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Final Exam

1. Describe how a violation of each of the assumptions of the Hardy-Weinberg Equilibrium model results in biological evolution.

The Hardy Weinberg principle models a population without evolution under these five conditions: no mutations, no genes are transferred to or from other sources (no immigrations or emigration takes place), mating is random (individuals do not choose mates based on their phenotypes or genotypes), no selection occurs, and finally a very large population (Raven, 399). However, it is impossible for a population to satisfy all five of these conditions. Since all five of these conditions cannot be met by a population at one time then this allows for biological evolution to take place. An important point to keep in mind is whether or not the condition being violated is increasing or decreasing genetic variability in a population. Five agents that can lead to evolutionary change due to their ability to violate the conditions are: mutation, gene flow, non-random mating, genetic drift in small population, and pressures of natural selection.

Mutation is the ultimate source of genetic variation and thus makes biological evolution possible (Raven, 401). The likelihood of a particular mutation occurring is not affected by natural selection (Raven, 401). Mutations do not occur more frequently in situations in which they would be favored by natural selection (Raven, 401). Mutations can be neutral, beneficial or harmful. However, mutations tend to try and favor the needs of the organism (Mutations, 2016). Mutations allow life to evolve, and adapt and without them life may or may not be existent. Without mutations, life would not be able to grow and change to new situations/environment and thus would begin to die out. Mutations allow for DNA to change and try to “benefit” the organisms due to mutations being the basis for biological evolution. This causes frequency of alleles to change generation to generation, and thus Hardy Weinberg’s principle has been violated.

Gene flow is the movement of alleles from one population to another (Raven, 401). Gene flow violates the condition of no immigration or emigration. Gene flow can be a powerful player of change (Raven, 401). Gene flow can be as obvious as animals physically moving from one place to another (Raven, 401), and can be as subtle as drifting of gametes of the immature stages of plants or marine animals from one place to another (Raven, 401). An example of a subtle movement is pollen and seeds. Pollen can be carried great distances by insect, and other animals that interact with flowers (Raven, 401). Seeds may blow in the wind, or carried by animals to new populations (Raven, 401). Another way in witch gene flow can take place is individuals mating from adjacent populations (Raven, 401). Gene flow brings in the rarer allele into populations (Raven, 401). This means allele frequencies will change from generation to generation, and Hardy Weinberg equilibrium will not be found within the population (Raven, 401).

Non-random mating tends to reduce genetic variation due to mating in order to reproduce offspring with advantages to survive (Raven, 401). An example is geographic structuring. In this case individuals are more likely to mate with individuals who are closer in proximity than to more distant individuals (McDonald, 2008). In rare allele advantage, a male with a rare allele will have a mating advantage, and increase the frequency of that rare allele thus increasing heterozygous genes (McDonald, 2008). Assortative mating is when phenotypically similar individuals mate which causes the frequencies of certain genotypes to differ (an increase in homozygous individuals) from the frequencies predicted by Hardy-Weinberg (Raven, 402). Disassortative mating is phenotypically different individuals mating, and producing an increase in heterozygotes (Raven, 402).

The next violation is genetic drift. Genetic drift violates the idea of a larger population. The effect of random genetic drift is inversely proportional to population size (Raven, 402). If population size decreases, then the force of genetic drift increases (Raven, 402). In small populations, the frequencies of alleles may change by chance alone (Raven, 402). Changes in allele frequencies happen randomly which is known as genetic drift (Raven, 402). If the population is small then alleles can change and have an effect on biological evolution rather than if the population was large alleles would not change as randomly, and Hardy-Weinberg equilibrium would be met (Raven, 402). Genetic drift can lead to the loss of alleles in isolated population (Raven, 402). Alleles that initially are uncommon are particularly vulnerable (Raven, 402). Genetic drift also effects the survival of mutations. The probability that every individual in the population will be homozygous for a certain allele, also known as fixation, is directly proportional to frequency in population (McDonald, 2008). When mutations first start off in a population the frequency is very low which means fixation probability is low (McDonald, 2008). When genetic drift takes place then the loss of infrequent alleles takes place, and the fixation of common alleles takes over (McDonald, 2008). A situation when population is large, genetic drift has little effect, so there would need to be a violation in Hardy Weinberg’s conditions and the population size would be small in order for genetic drift to have an influence (Raven, 402). The bottleneck effect influences population size drastically on occasion (Raven, 403). The bottleneck affect is when there is a natural disaster such as flooding (Raven, 403). This causes the frequency in alleles to be affected greatly (KF, Lecture). The variation in alleles will reduce greatly which means the frequency will as well (KF, Lecture). The founder effect is when a few individuals go off to create a new colony (Raven, 402). There will be far less variation due to the low number of individuals starting out, as well as a drastic change in frequency of alleles (Raven, 402). Both the founder and bottleneck effect affect biological evolution due to the changing of allele frequency (KF, Lecture).

