration
    - There is no mutation
    - The population must be sufficiently large to avoid sampling errors
    - Individuals must mate at random.
- The Hardy Weinberg equilibrium provides means for converting between allele and genotype frequencies.
    - Because we know that they won't change from generation to generation.

    - When you put a restriction that individuals will only mate with those of their own genotype (for example), this violates the 5th assumption and thus we cannot use HW equations to calculate changes in frequency.
- When we have a population whose allele or genotype frequencies are not in Hardy Weinberg equilibrium, then we can infer that evolution occurred.
    - It could be subject to selection, migration, mutation, genetic drift, or non-random mating. We won't know without more info.
- Genetic drift is variation in the frequency of genotypes in a small population, because of the chance of disappearance of particular genes because an individual dies and/or doesn't reproduce.

21.4 Natural Selection

- Natural selection results in allele frequencies changing from generation to generation according to the allele's impact on the survival and reproduction of individuals.
    - Deleterious mutations are eliminated by natural selection while beneficial ones can result in adaptation to the environment over time.
- Darwin mainly said that species evolve over time through natural selection which brings about adaptation.
- More specifically said, natural selection favors traits that lead to the greatest propagation of genes to the next generations.
- Thomas Malthus said that natural populations have the potential to increase in size geometrically (population doubles) but the problem is that the resources do not grow at the same rate and thus individuals must compete for resources.
    - This leads into Darwin's theory that only the fittest will survive.
- An organism that is better adapted to its environment is more fit. Fitness is a measure of the extent to which the individual's genotype is represented in the next generation.
    - If it leaves more offspring, it is more fit.
    - Fitness, said another way, is the number of living offspring that an individual contributes relative to the number produced by others in the population.
- Ronald Fisher realize that instead of a single gene contributing to a trait like height, there are several that contribute to it. This allows for continuous, instead of discrete, variation.
- Natural selection increases the frequency of advantageous alleles, which results in adaptation.
- Natural selection that increases the frequency of a favorable allele is called positive selection.
- Natural selection that decreases the frequency of a deleterious allele is called negative selection.
- Balancing selection maintains some allele's frequency between 0 and 100%.
    - One allele might be good in one environment and another might be good in another environment so thus we keep both alleles.
- If the heterozygote fitness is higher than either of the homozygotes, then we'll keep both alleles in the population. This is called the heterozygote advantage.

    - Aka sometimes it's better to be SA rather than AA or SS, because both of those might have some other bad effects.
- Stabilizing selection maintains the status quo and acts against extremes.
    - Birth weight is an example because a light baby isn't good and neither is a heavy baby.
- Directional selection leads to a change in a trait over time.
    - An example is when there is a change in the environment which favors certain parts of the population which may have a greater value for a particular trait (beak size) and thus there is a shift to the right of the population mean.
- Artificial selection is a form of directional selection where successful genotypes are selected by the breeder.
- Disruptive selection operates in favor of extremes and against intermediate forms.
    - Example is when it's good it have very small amount of a trait or a very large amount, but it's not beneficial to just be in between.
- Sexual selection is something that often acts in opposition to natural selection, and seeks to promote traits that increase an individual's access to reproductive opportunities.
    - Intrasexual selection focuses on interactions between individuals of one sex.
    - Intersexual selection focuses on interactions between males and females.

21.5 Migration, Mutation, Genetic Drift, and Non-random Mating

- Selection can be summarized as the effect of each new generation being best fit organisms to their environments.
- But other mechanisms like migration, mutation, genetic drift, and non-random mating can cause allele frequencies to change, but the unique thing is that they do not lead to adaptations.
- Migration is the movement of individuals from one population to another, resulting in gene flow, which refers to the movement of alleles from one population to another.
    - Consequence is making populations more similar to one another.
- Genetic drift is the random change in allele frequencies from generation to generation.
    - Can be changed when an originally large population falls to just a few individuals.
    - Consider a rare allele, *A,* with a frequency of 1/1000. Habitat destruction then reduces the population to just one pair of individuals, one of which is carrying *A.* The frequency of *A* in this new population is 1/4 because each individual has two alleles, giving a total of four alleles. In other words, the bottleneck resulted in a dramatic change in allele frequencies.
        - Now, when the new population reproduces, you'll see a drastic difference in the allele frequencies now compared to before the event occurred.
    - Can also happen when a few individuals start a new population, which is called a founder event.
    - Also related to when neutral mutations can either stay or die out from a population just by chance, not by selection.
- Impact of genetic drift is highly dependent on population size. If the size is small, then frequency can change rapidly and you'd have greater genetic drift.

- In non-random mating, by contrast, individuals preferentially choose mates according to their genotypes. The result is that certain phenotypes increase and others decrease.
    - This will just rearrange the alleles in the gene pool, so we'll see a change in genotypic frequencies, but not necessarily in allele frequencies.
- Inbreeding is mating between close relatives and this increases the frequency of homozygotes and decreases the number of heterozygotes without affecting allele frequency.
- If *b* is a deleterious recessive mutation, it may contribute to inbreeding depression in the child, a reduction in the child's fitness caused by homozygosity of deleterious recessive mutations.

21.6 Molecular Evolution

- Mutations in certain populations can go to fixation (through genetic drift or positive selection), or they can be maintained at intermediate frequencies, or they can be eliminated through natural selection.
- Molecular evolution is when populations can diverge genetically even if they have the same starting point.
- Species are *genetically* isolated because, by definition, members of one species cannot exchange genetic material with members of another
- The extent of genetic difference between 2 species is a function of the amount of time they have been apart.
    - This correlation between the time two species have been evolutionarily separated and the amount of genetic divergence between them is known as the molecular clock.
    - The rates of these clocks can differ for specific genes.
- Some proteins have a slower clock due to negative selection, which eliminates harmful alleles.
- A gene that no longer retains function is called a pseudogene.

Chapter 22

22.1 The Biological Species Concept

- Whether or not two individuals are members of the same species is a reflection of their ability to exchange genetic material by producing fertile offspring.
    - Mutations spread within a species, but cannot spread beyond it. Therefore a species represents a closed gene pool.
- Biological Species Concept: Species are groups of actually or potentially interbreeding populations that are reproductively isolated from other such groups.
    - Members of different species are reproductively isolated from each other.
    - Some animals may be of the same species but they may not get to mate because they are geographically separated.

    - BSC cannot apply to species that reproduce asexually and cannot be applied to species that are extinct because we only have fossil records.
- Because BSC is hard to test, biologists use morphospecies concept which says that members of the same species usually look alike and also if they have similar DNA sequences.
    - But this has flaws in that members of the same species can exhibit different phenotypes and members of different species can look like each other.
- Cryptic species are composed of organisms that had been traditionally considered as belonging to one species because they look similar, but actually are different species because of distinction at the DNA level.
- Ring species are those with populations that are reproductively but not genetically isolated.
    - This means that two populations may not be able to exchange genes directly, but they can do so indirectly with the material passing through many intermediate populations.
    - Think about the circular graph of gene flow.
- Species can be characterized by its ecological niche, which is a complete description of the role the species plays in its environment. Impossible for two species to coexist in the same location if the niches are too similar, since the competition for resources will lead to the extinction of one of them.
- Ecological species concept says that there is 1:1 correspondence between species and niche.
- Phylogenetic species concept is the idea that members of a species all share a common ancestry and a common fate.
- Ecological species is a concept that might differentiate species on the basis of specific dietary requirements.

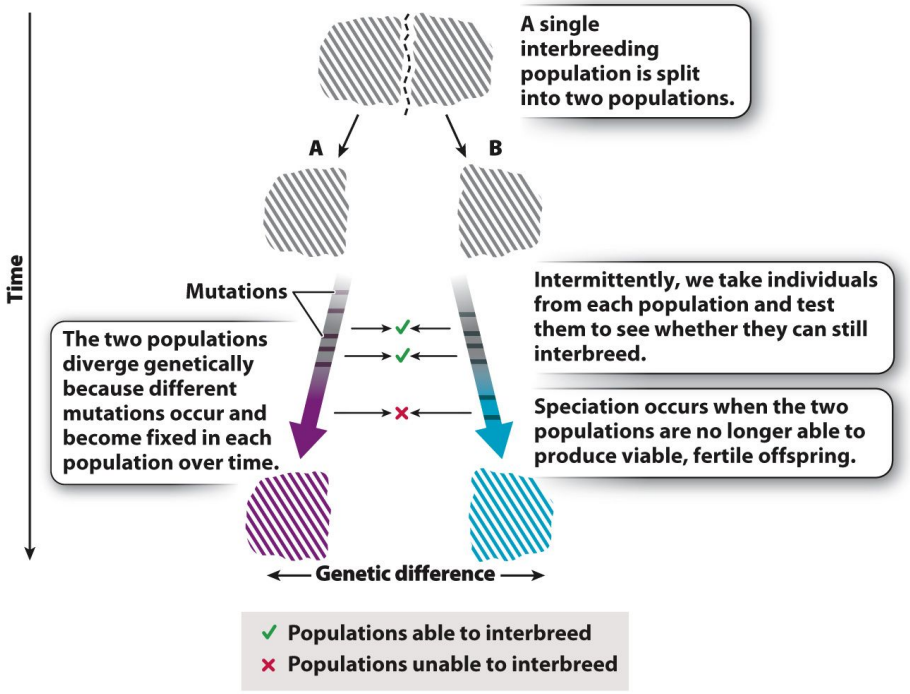
22.2 Reproductive Isolation

- Factors that cause reproductive isolation
    - Pre-zygotic factors act before the fertilization of an egg. Failure for fertilization to take place.
    - Post-zygotic factors come into play after fertilization. Result in the failure of the egg to develop into a fertile individual.
- Species can be behaviorally isolated where the individuals mate only based on special rituals, songs, other behaviours.
- Pre-zygotic isolation can happen when there is an incompatibility between the pollen and the receiving flower.
    - Gametic isolation is the incompatibility between the gametes of two different species,
    - Mechanical incompatibility is caused when the genitalia of one species only fit those of the same species.
    - Temporal isolation is when two species may not come into contact based on time or date.

    - Geographic isolation or ecological isolation is when two species don't mate because they're so concentrated on their own environments.
    - Behavioral isolation is when two species don't mate because of social norms.
- The above 4 are all examples of pre-zygotic isolation.
- Post-zygotic isolating factors involve some sort of genetic incompatibility. This could be because the parental genomes are too different to give normal development.
    - But the general rule is that the more closely related/genetically similar a pair of species are, the less extreme the genetic incompatibility between genomes.

