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Study Guide: Evolution

1. **Explain what science is. How does it try to explain natural phenomena?** Science is "the search for truth" through the scientific method. The word itself comes from a latin root meaning "to know" - It is a way of knowing - an approach to understand the natural world. It uses observations and facts to explain our natural world. It uses well-tested laws, and theories to explain natural phenomena, but not religion or unsupported ideas. It compares its theories objectively with the natural world.
2. **Explain the difference between inductive and deductive reasoning.** Inductive reasoning is a method of logic to come to *broad*, *general* conclusions based on specific observations. Deductive reasoning is a method of logic to come to a *specific* conclusion based on lots of general past knowledge or solid facts, usually formed through inductive reasoning. Deductive reasoning usually leads to hypotheses for experiments, and often many deducted conclusions can be formed from a single broad idea. It is also usually used to test the broad idea, because it is based off ofth
    a. example of inductive reasoning: Wallace formed the idea of biogeography (theory, broad idea) after studying the similarities of closely placed species (specific evidence).
    b. example of deductive reasoning: I know that mammals have no feathers (general statement); cows are mammals; therefore, cows do not have feathers (specific conclusion)
3. **Explain the difference between a hypothesis and a theory.** A hypothesis is a testable reasonable explanation of natural phenomena based on observations and research, that is not necessarily well-tested. A theory is a broad idea that is well-tested, supported by many well-tested laws, and can be proven wrong by new evidence. Hypotheses can *become* theories with enough supporting evidence. Theories are usually much broader, and can explain new observations and is general enough to generate new underlying hypotheses.
4. **Explain the difference between an observation and an inference.** An observation is an objective noting of a fact or occurrence. An inference is a logical conclusion based on observations.
5. **Explain the purpose of experimentation and the role of observation.** Experimentation is used in science to provide more evidence to support (not prove: see 9) or disprove hypotheses, laws, and theories. Observation is used to collect evidence from the natural world and from experimentation, as the basis of the inferences and support for hypotheses, laws, and theories. Observation and the inferences that can be inducted are crucial to science and are fundamental to understanding nature.
6. **Explain how the scientific meaning of the term theory differs from the way it is used in everyday life.** Literally, a theory is a guess, that does not have to be supported nor proven. In science, it is a widely-supported idea, with many well-supported laws to back it up. They explain a natural phenomenon by making sense of multiple laws, and they are very probable but falsifiable still.
7. **Explain the difference between a theory and a law. Be able to use the example in class of atomic theory versus the law of conservation of mass, as well as use at least one new detailed example, as part of your explanation.** A theory is a broad idea that makes sense of multiple laws and *explains* a phenomenon. A law is a more specific idea that *describes* a phenomenon, but only one part of it. Because theories are made up of many well-supported laws, observations, and well-tested hypotheses, they are well-supported as well, but are falsifiable and modifiable.
    a. example: Dalton's atomic theory was at first based off of three laws: the law of conservation of mass, the law of definite proportions, and the law of multiple proportions. The theory actually made the laws make sense - before they were just statements that were true, but now they were statements that had meaning. His original theory was modified after new evidence and laws appeared.
    b. example: The theory of General Relativity by Albert Einstein is a large theory that explains gravitation. It is based off of many ideas, including the theory of Special Relativity and (a generalized) Newton's law of Universal Gravitation. Newton's law is specific - it only states that all matter attracts all other matter with a force directly proportional to its mass.