The final violation to Hardy-Weinberg conditions is pressures of natural selection. Some individuals leave behind a greater number of offspring than others, and the rate at which they do so is affected by phenotype and behavior (Raven, 403). In artificial selection a breeder selects desired traits, and in natural selection the environmental conditions determine which individuals produce the greatest number of offspring (Raven, 403). Phenotypic variation must exist among individuals in a population in order for natural selection to take place (Raven, 403). Natural selection allows for a wide variation of alleles in the population and thus creates diversity in biological evolution. The variation found among individuals results in differences in number of offspring surviving till next generation which can affect the frequency of alleles (Raven, 403). This violation allows for biological evolution to take place allowing successful individuals in producing offspring to reproduce and exhibit variation (changing of allele frequency) (Raven, 403). Finally, phenotypic variation must have a genetic basis (Rave, 403). Genetically identical individuals can be phenotypically distinctive if they grow up in different environments (Raven, 403). It is important for there to be genetically different individuals in populations, otherwise if there is no genetically different individuals than no evolutionary change will take place due to no alter in genetic composition (Raven, 404). When selection occurs in order to avoid predators, allele frequency can be affected. Individuals mate with those who wish to have a certain genetic makeup for their offspring. An example of this would be a lizard in a desert climate would mate with a light colored lizard in order for offspring to blend into environment (Raven, 404). Allele frequencies would decrease because not as many offspring would be produced due to less option for mates. As well as variation in the environment in terms of alleles would decrease as well (Raven, 404). Selection in order to match climatic conditions is an example of biological evolution. Investigators have proven that certain allele frequencies vary with latitude (Raven, 404). A certain allele could be common in the north, and rare in the south due to different environments (Raven, 404). This causes a change in frequency of alleles, and thus biodiversity is affected (KF, Lecture). Once again, Hard Weinberg equilibrium is next to impossible for populations. This is because one of these violations is always taking place, whether it is genetic drift, or mutations.

2. For each of the example organisms below:

1. Describe the entire hierarchical classification of the organism to the highest resolution possible based on what we discussed in class, and
2. Describe the major distinguishing traits of the organisms in this group.