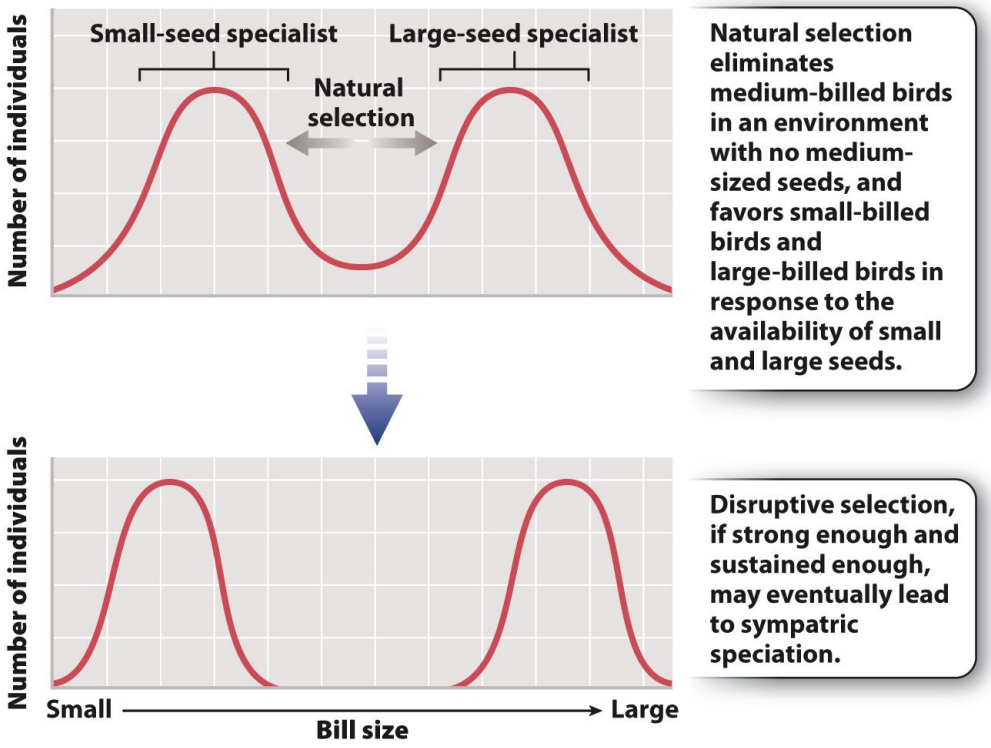
22.3 Speciation

- The key is speciation is the fundamental evolutionary process of genetic divergence between genetically separated populations.
- If a single population splits into two and they cannot interbreed, then different mutations will appear by chance, and these will be subject to genetic drift or natural selection and the populations will gradually become distinct. After a while they are no longer to interbreed again.



- Speciation is the development of reproductive isolation between population and is a byproduct of genetic divergence of separated populations.
- Populations can be partially reproductively isolated if they diverge quite a bit but they are not yet separate species and thus can still interbreed but their hybrid offspring will likely have reduced fertility.
- Geography is the easiest way to create genetic isolation with is required for speciation.
    - Allopatric populations are those that are geographically separated from each other.

- Just separating two populations isn't enough though, you have to separate and then allow time to pass for mutations to become fixed in the two populations, and then eventually they become reproductively isolated from each other.
- Each geographic form is a subspecies, for example Sri Lankan elephants and Indian elephants.
- Populations can become allopatric through dispersal, which is where some individuals colonize a distant place far from the source population, and then the other way is through vicariance which is a geographic barrier arising within a single population, which separates it into two or more populations.
    - Either way, the two separated populations will diverge genetically until speciation occurs.
- One kind of allopatric speciation is called peripatric speciation, where a few individuals from the mainland disperse to a new location and evolve separately. It could be intentional or could be on accident.
    - The resulting population is called the island population.
    - Change will accumulate faster in these isolated populations than with the main population.
- Adaptive radiation is a bout of unusually rapid evolutionary diversification in which natural selection accelerates the rates of both speciation and adaptation.
    - Occurs when there are many ecological opportunities available for exploitations. Opportunities can refer to there by a lot of food to eat or favorable climate or absence of competitors, etc.
- Two populations that are not fully separated from each other (basically if there is still gene flow between them) will not diverge from each other genetically because genetic exchange homogenizes them.
    - This is why most speciation is allopatric.
- Host parasite speciation is called co-speciation which is a process in which two groups of organisms speciate in response to each other and at the same time.
    - In co-speciation two groups of organisms will speciate in response to each other and in a coordinated manner.
- Populations that are in the same geographic location are sympatric.
- For speciation to occur sympatrically, natural selection must act strongly to counteract the homogenizing effect of gene flow. This kind is called disruptive selection because it will push the members of the population to one side or the other, and then after a while, we will see two populations.



- Instantaneous speciation is caused by hybridization between two species in which the offspring are reproductively isolated from both parents.
    - In cases of hybridization, chromosome numbers may change and that's what makes the offspring sterile for the most part.
- Formation of new species through polyploidy - multiple chromosome sets - is common in plants.
    - Sympatric speciation can occur instantaneously through formation of polyploid offspring.
- For some species, hybridization results in sterile offspring, which is known as reinforcement of isolation, which is like selection against individuals that hybridize.
    - Reinforcement is a situation where you have selection against individuals whose hybrid offspring have **reduced** fitness relative to non hybrids
    - Selective against the PARENTS of those hybrid offspring.
- In reinforcement, postzygotic isolation happens first, and so reinforcement facilitates prezygotic isolation because post-zygotic isolation causes reinforcement to happen.
- Allopatric species will not necessarily evolve pre-zygotic isolating mechanisms more rapidly than sympatric species.

22.4 Speciation and Selection

- Speciation can occur in the absence of natural selection, and natural selection doesn't always lead to speciation.
- Genetic divergence of two populations can be entirely due to genetic drift, with natural selection not playing a role.

    - Natural divergence can accelerate the rate of genetic divergence is allopatric situations
    - Sympatric speciation, on the other hand, needs some sort of disruptive selection.
- Natural selection can contribute directly to the process of speciation when individuals better at choosing mates from their own group are selectively favored over those that frequently mater with members of the “wrong” group.
    - The large billed animals will be able to distinguish between the large bills and the small bills and it would spread under natural selection. This is an example of reinforcement of reproductive isolation.
- Reinforcement is the process by which diverging populations undergo natural selection in favor of traits that enhance pre-zygotic isolation, preventing the production of less fit hybrid offspring.
- Natural selection is the force responsible for changes in allelic frequency of deleterious mutations while genetic drift is the reason for changes in neutral mutations.

Chapter 23

23.1 Reading a Phylogenetic Tree

- To summarize, speciation was the set of processes by which populations diverge from one another to the point where they can no longer produce fertile offspring.
- Fork in the branch in a phylogenetic tree is called a node, which represents the most recent common ancestor of two descendant species.
- Goal of taxonomy is to recognize and name groups of individuals as species, and subsequently to group closely related species into more inclusive taxonomic group of the genus.
- Phylogenetics aims to discover the pattern of evolutionary relatedness among groups of species by comparing their anatomical or molecular features.
    - Trees are the hypotheses about the evolutionary history of the species.
    - They can be tested by gathering more information about anatomical and molecular traits.
- A phylogenetic tree does not imply yhat more recently evolved groups are more advanced than groups that arose earlier.
- Two species are said to be the closest relatives if they share a common ancestor not shared by any other species or group.
- Groups that are more closely related to each other than either of them is to any other group are called sister groups.
- Monophyletic groups are those where all members share a single common ancestor not shared with any other species or group of species.
    - They include all descendants of a common ancestor and only the descendants of that common ancestor.
    - Monophyletic groups alone show the evolutionary path a given group has taken since its origin.

- A paraphyletic group includes some, but not all of the descendants of a common ancestor.
- Groups that do not include the last common ancestor of all members are called polyphyletic.
- Closely related species are grouped into a genus.
- Closely related genera belong to a family.
- Closely related families form an order.
- Closely related orders form a class
- Closely related classes form a phylum
- Closely related phylums form a kingdom
- The 3 largest limbs of the tree of life are domains
    - Eukarya, Bacteria, and Archaea

23.2 Building a Phylogenetic Tree

- Phylogenetic trees are constructed by comparison of character states shared among different groups of organisms. Characters are the anatomical, physiological, or molecular features that make up organisms.
    - An example of a character is lungs. A species can have them or not.
    - They have several observed conditions called character states.
        - Petal arrangement is a character with multiple possible states.
- Character states in different species can be similar if the state was present in the common ancestor of the two groups, or they can be similar if the character state independently evolved in the two groups as an adaptation to similar environments.
    - Characters that are similar because of descent from a common ancestor are said to be homologous.
    - Similarities due to independent adaptation by different species are said to be analogous. Result of convergent evolution. These arise due to similar selective pressures.
- To determine if characters observed in two organisms that homologous or analogous, we can weigh evidence from where other traits place the two organisms on a phylogenetic tree, we can look at where on the organisms the trait occurs, and we can look at the anatomical and genetic details of how the trait is constructed.
- Character states that are unique to a given species or other monophyletic group cannot tell us anything about its sister group.
- Shared derived characters that are shared by some, but not all members of the group are called synapomorphies.
- Phylogenetic reconstruction on the basis of synapomorphies is called cladistics.
- The strongest hypothesis for the tree is the tree with the fewest number of changes.
    - Example of parsimony where we choose the simpler of two or more hypotheses to account for a set of observations.
- Trees can be built of anatomical features and/or molecular data, but neither is better than the other.

- One theory is that the extent of similarity indicates how recently two groups shared a common ancestor. The assumption is that the rate of evolution is constant, and this assumption is less likely to be violated when we are using molecular data than when we are using morphological data.
- Molecular data are often combined with morphological data, and each can serve as an independent assessment of other other.

23.3 The Fossil Record

- Phylogenies based on living organisms provide hypotheses about evolutionary history.
- Fossils can provide evidence for phylogenetic hypotheses showing that groups that branch early in phylogenies appear early in the geologic record.
    - Also allows us to calibrate phylogenies in terms of time.
    - Estimates of divergence time can be made using molecular data but estimates have to be calibrated using fossils.
    - Fossils also place evolutionary events in the context of the Earth's environmental history.
- Most fossils preserve the mineralized skeletons. A fossil formation also depends on if the organism has other features that resist decay after death as well as if they lived in a place where burial was likely.
- Organisms that lack hard parts can leave tracks/trails as they burrow into sediments, and these are called trace fossils.
- Organisms contribute molecular fossils to the rocks.
- Fossils provide good sense of how the forms, functions, and diversity of skeletonized animals have changed over the past 500 million years.
- Geologic timescale refers to the series of time divisions that mark Earth’s history.
- Radioactive decay of Carbon 14 to date wood and bone is a process called radiometric dating.
    - Basically C14 is already inside of plants and humans, and after death, the C14 will be unstable and will break down, losing an electron, and forming N14. Half od the C14 will decay to nitrogen in 5730 years, its half life. In another 5730 years, another half of C14 will decay, and so on.
- Phylogenies show that all land vertebrates are descended from fish.
- Animal diversity in the oceans dropped both rapidly and substantially, and extinctions also occurred on land. These mass extinction events eliminated ecologically important taxa and provided evolutionary opportunities for the survivors.
    - Mass extinction at the end of the Permian Period eliminated half of all families in the oceans and 80% of all genera.
        - Was caused by lack of oxygen (from ash and smoke), ocean acidification, and global warming.
- Current biological diversity reflects the interplay through time of natural selection and rare massive perturbations to ecosystems on land and in the sea.

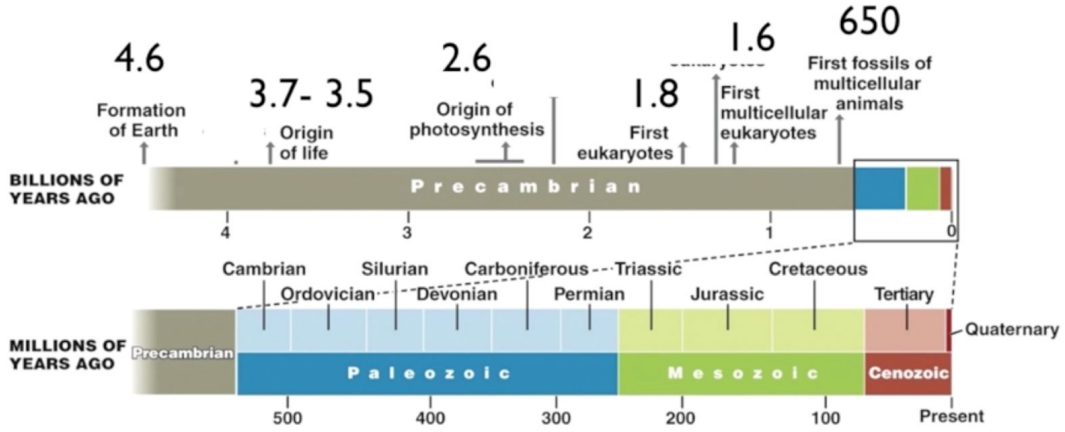
- Fossil record of marine life is more complete than that of those living in terrestrial ecosystems because marine habitats are places where sedimentation is more likely than erosion.
- First event in the fossilization process is the burial of the organism by sediments.
- Discovery of Tiktaalik roseae was significant because it provided evidence that terrestrial vertebrates are descended from fish.