The angiosperm has a hierarchical classification beginning with charophytes, then bryophytes, tracheophytes, and then the angiosperms (which is seeding) (Raven, 607). Charophytes are also known as green algae, and they have a close phylogenic relationship to land plants (Raven, 607). Bryophytes are the closest living descendant of the first land plants (Raven, 588). The bryophytes seemed to have little ability in regulating internal water levels, which would be a trait which tracheophytes would adapt (Raven, 588). Tracheophytes are vascular plants, and developed successful water and food conducting systems known as vascular tissues (Raven, 591). This is how researches have determines that tracheophytes are ancestors to angiosperms because of angiosperms containing this same vascular tissue. Two examples of the vascular tissue are the xylem and the phloem (Raven, 591). Finally, the angiosperm is known as a flowering or seeding plant (Raven, 605). *Amborella trichooda* is the closest living relative to the earliest angiosperms (Raven, 606). A major distinguishing trait of the angiosperm is their flowers. The flowers are considered to be modified stems and leaves (Raven, 608). The sepals are green and leaf-like, and the petals are colored which attract pollinators (Raven, 608). The carpel consists of the ovary (containing 1-100 ovules) (Raven, 608). The ovary eventually develops into a fruit (Raven, 608). The tip of the carpel is the stigma and are stick or feathery which allows for pollen to land on them (Raven, 608). The style is the neck and connects the stigma and the ovary (Raven, 608). The megaspore mother cell undergoes meiosis and produces four megaspores (Raven, 609). Typically there is only one megaspore left, and the nucleus of that megaspore divides mitotically (Raven, 609). Pollination is the transfer of pollen for its source (the anther) to a receptive area (the stigma on its own flower, and self pollination occurs (Raven, 611). The seed is the vehicle for dispersing the embryo to distant sites (Raven, 611). The protective layer of the seed allows the plant to survive in environments that might otherwise be killed (Raven, 611). Angiosperms also depend on fruits for survival (Raven, 611). The fruit of an angiosperm are the mature ovaries (carpels) (Raven, 613). The coordination of fruit, seed coat, embryo, and endosperm development follow fertilization (Raven, 613). Fruits and seeds of angiosperms allow the plant to live in new environments/areas that it may not have been able to live without the fruits or seeds due to their layer of protection. The snail’s hierarchical classification begins with the protostomes. Protostomes include bilaterians which include mollusks which gastropods fall under (Raven, 641). IN some protostomes, both mouth and anus form from the embryonic blastopore (Raven, 641). In other protostomes, the anus forms later in another region of the embryo (Raven, 641). Spiralia fall under the protostomes, and develop as embryos using spiral cleavage (Raven, 659). Most live in water and move through it using cilia or parts of the body musculature (Raven, 659). A clad of the spiralia is the lophotrochozoans (Raven, 659). Many of the animals in the lophotrochozoa either have free-living larva known as trochophore, or a feeding structure known as lophophore a horseshoe-shaped crown of ciliated tentacles around the mouth (Raven, 659). Among the lophotrochozoans with a trochophore is the phyla Mollusca (Raven, 659). Mollusks are unsegmented, and their coelom is reduced to a hemocoel and some other small body spaces (Raven, 659). Finally is the gastropoda which is made up of snails and slugs (Raven, 668). Most gastropods have a single shell, some have lost their shell through evolution, but almost all creep on a foot, or is modified for swimming (Raven, 668). The head of most gastropods has a pair of tentacles which serve as chemo/mechanoreceptors with eyes at the base (Raven, 668). During larval life, gastropods undergo torsion which is the twisting of the body so the mantle cavity and anus are moved from posterior to the front of the body (Raven, 668). The final picture is of a dinosaur. Before jumping into how dinosaurs evolved into modern day birds, it should be noted that dinosaurs fall under class Reptilia. Reptiles developed legs in order to support the body’s weight effectively, and allowing reptiles to have larger bodies (Raven, 707). The skin was covered with dry plates or scales to minimize water loss (Raven, 707). Dinosaurs are also close relatives to the bird, or aves. However, a distinguishing feature of the dinosaur shown is that it stands on two feet and has two small arms. However, this dinosaur downs not quite yet have feathers, so it cannot come after the *Sinosauropteryx* (Raven, 465). The picture shown of the dinosaur has to fall between the *Tyrannosaurus* and *Sinosauropteryx* (Raven, 465). This conclusion came to be because of its small demeanor, no feathers, loss of fingers 4 and 5, and two legs to stand on (Raven, 465). After, the *Sinosauropteryx* came the *Velociraptor* (Raven, 465). The *Velociraptor* evolved to have the following traits: long arms, highly mobile writs, feathers with veins, shafts, and barbs (Raven, 465). Following the *Velociraptor* is the *Caudipteryx*. The *Caudipteryx* has additional characteristics from the *Velociraptor* which are long, aerodynamic feathers (Raven, 465). Then, came the *Archaeopteryx* which had arms that were longer than legs (wing span began to increase) (Raven, 465). Following the *Archaeopteryx* is the modern birds. These modern birds lost teeth and had a reduced tail (Raven, 465). This hierarchal structure shows that modern birds did evolve from what once were dinosaurs (Raven, 465). The hierarchal chart on page 465 of Raven, shows how *Tyrannosauruses* evolved and changed to the needs of the environment through step-like changes through evolution, rather than a gradual process which eventually resulted in what is known as today as modern birds

3. Describe how Fick's law indicates a fundamental problem that multicellular organisms face and for each of the examples below, describe a way that this organism "solves" this problem.

Arthropods’ respiratory system consists of small, branched, cuticle-lined ducts known as tracheae (Raven, 681). Tracheae eventually branches into very small tracheoles which directly contact individual cells (Raven, 681). Due to the tracheae receiving the air directly, high levels of oxygen can be found here (KF, Lecture). The Tracheae is in close proximity to the cells of the arthropods respiratory system (KF, Lecture). The oxygen leaves the tracheae and moves to the cells. The cells then use the oxygen through cellular respiration (KF, Lecture). In order to keep diffusion going, the tracheae continues to receive high concentrations of oxygen in order to give to the cells (KF, Lecture). This is how concentration gradient is increased in arthropod’s respiratory system. The branching of the tracheae into tracheoles increases surface area. The multiple branches of tracheoles maximize the surface area within the arthropods respiratory system (Raven, 681). Insects depend on respiratory system rather than circulatory to carry oxygen to their tissues (Raven, 681). This means all parts of the body must be near a respiratory passage, and thus reduces distance (Raven, 681). The length of diffusion of oxygen and carbon dioxide is shortened due to close proximity to the respiratory system (Raven, 681). Distance in the arthropods respiratory system is decreased through the direct contact of tracheoles to the tracheae (Raven, 681). Although the tracheoles are branched and increase surface area, the make sure oxygen and carbon dioxide diffuse across plasma membrane in order to reach the cells, or the tracheae (Raven, 681). Arthropods uses Fix law to fix fundamental problems in which multicellular organisms face.