23.4 Comparing Evolution's Two Great Patterns

- Two great patterns are the nested similarity observed in the forms and molecular sequences of living organisms and the direct historical archive of the fossil record.
- To generate phylogenetic hypotheses, we can use a full range of features, like skeletal morphology, cell structure, and DNA sequence.
    - Disadvantage of comparative biology, though, is that we lack evidence of extinct species, the time dimension, and the environmental context. This is where the fossil record comes into play.
- Biology provides a functional and phylogenetic framework for the interpretation of fossils, and fossils provide a record of life's history in the context of continual planetary change.
- Agreement between fossils and phylogenies can be found when fossils confirm that one species lived before another, or vice versa.

History of Biodiversity Part 1

- First period of life is the Precambrian, and this was 4.6 billion years ago to 542 million years ago, and it encompasses the formation of Earth, evolution of life (bacteria, archaea, eukarya), and multicellular life.
- Next is Paleozoic, which is 542 - 251 MY ago, and it had the rise of animals, insects, spiders, tetrapods, and mass extinctions.
- Then is Mesozoic, which is 251 - 65 MY ago, and it has the phytoplankton, and dinosaurs, and also some mass extinctions.
- Finally is Cenozoic, which is 65 MY to present, and we have mammals, hominids, and the ice ages.



- History of life on Earth is revealed by the fossil record.

- 3.7 billion years ago, we see that the carbon ratio in zircons (which capture early atmospheric conditions) suggests life.
- Oldest stromatolite bacteria fossils date to 3.45 billion years ago.
- Earliest fossils from bacteria are 3.45 bya, archaea are 3.5 as well, eukarya are 1.8 bya.
    - For eukarya, the red algae showed at 1.2 bya and green algae at 750 mya.
- Archaea and eukarya are sister taxa while bacteria are the outgroup.
- Oldest fossils of multicellular life date back to 2.1 billion years.
- There is a long interval between origin of life and the appearance of multicellular organisms.
- First evidence for animals come 650 mya. These are called the Ediacaran fauna.
    - Life forms are were soft bodied and have very few characteristics.
- Cambrian marks the beginning of the Paleozoic and most of the major groups of animals living today emerged in this period. Most life was aquatic and fossil beds have preserved the soft parts of many organisms.
- The Cambrian explosion refers to how evolution of the diversity we see today was disproportionately in this time period.

History of Biodiversity Part 2

- During that Cambrian period, animals diversify a lot, the oxygen concentrations are near today's levels, and 10x increase in the rate of species formation relative to Precambrian.
- Periods of rapid diversification are known as evolutionary radiations.
- The diversity we saw with the Ediacaran fauna is dwarfed by that seen during the Cambrian. The Ediacaran don't last very long after the Cambrian and almost all go extinct in 40 million years.
- Ordovician and Silurian periods see radiation of marine organisms and mass extinction at the end of the Ordovician which was caused by a lot of glaciers and thus a drop in temperature.
- First vascular plants and jawless fish appeared in the Silurian.
- Devonian period had rapid evolutionary changes in many multicellular groups. We also see first seed plants, radiations of corals and cephalopods, and earliest spider and tetrapod fossils. Mass extinction at the end of this period was due to global cooling and there was a loss of 75% of marine species.
- Carboniferous had large glaciers at high latitudes but great swamp forests on tropical continents, which fossilized and gave us coal. Shark and insects diversify.
- Permian and Triassic periods are where the continents come together to form Pangaea. At the end of the Permian, we see lots of volcanic eruptions which block sunlight, cause cooling, and result in glaciers and drop in oxygen concentrations. This caused 96% of multicellular species to go extinct.
- Because of the previous mass extinction, the Mesozoic inhabitants didn't have a lot of competition. During this period, we saw the continents drift apart, sea levels rise.
- In the Triassic, we see Pangaea break apart into Laurasia and Gondwana and the rise of reptiles. We see dinosaurs, but then another mass extinction which reduces 65%.

- In the Jurassic, we see more continent shift, flying reptiles, sauropods diversify, and flowering plants and mammal groups appeared.
- In the Cretaceous, rise in sea levels causing warm and humid temperatures, and dinosaurs diversify and flowering plants dominate. Another mass extinction caused by a meteorite.
- In Cenozoic, positions of continents are like what they are today.
- In Tertiary, snakes and lizards and birds went through radiation.
- In Quaternary, some major ice ages, and hominid evolution.

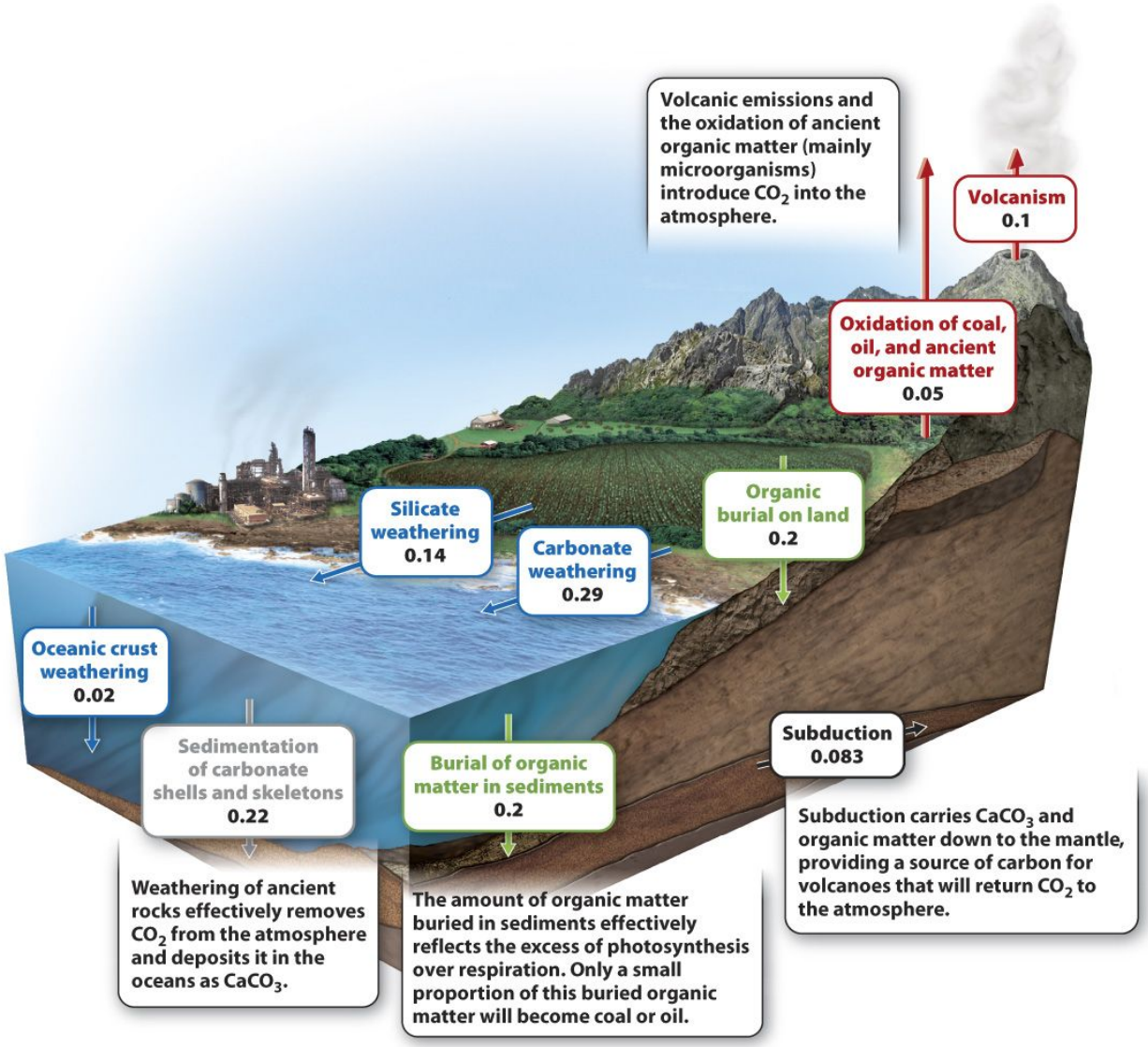
Chapter 25

25.1 Short Term Carbon Cycle

- CO2 concentration goes in a sine cycle.
- Carbon dioxide is added to the atmosphere by (1) geologic inputs, mainly from volcanoes and mid-ocean ridges; (2) biological inputs, especially respiration; and (3)human activities, including deforestation and the burning of fossil fuels. Processes that remove CO2 from the atmosphere include (1) geologic removal, especially by chemical weathering in which CO2 in rainwater reacts with exposed rocks, and (2) biological removal, mainly through photosynthesis.
- CO2 oscillation (shown in Keeling curve) is because photosynthesis is seasonal, high in summer and low in winter, and also because land is distributed asymmetrically.

25.2 Long Term Carbon Cycle

- Long term changes mean we consider physical processes like climate change.
- Reservoirs are places where carbon is found on Earth.
    - Organisms, atmosphere, soils, ocean, etc
    - Most of it is in the atmosphere though.
- Biggest carbon reservoir is within sediments and sedimentary rocks.
- Fluxes are the rates at which carbon flows from one reservoir to another.
    - Sensitivity depends on the relative sizes of the reservoir and the amount of movement of material into and out of it.
- Volcanism can add more CO2 into the atmosphere.
- Chemical weathering is a physical process that removes CO2 and creates calcium carbonate.
    - Carbon moves from atmosphere to the sediments.
- Biomineralization is the precipitation of minerals by organisms.
- Carbon fluxes associated with geologic processes are small relative to those from photosynthesis and respiration.



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- Geological processes shown above
- Increasing the elevation of mountains would increase rates of chemical weathering and erosion. Chemical weathering will consume CO2.
- The stomata, which are the small pores on leaf surfaces, decrease in density as atmospheric CO2 levels increase.

25.3 The Carbon Cycle: Ecology, Biodiversity, and Evolution

- All the organisms in a habitat constitute an ecological community.
- Primary producers generate organic molecules like carbon through photosynthesis. The primary consumers obtain carbon by eating the producers, and then the secondary consumers obtain the carbon by eating the primary consumers. Tertiary consumers are those that feed only on secondary consumers.
- Carbon is eventually returned to the atmosphere by the respiration of fungi, bacteria, and other decomposers that break down dead tissues.

- Biodiversity is shaped and sustained by ecological interactions among organisms and between organisms and the physical environment.
- 2 bya, the carbon cycle included photosynthetic bacteria and heterotrophs because there were no plants or animals.
- Oxygen rich atmosphere is possible because the rates of oxygen consumption are lower than rates of photosynthesis.
- Accumulation of oxygen in the atmosphere was the result of photosynthesis, evolution of cyanobacteria, decoupling between photosynthesis and respiration, as well as the fact that oxygen is also cycled during the carbon cycle.

Chapter 26

26.4 The Diversity of Bacteria

- Pure culture is when you only have one type of bacterium that is present.
- Back then, bacteria was identified based on cell structure and cell division. Now, they are characterized by their DNA sequences, and the genes for the rRNA.
- Molecular phylogenies are where gene sequences are compared to draw conclusions about evolutionary relatedness.
- Nucleotides in gene sequences may change multiple times, thus erasing features that the ancestors may have had. Also, in some groups, rates of evolution may be different.
- Horizontal gene transfer is the movement of genetic material between organisms other than the vertical transmission of DNA from parent to offspring.
- Distantly related bacteria can exchange genes. This is different from multicellular organisms.
- Periodic selection is when you have a gradual increase in genetic diversity but then a rapid decrease with the emergence of one successful variant that outcompetes the rest.
    - Populations subject to the same episodes of periodic selection belong to a single species.
- Proteobacteria are the most diverse of bacterial groups, and they include many organisms that populate our carbon cycle. They have relationships with eukaryotic organisms. Some of mutually beneficial and some cause diseases in humans.
- Gram positive bacteria are those than retain the dye that indicates bacteria with thick walls.
    - Some can be pathogens and some can be streptomycetes which secrete compounds that kills other bacteria and fungi.
- All bacteria capable of oxygenic photosynthesis form a single branch of the bacterial tree, and they are called cyanobacteria, which have unicellular rods and spheroidical cells and they can form different cell types for different functions.
- Anoxygenic photosynthesis is distributed widely on the bacterial tree.
- E.coli is classified as a proteobacterium.
- Photosynthetic bacteria are all found on different places in the bacterial tree.

26.5 The Diversity of Archaea

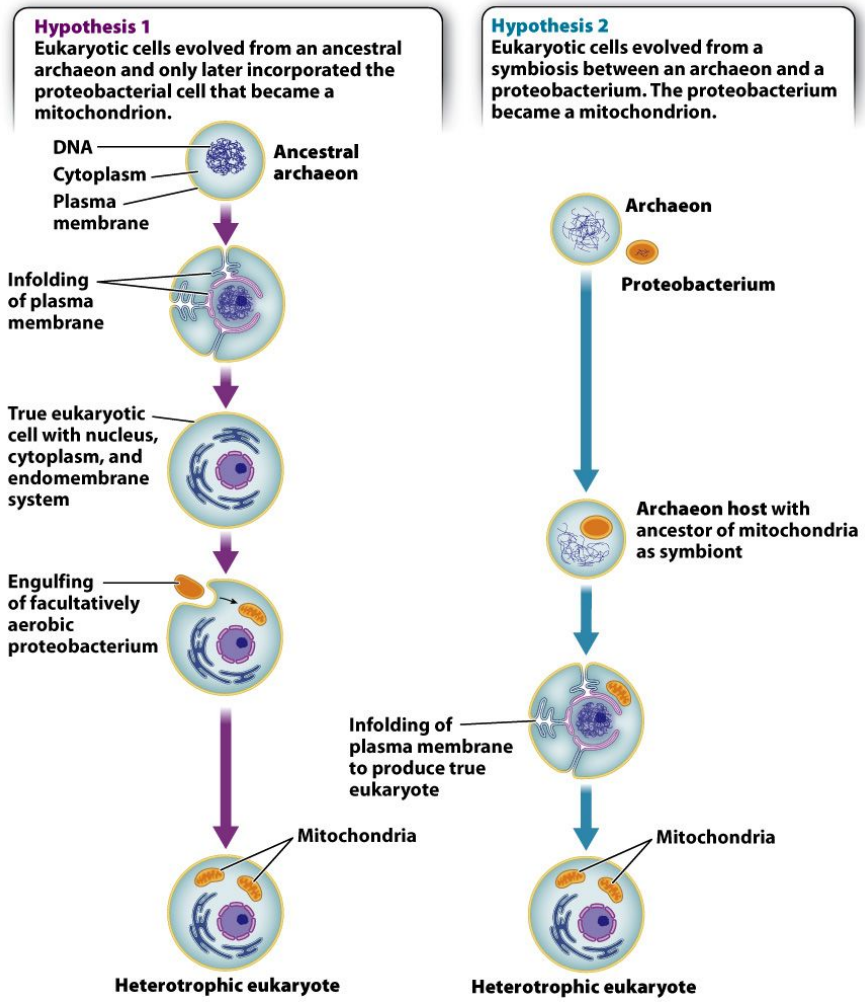
- Archaea and bacteria are both prokaryotic, but differ in membrane and wall composition.
- Many archaeons tolerate environmental extremes such as heat or acidity.
    - They thrive in places where the energy available to fuel cell activities is limited. They live where energy resources are too low to support bacteria and eukaryotes.
- Bacteria and archaea diverged from the last common ancestor more than 3 bya.
- Hyperthermophiles are archaeons that require high temperatures to live and grow. They are anaerobic. They sit on the lowest branches of the tree and thus that means there wasn't a whole lot of oxygen in the beginning of Earth.
- Acid mine drainage is when abandoned mines fill up with acidic water. Some archaeons thrive in it and require acidic environments because they have modified protein and membrane structures.
- Methanogens are those that generate methane and they can recycle organic molecules in environments where the supplies of electron acceptors for respiration are limited.
    - They are basically a biological source of natural gas.
    - Steady supply of methane generated by archaeons contributes significantly to greenhouse gases.
- Methanogens are types of euryarchaeota, and another type that is inside that supergroup is called Haloarchaea which are salt loving organisms. They live in waters salty enough to precipitate table salt.
- Thaumarchaeota are those that derive energy from the oxidation of ammonia.
- Some bacteria can survive at high temperatures (b/c PCR gets to 70 degrees) but archaeons can survive in much hotter environments.

Chapter 27

27.2 Eukaryotic Origins

- Chloroplasts in plant cells are very similar to cyanobacteria.
- A symbiont is an organism that lives in closely evolved association with another species.
    - The association itself is called the symbiosis.
- Chloroplasts, therefore, could have been symbiotic cyanobacteria that become permanently incorporated into their hosts.
    - A symbiosis where one partner lives inside of another is called endosymbiosis.
- The two discoveries that helped validate was seeing that chloroplasts had their own DNA and that they were surrounded by their own outer membranes.
- Thus, eukaryotes were able to acquire photosynthesis because they could engulf and retain cyanobacterial cells.
- Some of the DNA from those cyanobacterial cells stayed in the chloroplast area but some got transported to the nucleus.

- Researchers are trying to determine whether the chloroplasts of all photosynthetic organisms are derived from a single ancestor or if the endosymbiosis happened more than once.
- Mitochondria also originated as endosymbiotic bacteria.
    - They are close in form to proteobacteria.
- The mitochondrial genome is dramatically reduced compared to the ancestral proteobacterial genome and again, many of the genes from the original endosymbiont migrated to the nucleus.
- Organelles called hydrogenosomes are those that generate ATP by anaerobic processes. The organelles don't have DNA but genes of mitochondrial origin in the cells' nuclei code for proteins that function in the organelle.
    - These are mitochondria altered by evolution to generate energy where oxygen is present.
- Many nuclear genes originated with the mitochondria and chloroplasts acquired from specific bacteria.
    - Genes from other bacteria groups also reside in the nucleus, as we see multiple episodes of horizontal gene transfer.
- There are also some genes that we see after the eukaryote domain originated and there are some genes that are related to the genes of Archaea.



- Some hypotheses to explain the above
- There are some cases where single celled eukaryotic organisms can live in environments without oxygen by supporting symbiotic bacteria on or within the cells.
- Single celled eukaryotes have evolved numerous symbiotic relationships with chemoautotrophic bacteria, associations that feed and protect the eukaryotes, letting them live in tough environments.
- Theory that chloroplasts evolved from cyanobacteria is supported by the facts that they both have similar internal membranes and small circular DNA genomes.
- The difference between the two hypotheses for the origin of the eukaryotic cell is that one hypotheses that engulfment of a proteobacterium occurred after formation of the nuclear envelope rather than before.

27.3 Eukaryotic Diversity

- Eukarya was divided into 4 kingdoms: plants, animals, fungi, and protists.
    - Protists that those are have a nucleus but lack other features specific to the other 3.

- Algae are photosynthetic protists and protozoa are heterotrophic protists and are mainly single celled organisms.
- In Eukaryotes, we see 7 different groups, called superkingdoms.
- Among those, 75% of the species that we have discovered fall within the Opisthokonta, which encompasses animals, fungi, and some protists.
    - Name calls attention to the fact that cell movement is propelled by a single flagellum.
    - Mainly heterotrophic, although some species harbor photosynthetic symbionts.
- Animals and fungi are somewhat related, but closer to the animals are the choanoflagellates which are unicellular protists.
    - A number of signaling molecules that play a role in animal development are present in our choanoflagellate relatives.
- Microsporidia are another group of single celled opisthokonts and they are parasites that live inside animal cells. They infect a host and complete their life cycle.
    - They have no mitochondria, no Golgi, no flagella, reduced metabolism, and one of the smallest genomes.
    - They are descendants of more complex organisms but their simplicity is an adaptation for life as an intracellular parasite.
- Amoebozoa is a group of eukaryotes with amoeba like cells. They play a role in soils as predators on other microorganisms.
    - Slime molds are types of amoebozoans and they have haploid cells that fuse to form zygotes that undergo rounds of mitosis but not cell division. The structures are called plasmodia and they are coenocytic which means they contain many nuclei within one cell.
    - The plasmodium eventually forms structures called sporangia where cell walls form around the nucleus and we get discrete cells which undergo meiosis and generate haploid spheres that go into the environment.
- Cellular slime molds are another type of mold where they feed on bacteria in the soil. When they starve, they create AMP which induces cells to form a multicellular slug form that can migrate an forage for food. They also will eventually differentiate to form sporangia.
- These slime molds aren't related to animals, fungi, or other groups though.
- Another superkingdom is called Archaeplastida and this is where we find the land plants. All of them are photosynthetic.
- One type of archaeplastid are the glaucocystophytes, which are a group of single celled algae found in freshwater ponds and lakes. Their chloroplasts retain a lot of similarities from the ancestral cyanobacterial endosymbiont. Their walls have peptidoglycan and their pigments include biliproteins.
- Red algae are another type and they have walls made of cellulose and have chlorophyll a in its pigments.
- Another branch in this superkingdom contains the green algae which have the presence of chlorophyll a and chlorophyll b in chloroplasts that have two membranes, and they have a unique attachment for the flagella.

- Chlorophytes are a particular branch of green algae and they radiate mostly in the sea and include common seaweeds.
- Another superkingdom is called Stramenopila and it includes unicellular organisms and giant kelps and algae and protozoa. They have a flagellum that bears two rows of stiff hairs. Most of them are photosynthetic.
- One diverse type of stramenopiles are the diatoms where they are recognized by skeletons of silica.
- Another type called the oomycetes cause a number of plant diseases.
- Another superkingdom is called Alveolata and it includes both heterotrophic and photosynthetic species. They contain small vesicles called cortical alveoli that store calcium ions for the cell.
- The photosynthetic alveolates belong to a subgroup called the dinoflagellates which have two flagella that produce rotary motion of the cell,
- There is also another group that are called ciliates and they have two nuclei in each cell and short flagella called cilia. They are heterotrophs that feed on bacteria and other protists.
- The 3rd group of alveolates are called apicomplexans, and they cause malaria. They have heterotrophic cells and they have chloroplasts that suggest evolutionary loss of photosynthesis.
- In the eukaryotic tree, photosynthetic eukaryotes that distributed widely but discontinuously among the branches.
    - The eukaryotes acquired photosynthesis multiple times by repeated episodes of endosymbiosis.
- The main evidence for the above claim is that we have different types of chlorophylls.
- There was the primary endosymbiosis that gave rise to green and red algae, two further events that established chloroplasts derived from green algae in euglenoids and chlorarachniophytes, and at least one to three events that established chloroplasts derived from red algae in cryptophytes, haptophytes, and stramenopiles.
- The basic idea is that photosynthesis didn't first evolve in eukaryotic cells, but they evolved only once in the common ancestor of living cyanobacteria.
    - The eukaryotes then gained the ability to perform photosynthesis by endosymbiosis.
- Choanoflagellates are the closest protistan relatives of animals.
- Green algae are most closely related to land plants.