The next figure is a representation of a fish. Gills play a major role in the respiratory system for fish. Gills are specialized extensions of tissue that project into the water (Raven, 1004). Gills increase the surface area when relating back to Fix’s law because of the extended tissue (Raven, 1004). This increased diffusion of surface area allows aquatic organisms to extract much more oxygen from the water than their body surface area would allow them without the gills (Raven, 1004). External gills provide a greatly increased surface area for gas exchange (Raven, 1004). However, a downside to external gills is that they have to be moving constantly in order to ensure fresh water contact (Raven, 1004). If the gills are not moving then oxygen diffuses from the water to the blood of the gills (Raven, 1004). The brachial chambers pump water past stationary gills (Raven, 1004). The internal mantle cavity opens to the outside and contains the gills (Raven, 1004). Contraction of the muscular walls of the cavity draws the water through the inhalant siphon and expels through the exhalant siphon (Raven, 1004). The fish acts to increase concentration gradient through the countercurrent flow. The countercurrent flow acts to maximize the oxygenation of the blood by maintaining a positive oxygen gradient along the entire pathway for diffusion, which also increases diffusion (Raven, 1005). Countercurrent flow ensures that oxygen concentration gradient remains between the blood and water throughout the length of the gill lamellae (Raven, 1005). Countercurrent flow also oxygen o diffuse while blood leaving the gills has as high an oxygen concentration as the water entering the gills (Raven, 1005). A fish decreases distance by only being two cell walls thick (KF, Lecture). In fact, there is not much distance in fish. Instead, a layer is always in contact with either oxygen/water or blood. The lamellae which is a layer in which oxygen must pass is constantly in contact with oxygen and water (KF, Lecture). The capillary is another layer that is in constant contact with the blood within the fish’s respiratory system (KF, Lecture). These are the ways in which fish deal with the problems thrown at multicellular organisms.

Jellyfish are quite simple. Instead of having specialized respiratory systems, or circulatory systems they have a gastrovascular space (Raven, 650). This space is where everything happens (KF, Lecture). The epidermis and the gastrodermis decrease the distance. The epidermis is in direct contact with water, and the gastrodermis is in direct contact with the gastrovascular cavity (Raven, 650). The air the jellyfish receives enters directly into the gastrovascular cavity from the mouth (Raven, 650). This allows for the oxygen to be used by cells in the cavity, and allow air to continue entering the gastrovascular cavity. This keeps diffusion going, and thus keeps gradient increased (KF, Lecture). The gastrovascular cavity increases surface area in the jellyfish itself. However, the tentacles on the jellyfish itself also maximized surface area (Raven, 650).

Angiosperms contain a system known as the root system. The root system anchors the plant and penetrates the soil which absorbs nutrition which is needed by the plant to survive (Raven, 731). Root systems can be quite extensive which increases a plant surface area greatly due to the many branches. The root hairs and the branching of roots in the soil increase the surface area of the angiosperm (KF, Lecture). The root hairs bring nutrients (i.e. water) up to where they need to cross over in order to enter the shoot. Root hairs decrease distance within the angiosperm and allow intimate contact with surrounding soil particles (which provide nutrients to the plant) (Raven, 736). Root hairs also serve a dual purpose in Fix’s law by increasing surface area and efficiency of absorption for the angiosperm as well (Raven, 736). The root hairs are only a few cells away from the vascular system (KF, Lecture). This is how a plant is able to have hundreds of branching roots, but yet still gets it’s nutrients to the place it needs to go efficiently (KF, Lecture). This is how a plant decreases distance. The concentration gradient for angiosperms is a little tricky. However, the roots receive oxygen from the shoot system. The shoot carries oxygen to the roots, and then the roots use the oxygen and that allows for diffusion to keep taking place. This process allows for the concentration gradient to increase which solves problems thrown at multicellular organisms.