Chapter 33

33.1 Plant Diversity: An Evolutionary Overview

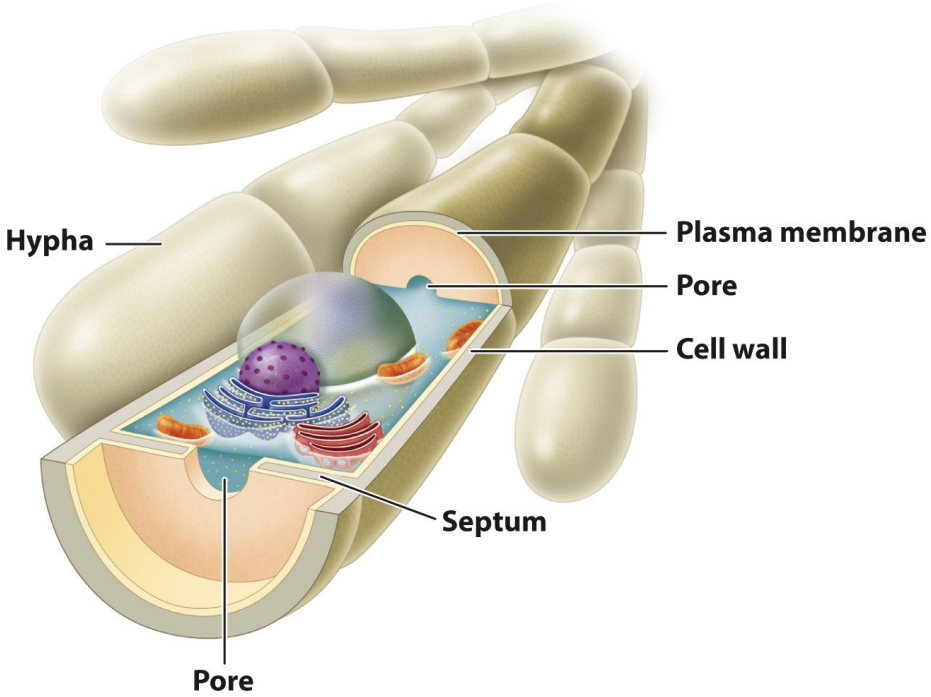
- Closest living relatives of plants are green algae. Features like plasmodesmata and enzymes used to reduce CO_2 loss are common among plants and algae.
- Plants were forced to live on land and deal with air and its problems while the algae could rely on the water.

- 4 transformations in life cycle and structure characterize the evolution of plants
    - 1st: Evolution of alternation of generations. Basically a way to enhance dispersal of gametes where multicellular haploid generation alternates with a multicellular generation composed of diploid cells.
        - Specifically, the diploid zygote develops by mitosis into a multicellular spore-producing plant, called a sporophyte, while still attached to and supported by the haploid gamete-producing plant, called a gametophyte. In the first diverging groups of plants, the multicellular diploid generation produces many haploid spores by meiosis and, because it is typically erect, can release these spores into the air where they can be carried off by a breeze.
        - Problem is that plants didn't have roots and thus would need surface water for fertilization and hydration of cells.
    - 2nd: Evolution of vascular plants which allowed for internal transport of water and carbohydrates. More strength in cellular wall too. This means that the plants are now taller and able to photosynthesize in more conditions.
    - 3rd: Eliminating the dependence of reproduction only when and where surfaces were sufficiently wet.
    - 4th: Evolution of flowering plants, aka angiosperms. They are seed plants. The life cycle of those plants include spores that germinate and develop into morphologically distinct male and female gametophytes as well as male and female gametes being brought together by the transport of the male gametophyte.
        - Angiosperms also have 4 reproductive features that attract pollinators. They are the flower (structure that attracts the pollinators), the carpel (closed vessel in which seeds develop), double fertilization (one sperm fuses with the egg while the other fuses with two haploid nuclei), and development of fruits (structures that surround seeds and attract animals to enhance seed dispersal).
- Of the 400K species of plants today, 90% are angiosperms and they are very new in the evolutionary time frame.
- The gymnosperms were the most dominant group of land plants before the angiosperms came around.
- As the number of angiosperm species rose, the number of species in other groups fell.
- Angiosperms may have been necessary for the formation of areas like tropical rain forests.
- The last common ancestor of gymnosperms and angiosperms had vascular tissues, seeds, and pollen.
- Without the higher rates of transpiration shown by angiosperms, the tropical regions would have higher temperatures and lower rainfall.

Chapter 34

34.1 Growth and Nutrition

- Fungi are heterotrophs, they don't have ways to ingest food and break it down, and instead absorb nutrients through their cell wall.
    - The simple molecules will pass through but not the complex ones. For those, fungi need enzymes that break them down into the simpler components.
- Fungi also cannot move around in the environment, so the organisms need to use the process of growth itself to find nourishment.
- They have highly branches, multicellular filaments called hyphae which give a large surface area for absorbing nutrients.
- They only grow at their tips which allows for the slender figure.
- With they find a rich food resource, they grow rapidly, forming a network of branching hyphae called a mycelium.
- Strong but flexible cell wall is key to hyphal growth and nutrient transport. The walls are made of chitin, which is a polysaccharide that contains nitrogen. They are thinner than plant cell walls because of this makeup. The wall prevents the cell from rupturing and swelling.
- Fungi can grow between resource patches since it can transport food and nutrients over large distances.
- Molecules that go into the fungi increase turgor pressure, but then the growth and respiration consume these molecules, which decreases the pressure. These differences in pressure cause the bulk flow which seeks to spread the resources out to the areas that need it.
- Continuous stream of cytoplasm is needed to have long distance movement.



- Septa are walls that divide the cytoplasm into different cells. They also have pores that allow water and solutes to move between the cells.
- The main jobs of the hyphae are to enable the fungi to seek out new food resources and to transport nutrients from one part of the fungus to another.
- Yeasts are single celled fungi that don't need hyphae. This is something that got lost during evolution.
- Yeasts divide by budding, where an outgrowth eventually breaks off and creates a new cell.
- For most fungi, dead organic matter is the source of energy and raw materials. They use it and it then gets converted to carbon dioxide and water.
- The unique thing about fungi is that the hyphae allows them to seek more nutrients while most bacteria have to wait for new food resources.
- The most abundant biomolecules on and within soils are cellulose and lignin, which are difficult to degrade.
- Fungi feed on dead plants and animals mostly, but they can infect living tissues as well.
- First, they need to get past a plant's physical and chemical defenses. Some go through wounds or through the stomata, or through epidermal cells directly. Then the hyphae gets pushed into the interior of the plant.
- Above the ground, plant infections are transmitted through fungal spores, through wind or on the bodies of insects.
- Below the ground, infection is transmitted by hyphae that penetrate the root.
- For dealing with animals, the fungi can form sticky traps with their hyphae.
- The fungal infections are rare for vertebrates though, mainly since they grow poorly at mammalian body temperatures, they need temperatures a bit colder.
- Mycorrhizae fungi are those that help both the fungi and the host. The hyphae of ectomycorrhizal fungi surround but don't penetrate the root cells. The hyphae of endomycorrhizal fungi penetrate into the root cells.
    - Endomycorrhizal fungi constitute a monophyletic group.
- Fungi called endophytes live within leaves. They grow within cell walls and in the spaces in between cells. They can also help the host plant.
- Another beneficial association is when an insect can grow fungi for food. The fungi get shelter, food and protection in return.

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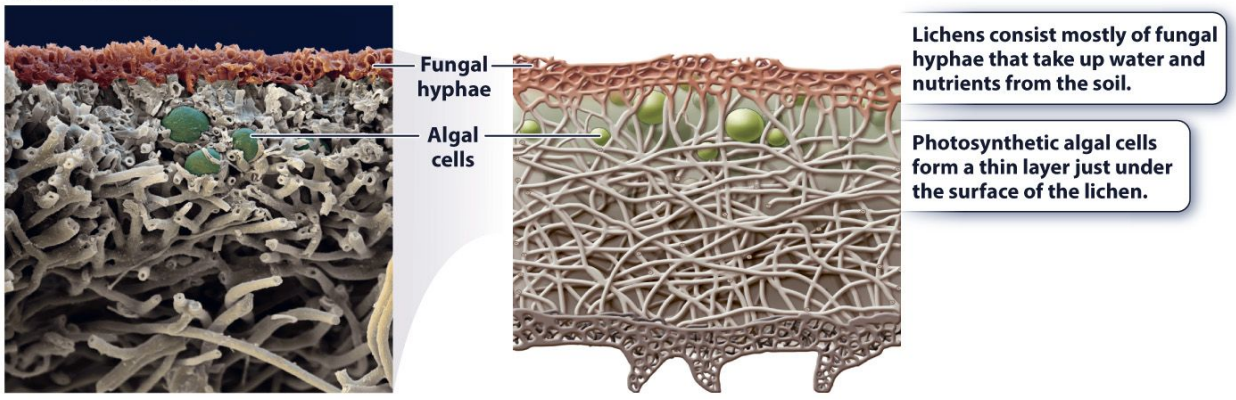


- Lichens are stable associations between a fungus and a photosynthetic microorganism. They consist of fungal hyphae and the algae/cyanobacteria form a thin layer under the surface.
    - The hyphae take in water and nutrients and produce chemicals for protection, while the photosynthetic partners provide carbohydrates.
- There are 13.5 lichens, but only 100 participating photosynthetic species. Different lichens can have the same algae or cyanobacteria.
- Lichens spread asexually by fragmentation or through the formation of dispersal units that have a single photosynthetic cells surrounded by hyphae.
- They can also grow on different surfaces, and get nutrients from rainfall and getting nutrients from rocky surfaces. They also have high tolerance for desiccation, and can tolerate fluctuations in temperature and light, but are sensitive to air pollution.
- The advantage of having a lot of thin hyphae is that a greater surface area is available for absorption of nutrients.
- Lichens are able to obtain nutrients from environment by secreting organic acids that liberate the nutrients from the surrounding material.

Chapter 44

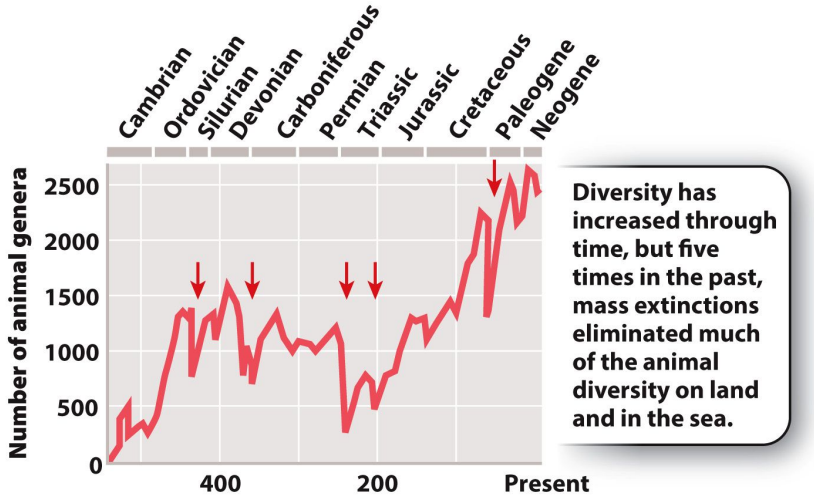
44.1 A Tree of Life

- There are key evolutionary relationships among vertebrate animals.
- Organisms most closely related to animals are called choanoflagellates. Multicellularity is the thing that separates the two, though.
- Animals are heterotrophs and they gain energy and carbon from preformed organic molecules.
- Animals and different from fungi since they follow a pattern that includes gastrulation.
- Animals can therefore be described as multicellular heterotrophic eukaryotes that form a gastrula during development.
    - The organ systems are what enabled them to diversify in ways that plants, fungi, and algae could not.
- Sponges only have a few cell types and are poorly organized and irregular in form with no plane of symmetry.
- Radial symmetry is where the bodies have an axis that runs from mouth to base with many planes of symmetry through that axis.
- Bilateral symmetry is where you have a distinct head/tail with a single plane of symmetry running between it. This enables you to move in one horizontal direction.
- The bilaterians can be divided into those without a body cavity (acoelomates), those with a body cavity.
    - The cavity cushions internal organs against hard blows and allows them to expand, which helps digestive function.
- In the phylum Cnidaria, the embryo has two germ layers, the endoderm and the ectoderm. This is where the adult tissues develop. They are diploblastic.

    - Bilaterally symmetrical animals are the Bilateria and they are triploblastic, because they have a mesoderm.
- Bilaterian animals can divide into two groups, one is called protostomes (earliest forming opening becomes the mouth) and the other is deuterostomes (earliest forming opening becomes the anus).

44.5 The Evolutionary History of Animals

- First fossils of animals start to appear 579 mya.
    - Those show simple fluid filled tubes without identifiable organs.



- Cambrian explosion showed a large accumulation of new characters.

Chapter 45

45.6 Social Behavior

- Altruistic actions are technically those that should decrease your individual fitness and should be selected against.
- Group selection is the idea that natural selection operating on individuals is a less powerful force than selection that operates on groups.
    - Groups that have altruistic individuals are more likely to survive.
    - Group selection is not seen as an evolutionarily stable strategy because selfish behaviours are more likely to increase individual fitness.
- Evolutionary stable strategies are behavior that can be driven to extinction by an alternative strategy?
- Organisms do not act “for the good of the species” because natural selection operates on individuals: It is the individual that lives or dies, reproduces, or fails to reproduce. Traits that are disadvantageous to the individual are therefore selected against by natural selection, even if they are beneficial to the species as a whole.
- Reciprocal altruism is where individuals exchange favors, and this is a way that altruism can evolve.

    - For it to work, individuals must recognize one another and remember previous interactions.
- Kin selection is a form of natural selection that favors the spread of alleles that promote behaviours that help close relatives.
- Species that are eusocial have overlapping generations in a nest and a consistent division of labor between the reproducers and the non reproducers.
- If B = the benefit of a behavior to a recipient, C = the cost of the behaviour of the donor, and r = degree of relatedness between recipient and donor, then if rB > C, altruism can evolve.

Chapter 46

46.1 Populations and Their Properties

- Rapid growth of American population was due to ample food supply and active encouragement of marriages.
    - But in other places where there wasn't as much food, Malthus worried about rate of deaths exceeding that of births because of starvation.
    - The struggle for existence is what results in adaptations that enhance survival.
- Populations evolve, not individuals. Population is all the individuals of a species that live and reproduce in a certain place.
- Populations are characterized by features like changes in population size, birth versus death rate, number of resources, and interactions with other species. This can all affect the flow of genes through a population.
- Populations have size, range, and density.
    - Size is the number of individuals alive at a particular time and place.
    - Range is how widely a population is spread. Reflects the range of climates that a population can be in as well as the other species it encounters.
    - Density is the size divided by the range. Tells us how crowded the population is.
- Uniform populations are where the individuals are distributed evenly.
- To estimate population size, we take samples of a population and then extrapolate.

46.2 Population Growth and Decline

- Factors that impact population size are birth rate and immigration rate, as well as mortality rate and mortality rate.

number of individuals at an earlier time (time 0), which is notated as $N_1 – N_0$. The processes leading to a change in population size through time include births (B), deaths (D), immigration (I), and emigration (E), so we can quantify ΔN as:

$$\Delta N = N_1 – N_0 = (B – D) + (I – E)$$

- Equations above

- Then, we can find the rate by taking that change, and dividing by the population at time 0 and a unit of time.
    - That gives us the average per capita growth rate
- Exponential growth is characterized by a constant per capita growth rate.

$$N_t = N_0 (1 + r)^t$$

- Equation above to find the population after t years.
- Feature of exponential growth is that the number of individuals added to the population in any time interval is proportional to that at the start of the interval.
- The per capita growth rate r is the intrinsic growth rate of a population, and is the max rate of growth when there are no environmental factors that limit the increase.
- When individuals within a population compete for resources, this is intraspecific competition, which results in natural selection.
- When individuals compete for resources with other species, this is interspecific competition, which results in increase or decrease in population size.
- As a population grows, there is normally a decrease in availability of resources which cause growth rate to decline.
- Birth and death rates are affected by population density. Increasing density has bad effects, but can help.
- Carrying capacity is the max number of individuals that a habitat can support.
    - It reflects the interplay between requirements of individuals and the resources that are available.
- Many populations are characterized by the logistic curve.

S-shaped curve, is termed **logistic growth**. Population size at time 2 (N_2) can be calculated using the equation:

$$N_2 = N_1 + rN_1 [(K - N_1)/ K]$$

- Equation above
- Logistic curves are S-shaped because exponential increase during early stages of population growth causes the first half of the curve to rise steeply, but then growth becomes limited by resource availability and so slows as population size approaches the carrying capacity of the environment.
- Factors such as resource availability and predation are density dependent factors.
- Density independent factors like a drought or a cold period can affect size but not density.
- External fertilization relates to large number of gametes released, with low probability of survival for each. Internal fertilization normally produces fewer, but more resources are invested into them.

    - Those that produce large number of offspring are r strategists.
    - Those that produce small number of offspring are k strategists.
- R strategists are normally in unstable and changing environments.

46.3 Age-Structured Population Growth

- Not all organisms contribute to population growth equally.
- Age structure of population is the number of individuals within each age group of the population studied.
- Growing population is shown by a pyramid shaped age distribution.
- Demography is the study of the size, structure, and distribution of populations over time.
    - Includes changes to birth/death rates, aging, and migration.
- Cohort is a group of individuals born at the same time. They can be summarized in a life table, where we can see patterns of survival in the population.
- Proportion of individual that survive to each successive stage is called survivorship.
- Survivorship curves Type 1, 2, and 3 refer to whether mortality occurs late in life, throughout life, or early in life.
    - Humans show a Type 1 curve because we die later in life.
- For those that have Type 3 curves, they are normally r strategists because they want to have as many offspring as possible because most will end up dying.
    - Type 1 curves associated with k strategists.
- A reproductive individual has access to a finite amount of resources and can invest either in many inexpensive young or few well-provisioned offspring.

46.4 Metapopulation Dynamics

- Metapopulation is group of populations linked by immigrants.
- A patch is a bit of habitat that is separated from other bits by inhospitable environments that are difficult for individuals to cross.
- Each group of inhabitants in a patch is called a local population, which make up metapopulations.
- Local populations within a metapopulation have independent fates and commonly become extinct because of their relatively small sizes.
    - When populations get small, they can also recolonize to other habitats.
- Species survival depends not only on the health of local populations, but also on the ability of individuals to colonize new habitat patches.

Chapter 47

47.1 The Niche

- Competition between species can occur when different species use the same resources in the same place.
- The combination of a species' physical habitat and its ecological role in that habitat defines its niche.

    - Determined by abiotic (physical) factors like climate and soil chemistry as well as biotic (biological) factors that are based on interactions with species.
- The factors can lead to adaptations which come from natural selection.
- The fundamental niche refers to the full range of climate conditions and food resources that permit the individuals in a species to live, but the actual range of habitats (due to competition or predation) is called its realized niche.
    - Fundamental niche is larger because it represents all the habitats where a species could live, but then other factors could restrict that species to a smaller area, which is the realized niche.
- The observation that some aspect of the niches of closely related species is similar and are evolutionary conserved is called phylogenetic niche conservatism.

47.2 Antagonistic Interactions Between Species

- Interactions between species often narrow the geographic distribution of species within the larger boundaries of their physical requirements, and help shape the realized niches.
- Interactions can be indirect in the example of influencing another species through competition for a shared resource.
- Competition is an interaction in which the use of a mutually needed resource by one individuals or group of individuals lowers the availability of the resource for another individual or group.
    - Intraspecific competition is competition between individuals of a single species.
        - This is the reason for the eventual slowing down of population growth.
        - A species' rate of reproduction and the carrying capacity of the environment are the factors that contribute most.
    - Interspecific competition is competition between individuals of different species.
        - This is a lose lose situation.
- When two species have overlapping niches, one will become extinct or change its niche.
- When competition prevents one species from occupying a niche, this is competitive exclusion.
- Resource partitioning can happen with species whose niches overlap end up diverging and they become different species.
- Species not only compete for food, but they also compete for space, nutrients, sunlight, etc.
- Predation is an interaction where one organism consumes another. Predator benefits at the expense of the prey.
- Populations don't always go to competitive exclusion if they are using the same resources, the populations also have to be large enough for competition.
- Parasites live in close association with another species, and they gain nutrition by consuming their hosts' tissues and this can reduce the hosts' fitness.
- An example of an indirect interaction between two attacking species that benefits them both is called facilitation.

47.3 Mutualistic Interactions Between Species

- Interspecific interactions between individuals of different species can be beneficial, detrimental, or neutral.
    - Competition between individuals can create a detrimental interaction.
    - Competition can come in the form of competing for resources or for space.
- Consumer resource interaction is where the consumer benefits while the consumed organism loses.
- Mutualism is an interaction that benefits both species.
- Commensalism is where one species benefits while the other is unaffected.
- Amensalism is where one species is harmed while the other is unaffected.
- Nature of the interaction may depend on the environment.
- Niche is the set of environmental conditions that determine whether a species can live.
- Benefits that come with the interactions between two species normally involve nutrients, shelter, reproduction, but all the benefits are ultimately measured by natural selection in terms of reproductive output.
- Possible costs are new organs/tissues that an organism has to have, and some energy consuming activities.
- Each side in an interaction is acting in its own self interest and does its own cost benefit analysis.
- Close interactions between species that have evolved over long periods of time are called symbioses.
    - Relationships also generally get passed on through generations.
    - An example is aphids harboring bacteria in their bodies.
- Chloroplasts and mitochondria are the best known examples of coevolution.
- Mutualism doesn't have to only involve two specific species. It can involve one species and then a group of species.
    - Fruits can evolve in plants in association with both birds and mammals.
- An common interaction is having bacteria inside of your gut since the bacteria are the ones who can break down the tough food, and in exchange, we're are giving them protection and a place to live.
- Insect fungi symbiosis have had a large impact on the biosphere through the efficient breakdown of plant materials.
- When one or both sides of a mutualism cannot survive without the other, the association is said to be obligate.
    - When they can survive without the other, the interactions are called facultative.
    - It can be facultative for one species and obligate for the other.