4. Below is a t-shirt design that uses a reference to evolutionary theory to make a point about human behavior. Based on your knowledge of Earth's evolutionary history and biodiversity, describe what this design gets right and what it gets wrong about evolution and biodiversity. (Don't just focus on it's depiction of human evolution in the image, but think about it in the broader context. For example, does the Hug et al. 2016 paper on the new Tree of Life support the message of this t-shirt design?)

Something that this picture gets right is the idea of natural selection (Raven, 417). Without natural selection it is unlikely that Earth’s biodiversity would not be where it is today. Natural selection allows for mutations to take place. These mutations can either be beneficial, or harmful. In fact, mutations are a necessity for evolution to occur (Raven, 401). Mutations allow for DNA sequences to change, and mutate in order to develop new possibly improved offspring in order to better survive in that environment. Also, selective breeding occurs throughout evolutionary history. DNA in organisms allow for them to choose a partner based off of desirable traits in which will increase fitness (Raven, 422). This process can cause a change in genetic makeup from just one generation. This would contribute to the idea of evolution being a step-by-step process instead of a slow gradual process. The picture shows the development of man, however, if one observes closely it is more than that. It shows the evolution over years of how the body became increasingly larger than when it originated. Also, the picture on the exam says, “ You are the product of four billion years of evolutionary success.” Yes, there are many successful products of evolution on Earth, however, there are many unsuccessful attempts as well, and that is important to discuss when talking about Earth’s evolutionary history and biodiversity. The most direct evidence that evolution has occurred is found in the fossil record (Raven, 424). By dating the rocks in which fossils occur we can get an idea of the age of the fossils (Raven, 424). When geologists use isotopic dating they are able to determine the absolute age of rocks (Raven, 424). Fossils also show the history of evolutionary change (Raven, 424). Fossils at the larger scale document life through time, from origin of the first prokaryotic and then eukaryotic organisms through the evolution of fishes and the rise of land organism, dinosaurs, and eventually the origin of humans (Raven, 424). Fossils also show mass extinctions in time which would be when evolution went wrong (Raven, 424). Certain species were unable to adapt and change to the environment in order to fight off predators, or whatever caused them to go extinct (Raven, 424). This design shows evolution as a gradual process on which traits build on one another. This is partially correct, and partially incorrect. Evolution is more of a step-by-step process, and not a gradual adaptation. This means when an offspring is reproduced this new offspring could have developed a mutation in the genetic code that allowed for a beak, and wider wingspan which developed into the species of modern birds, from the *Archaeopteryx* (Raven, 714). A very important point is that time does not cause evolution. We don’t know how life began on Earth, but we have lines of scientific exploration to piece together life’s origins (Raven, 511). A major example of time not causing evolution is when we think of how Earth where living organism could live came to be (Raven, 511). Hadean Earth was a hot mass of molten rock, and as it cooled the water vapor in Earth’s atmosphere condense into liquid water that accumulated on the surface in chemically rich oceans (Raven, 511). Life arose spontaneously from early waters, but the formation of proteins, nucleic aids, carbohydrates, and lips were essential for life to occur (Raven, 511). The evolution of cells required early organic molecules to assembler into functional, interdependent units (Raven, 511). In the Hug et al paper on Tree of Life, it discussed the nature of deep evolutionary relationships, or on the well known, well-classified diversity of life (Tree of Life, 2016). The results of the paper found that dominance of bacterial diversification and underline the importance of organism lacking isolated representatives with substantial evolution concentrated in major radiation of such organisms (Tree of Life, 2016). The picture on the exam gets right the idea that diversity of life grows from ancestor to ancestor, however, this process is not necessarily slow or gradual. Organisms may need to make immediate changes in order to adapt to a new climate environment after a natural disaster, or maybe new predators have entered into their environment, and now these organisms need to be able to blend in with the environment. Evolutionary history will continue to grow from one generation to the next even if the changes are minor. All organisms originated from an ancestor, however, this ancestor could be nothing like them. Somewhere along the phylogenic tree new traits evolved, and thus new species derived from these traits which is the whole idea of evolutionary history and biodiversity.

References

McDonald, D. (2008). Lect 3 Pop. Gen. I Intro. Retrieved April 30, 2016, from http://www.uwyo.edu/dbmcd/molmark/lect03/lect3.html#fixation

Mutations. (2016). Retrieved April 30, 2016, from http://evolution.berkeley.edu/evolibrary/article/evo\_18