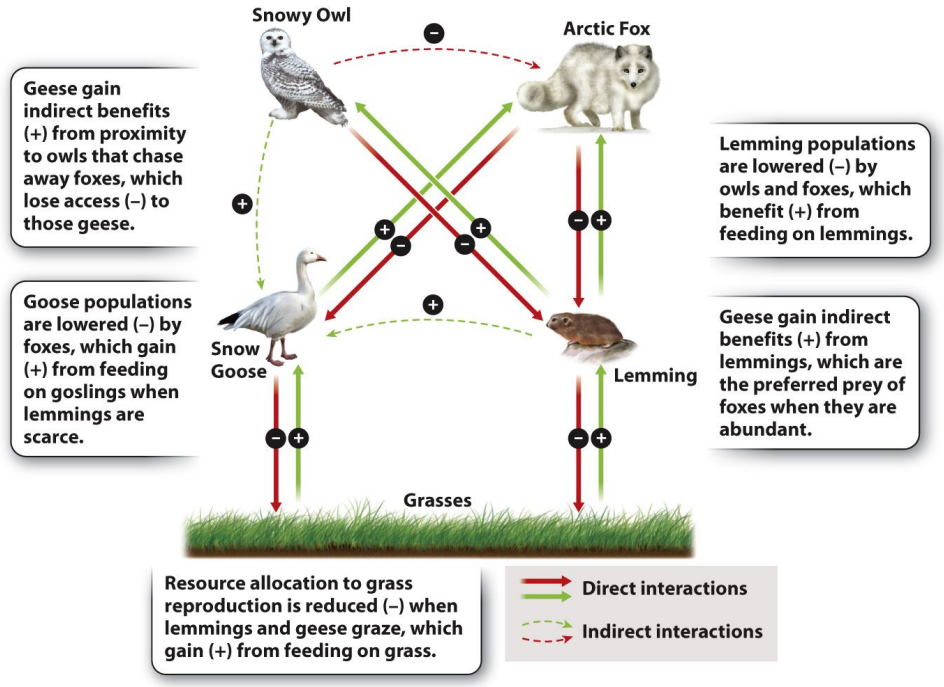
TABLE 47.1 Major Types of Species Interactions

INTERACTION	EFFECT ON EACH SPECIES	EXAMPLE
Competition	−/−	A grass and a wildflower: Each species loses the water, nutrients, and access to sunlight that the other takes.
Predation	+/−	Arctic Foxes and lemmings: Foxes benefit from eating lemmings; lemmings lose opportunities to reproduce.
Herbivory	+/−	Bison and grass: Bison benefit from eating grass; grass loses biomass that is eaten.
Parasitism	+/−	Tapeworms and humans: Tapeworms benefit from absorbing nutrients in human intestine; humans lose nutrients.
Mutualism	+/+	Flowers and bees: Flowers gain pollination; bees gain nectar and some pollen.
Commensalism	+/0	Egrets and cattle: Egrets benefit from insects stirred up by cattle; cattle are unaffected by egrets.

- Types of interactions above. These can change over time depending on the actions of the species as well as the environment changes.
- Symbiotic relationships are subject to natural selection.
- When both participants in a species interaction develop adaptations in direct response to one another, this could progress to coevolution in the long term.

47.4 Ecological Communities

- Biodiversity refers to the number of species, the variety of different genetic sequences, cell types, ecosystems, etc.
    - Good indicator of the number of species is the number of plant species.



- Example of predator prey relationship above.

- Keystone species are those that influence a large proportion of biomass and energy from one trophic level to another, or when the species modifies the physical environment.
    - The ones that shape the physical environment are called ecosystem engineers because they create habitats for others.
- A key point is that a species is not a keystone species simply because of their large abundance. They have to have effects on communities that are disproportionate to their numbers because of the particular roles that they prey.
    - A lot of examples involve predators.
- Events that lower the abundance of some species are called disturbances and they have effects that are independent of population density.
- Diversity of species in a community in part reflects the frequency and intensity of disturbance.
- The process of species replacing each other in time is called succession, and this is common after a disturbance.
    - After a disturbance, small plants and animals (r-strategists) colonize first, and then the k-strategists come in when the environment becomes more stable.
- A mature assembly called a climax community is formed when the final stage in the succession is completed.
- Sum total of populations that live in a given area is called a community.
- Biodiversity not only includes the number of species in an area, but also the unique phylogenetic lineages.
- The sequence of species that colonize a recently disturbed area through succession is a predictable process.

47.5 Ecosystems

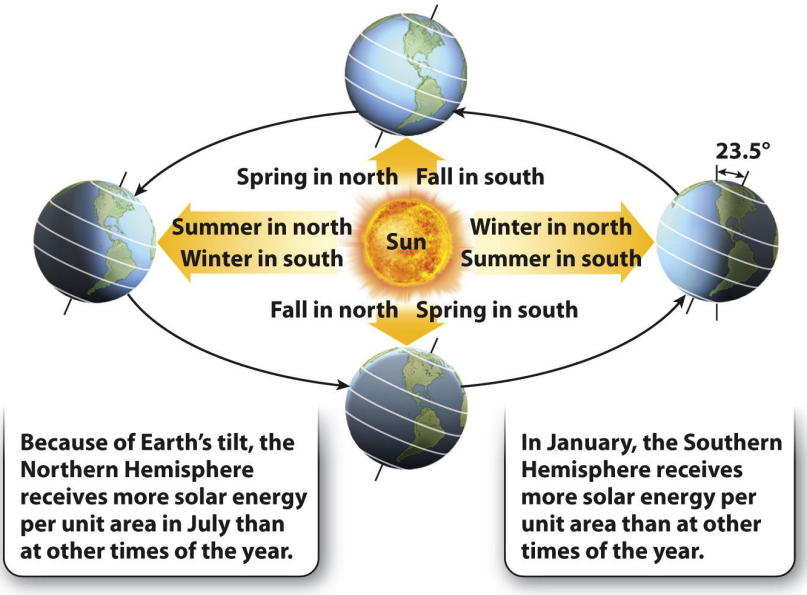
- Community of organisms and the physical environment it occupies together form an ecosystem.
    - Physical and biological components linked by the processes that cycle nutrients and transfer energy through the system.
- Difference between a community and an ecosystem is that an ecosystem also involves the physical environment, not just the set of organisms that lives there.
- When one species preys on another, we can view it as predation and as a link in the carbon cycle since there is a transfer of carbon.
- An organism's place in a food web is its trophic level. First level are the producers, then the primary consumers, then the secondary, and then apex predators.
    - Parasites exploit all levels of the system.
- Trophic pyramids are diagrams that show the biomass and energy available at each level to feed the next.
- Pattern of decreasing biomass as you go up the food web is because the transfer of energy and biomass is not 100% efficient. Wastes, work, and heat dissipation all contribute to the fact that only 10% of the energy and biomass available at one level is incorporated into the next.

- Rates of photosynthesis are dependent on the amount of sunlight, water, and nutrients.
- Liebig's Law of the Minimum says that primary production is limited by the nutrient that is least available relative to its use by primary producers.
- Biodiversity of a region reflects its level of primary productivity.
- Food webs show the flow of carbon through an ecosystem while trophic pyramids show a transfer of energy.
- Tertiary consumers have the least amount of energy available for exploitation.
- Bacteria and algae are the organisms that form the energy base for the early successional communities.

Chapter 48

48.1 The Physical Basis of Climate

- Biomes are broad geographic areas with similar sets of communities.
- Climate is long term average weather
    - Determined by solar radiation, global patterns of wind and ocean circulation, and Earth's topography.
- The amount of solar radiation we get maintains surface temperatures that can keep water in its liquid form.
- The latitudinal difference in incoming solar energy density explains why Earth's surface is hotter at equator than at poles.
- At higher latitudes, temp is lower and has greater variation.



- Climates would not show strong seasonality if the Earth wasn't on the 23.5 degree tilt.
- Topography refers to the physical features of Earth, and contributes to global temperature patterns.
    - Temperature declines with increasing elevation

- Temps at the equator are cooler and hotter at the poles than the predicted temperatures because there is heat transport from low to high latitudes by wind and ocean currents.
    - Heated air moves faster and rises and then moves north or south.
- Coriolis effect is when the wind is deflected to the right in the Northern Hemisphere and to the left in the South.
- Ocean currents also transport heat since water can carry more heat than air.
- Wind and water, together, transfer heat from the equator to the poles.
- Areas of high and low annual rainfloor are created by patterns of rising and descending air masses.
- Cascade Mountains are the ones that impose a regional pattern of rainfall and the effect was called a rain shadow.
- As wet air moves from the ocean up into the mountains, it cools, releasing its moisture as precipitation. Moving past the mountains, air masses descend, warming as they go and taking up water vapor. For this reason, lands in the rain shadow of the mountains are arid
- Warm air is less dense than cold air, and warm air holds more moisture than cold air.

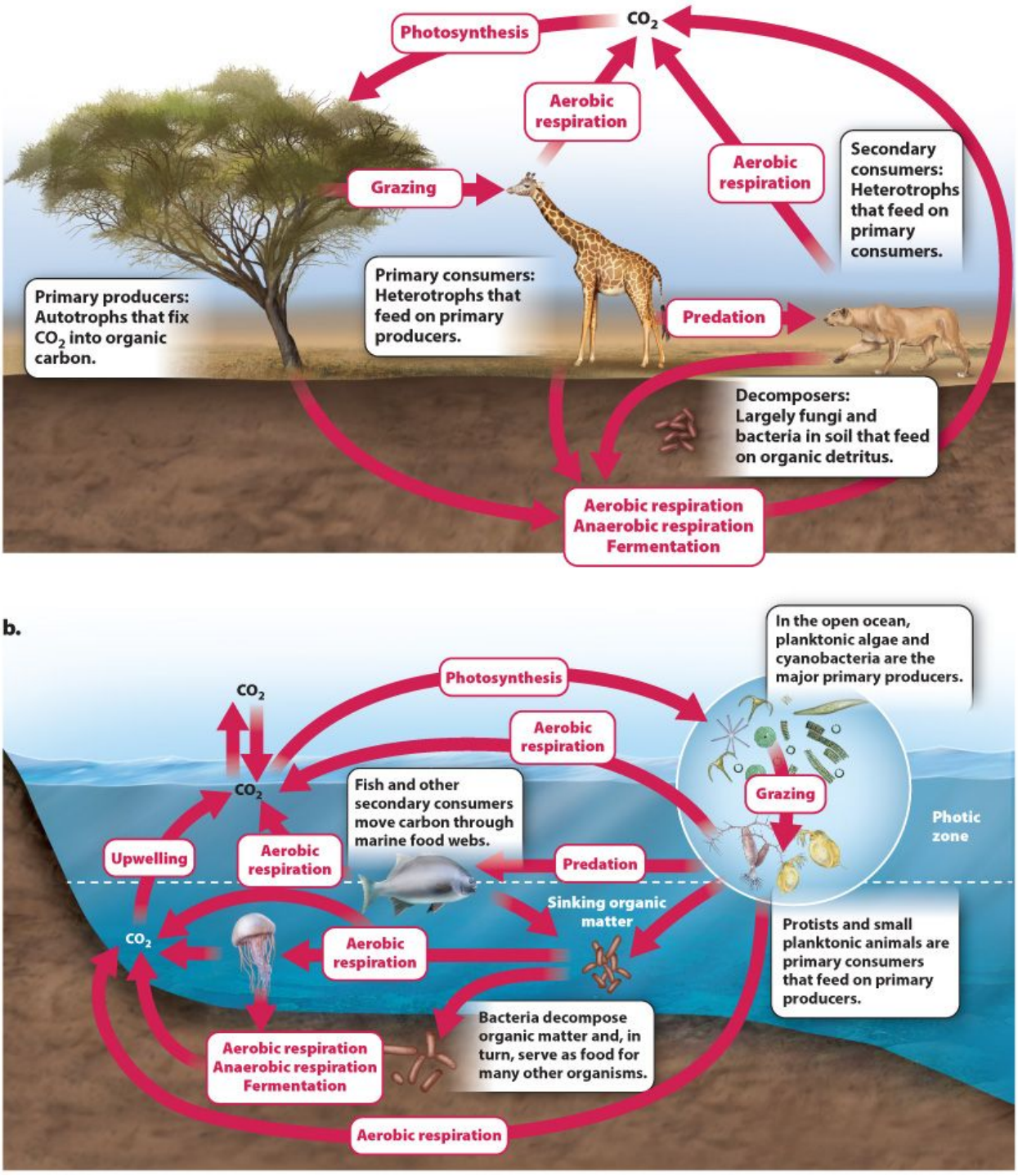
48.2 Biomes

- Vegetation in an area reflects the evolutionary adaptation of plant from and physiology to climate.
- Plant form strongly correlates with global patterns of temperature and rainfall.
- Plants allow CO2 into their leaves, but lose water vapor through transpiration (which is evaporation through leaves). Evapotranspiration is the sum of evaporation directly from soils and water bodies plus the amount transpired by plants.
    - It returns a large amount of water vapor back to the atmosphere.
- Potential evapotranspiration is the amount of evapotranspiration that temperature, humidity, and wind would cause if water was not the limiting substance.
- Ratio of water demand to supply is the potential evapotranspiration ratio and tells us what vegetation can be supported in a region
    - Deserts have high ratios and rainforests have low ones.
    - The amount of precipitation corresponds with how much plants can transpire and also with their photosynthetic rates.
- There can still be wet soil if you have low precipitation but the rates of evaporation are also low.
- Tundra (coldest + lowest biodiversity + layer of ice beneath soil), Alpine, Taiga, Temperate coniferous forest, Deciduous forest (moderate temperatures and precipitation + nutrient soil due to annual leaf fall), Temperate grassland, Desert, Chaparral, Savanna, and Tropical rain forest are different biomes.
- Distinction between terrestrial and aquatic biomes is that water is denser than air.
- Freshwater biomes include Lakes and Rivers.
- Sunlight doesn't penetrate deeper than 200 meters. Above this is the photic zone.
- Marine biomes include Intertidal, Coral reefs, Pelagic realm, and Deep Sea.

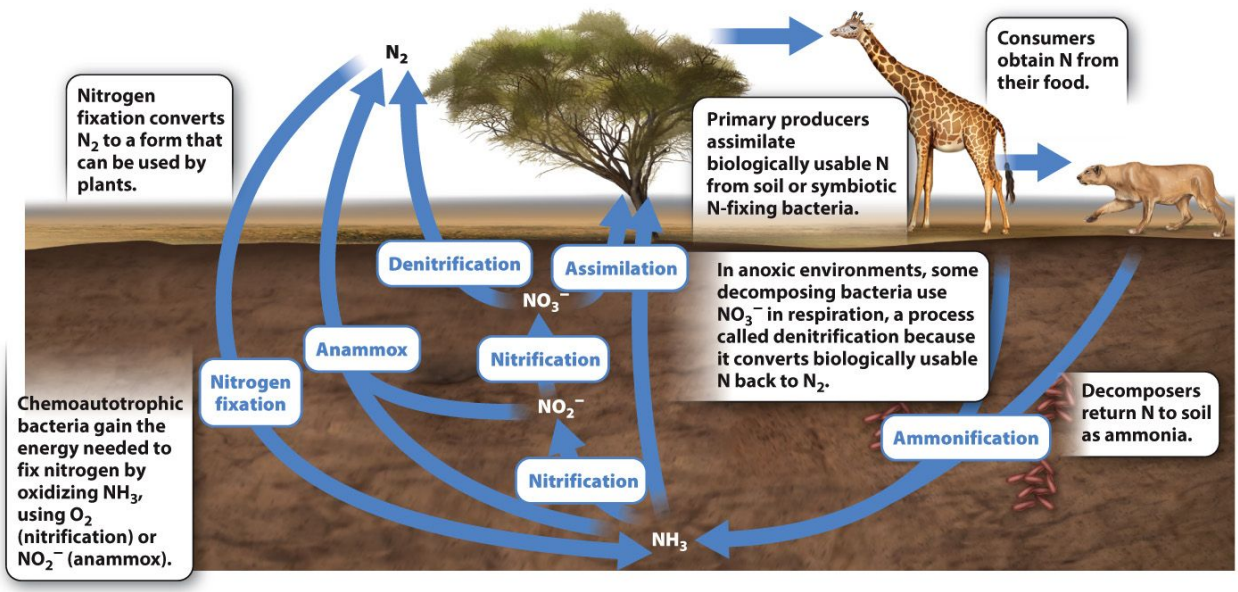
- The highest productivity in freshwater or marine biomes comes from near the surface where sunlight penetrates.
- In deeper waters, nutrients come from detritus from more productive shallower waters.

48.3 Global Ecology: Cycling Bioessential Elements

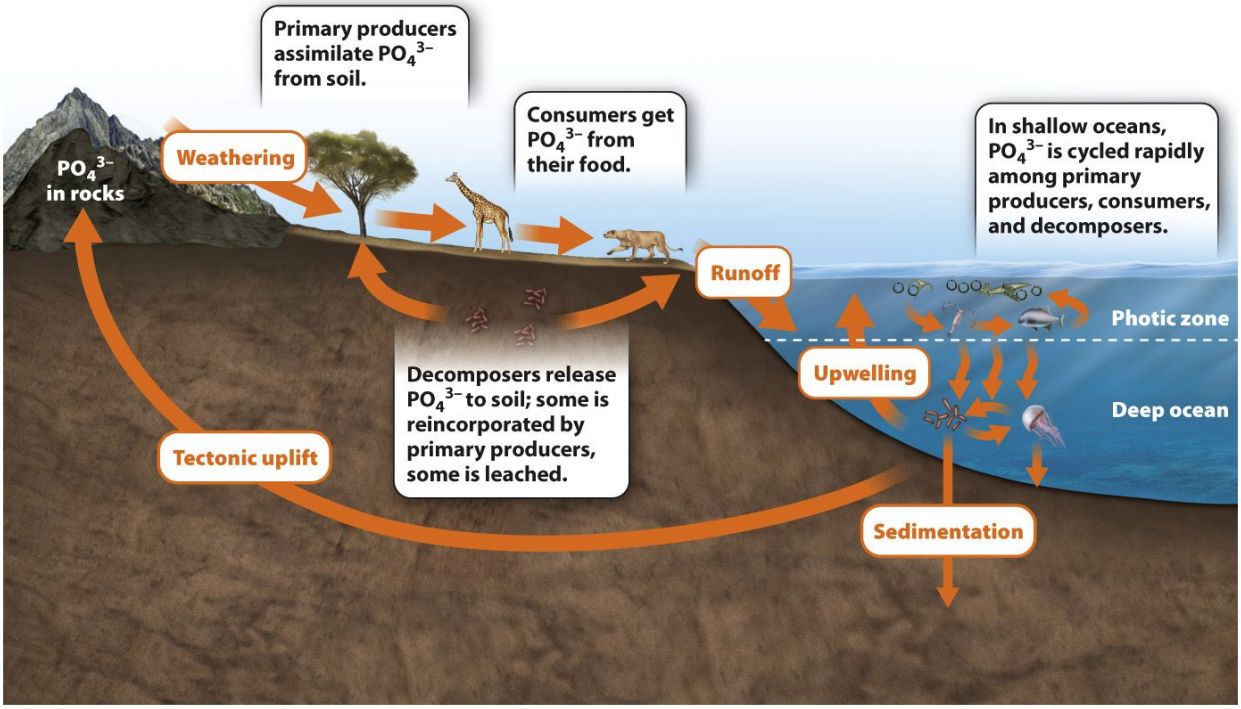
- Cycles of carbon are other biologically important elements are called biogeochemical cycles. They link organisms and their environment in the chemical cycling of raw materials needed for life.



- Specifics of the carbon cycle above in terrestrial and aquatic biomes.
- On land, there primary production is dominated by vascular plants, while there are many algae and cyanobacteria that convert CO2 into organic molecules.



- Nitrogen cycle above
- Primary producers play a key role because they can assimilate the nitrogen found in soil or water.
- One difference from the carbon cycle is that most primary producers cannot assimilate nitrogen directly from N2 in the atmosphere. There needs to be nitrogen fixation which is the reduction of N2 to biologically useful ammonia by bacteria and archaeons.



- While CO2 is never the limiting resource in the carbon cycle, phosphorus and nitrogen are the limiting ones in most biomes.
- Patterns of primary production reflect variations in climate and nutrient availability.

- Rates of primary production are high around continents because runoff of nitrogen and phosphorus from the continents supplies abundant nutrients to the sea.
- The Redfield ratio says that cells have 1 atom of phosphorus and 16 atoms of nitrogen for every 100 atoms of carbon.
- Microorganisms like fungi, bacteria, and archaeons generate CO2 making it available for primary producers.
- If phosphorus concentrations increase in a marine ecosystem, then there would be an increase in primary productivity.
- Nitrogen is returned to the atmosphere by denitrifying bacteria.

Chapter 49

49.1 The Anthropocene Period

- Modern era is called Anthropocene Period.
- Ecological footprint quantifies individual claims on global resources by adding all the energy, food, materials, and services we use and estimates how much land is required to provide those resources.

49.2 Human Influence on the Carbon Cycle

- Photosynthesis removes CO2 from the atmosphere and respiration replaces it.
- CO2 is a greenhouse gas, which is one that absorbs heat energy and emits it in all directions.
- Greenhouse gases in the atmosphere absorb the infrared radiation reflected up from Earth's surface and emit it in all directions—some is directed upward, out of the atmosphere, but half of the trapped heat is directed downward, toward Earth
- Methane and water vapor are other examples of greenhouse gases.
- Historically, the major effect of large volcanic eruptions has been to *decrease* temperature because volcanic ash and aerosols reflect incoming solar radiation back into space.
- Global warming is the measured increase in Earth's surface temperatures over the past 50 years. The greenhouse effect describes a process by which global warming can occur.

49.3 Human Influence on the Nitrogen and Phosphorus Cycles

- All organisms require nitrogen to synthesize proteins, nucleic acids, and other molecules.
- Humans add a lot of fixed nitrogen to the biosphere every year.
- Eutrophication is where (a little phosphorus) and nitrogen from fertilizers cause great increase in populations of algae and cyanobacteria (by fertilizing them) and heterotrophic organisms (like bacteria) eat them and fuel high rates of aerobic respiration and thus can deplete oxygen in the waters.
- Much of phosphate added to fields as fertilizer leaves as runoff.

- Red queen hypothesis says that organisms must constantly adapt, evolve, and proliferate to survive.

49.4 Human Influence on Evolution

- Some species grew due to human effects.
- Overexploitation makes the problems of habitat loss even worse.
- Humans make use of 25% of the entire photosynthetic output on land through crops and livestock that we harvest.
- As habitable area for species declines then the species diversity also will.
- There is an arms race between antibiotics and pathogens.
- Antibiotic resistance evolved in one species can jump to another.
- Non native species that become established in new ecosystems are invasive species.
    - These can displace native plants through competition for space and resources.

49.5 Conservation Biology

- Biodiversity refers to the summed variation of life on Earth.
- Conservation biology addresses the challenge of sustaining biodiversity in a changing world crowded with people.
- Biodiversity hotspots are small areas that have high numbers of endemic species and are under threat from human activities.
    - 2 percent of the surface of Earth but 43 percent of the species.
- Sustainable development says that the rate of use of resources shouldn't be higher than the rate at which they can be replenished.