8. **Explain whether or not evolution is just a guess and probably not correct because it is just a theory.** Evolution is a theory, but that does not mean it is just a guess and probably incorrect. It is based off of much evidence, such as the theory of natural selection and observations of fossils, DNA, and structures of living things.
9. **Explain whether or not anything in science is ever proven.** Nothing in science is ever proven. Everything in science is falsifiable, because new evidence can always prove it wrong. For example, the widespread ideas about the Sun and the Moon revolving around the Earth was a theory that was superseded by Copernicus's (correct) idea through observation that the Earth revolves around the sun, and the Moon revolves around the Earth.
    a. "Proofs only exist in mathematics and logic, not in science"
10. **State and explain characteristics that made Darwin well suited for science.** Darwin had an open mind, and was very curious even as a boy. He was a naturalist, so he observed nature, and collected evidence for himself, free of bias. He also had the means to travel all over the world, so he collected a lot of evidence. He also had the courage to publish his idea, which was so revolutionary at the time, to the world.
11. **State and explain why evolution is such an important theme in biology. Explain why it has been described as the single best scientific idea to date.** Evolution is so important because it explains and makes sense of life as we know it, with so much diversity and unity. It explains why we are all related but different at the same time. It explains how we became this way, which has been a huge mystery before it. It provides details, unlike creationism, and it makes sense. It has so much evidence to back it up. This is also why it has been described as the best scientific idea.
12. **Explain natural selection as a theory for how evolution occurs.** Natural selection is a mechanism for evolution. It depends on the genetic variation in a population - individuals in a population will have different DNA due to mutations. Some of these will be harmful, and will kill the organism. But when there are times of disastrous and enormous change, when only the mutated organisms survive, then they will have been naturally selected because of their mutated genes. Because a higher percentage of these better adapted organisms will survive in a species, a higher percentage of the next generation (the offspring) will have inherited these helpful genes.
13. **Be able to apply the parts of the theory of natural selection to a given example to explain the process. For example, in class we applied the parts of the theory to giraffes to explain how they evolved to have long necks. We also looked at bed bugs, furless bunnies, cat whiskers, vultures, finches, peppered moths, etc. Be able to apply the parts of the theory to new examples (This connects to the PBS "list of four").** Necessities for natural selection and examples:
    a. observations and inferences supporting the theory of natural selection:
        i. genetic variation (genetic mutation)
        ii. overproduction of offspring (higher changes of genetic mutation and helpful genes)
        iii. struggle for existence (competition for necessities; survival of the fittest)
        iv. differential survival and reproduction rates (strongest individuals survive and reproduce best)
    b. example: bed bugs
        i. some bed bugs have genes resistant to pyrethrums
        ii. many bed bug offspring created to ensure that some have good genetic mutation (resistance to pyrethrums)
        iii. bed bugs who have resistance survive better (less likely to die when sprayed)
        iv. bed bugs who have resistance have higher chance and rate of survival and reproduction
14. **Explain how Darwin arrived at his theory of natural selection. Who were Lyell and Malthus? How did they influence Darwin? How did Darwin's voyage on the HMS Beagle influence him?** Darwin was a naturalist, and his (unbiased) study of nature led to his discovery of nature. He saw Lamarck's work on evolution, and modified it, coming up with his idea of natural selection. He also saw biogeography as evidence. He also knew about Wallace's (another naturalist with similar ideas) ideas on evolution, which was similar. His trip on the HMS Beagle influenced his work, because he got a chance to go travel far away

and to collect many samples to study. He spent five years noting the characteristics of the animals and staying on the beaches to collect samples. He noticed that the islands all had different species, and that closely located islands had closely related species. This made him seriously doubt the idea that all species were created individually, at the same time. He felt like "a blind man being given sight." Lyell was a geologist who thought about geological time, and created the fossil record that dated back millions of years. This gave enough evidence of evolving species in the past for Darwin's theory to make more sense. Malthus was a mathematician focused on population studies, and noticed that there is an overpopulation of offspring (more than could produce, and more than an ecosystem could sustain) and that there were competitions for resources in a population. These were two of the components for natural selection - but he didn't know about genetic variation and therefore the different rates of reproduction based on the randomly selected advantageous traits, something that Darwin knew from being a farm boy.

15. **Explain how Darwin's theory of evolution differs from Lamarck's. Why did Darwin's theory prevail and Lamarck's did not?** Lamarck had an idea of evolution similar to Darwin's, but his proved obsolete. Lamarck said that individuals in a species evolved *during* their lifetimes, simply by *willing* themselves to survive. Although he was correct that individuals can evolve, both of these assumptions are incorrect. Darwin said that species cannot modify their own genes, but can pass down mutations, and those organisms naturally selected (not willed by themselves) survived the best. He said that organisms only evolved over multiple generations, not during a lifetime.
16. **State, explain, and be able to use and use vocabulary associated with evolution.** Vocabulary:
    a. mutations
        i. when a gene is reproduced with an error in an individual; can be passed down
    b. variation
        i. when a mutation occurs; differences in a population
    c. adaptations
        i. change in species or organism when it becomes better suited to its environment (more fit)
    d. survival of the fittest
        i. better survival for more fit species (see fitness below)
    e. natural selection
        i. a theory that supports evolution and is a major mechanism of evolution (see 12)
    f. descent with modification
        i. as species reproduce and more mutations occur, bad mutations are weeded out and good mutations stay in the gene pool, and modifications stay. This is descent (reproduction) with modification (good mutations)
    g. fitness
        i. the ability of an organism to survive based on its naturally selected traits, better suited to its environment
    h. gene frequency
        i. amount of a gene left in a population; advantageous traits stay in a population with a high gene frequency and vice versa
    i. comparative anatomy
        i. comparing structures of different species; if the structures are similar, suggest evolution from a common ancestor with that structure
    j. analogous structures
        i. structures that are similar in different species that do not have a common ancestor; fit a certain environment; do not suggest evolution
            1. formed from convergent evolution: when two non-related species form similar features to because those features best fit their environment
            2. fins in whales and fish are analogous structures
    k. homologous structures
        i. structures that are similar in different species; suggest evolution

l. vestigial structurous
    i. remnants of structures in a species left over from an ancestor species (shows descent) that are not subject anymore to natural selection and therefore decaying
m. comparative embryology
    i. comparing the structures of embryos to other species to show that a species has evolved from another species; used when similarities only shown in embryos and not adults
n. comparative biochemistry
    i. comparing DNA of different species; usually closely-related species have similar DNA
o. comparative biogeography
    i. to compare the distribution of individuals in a species geographically; usually species are grouped together; shows that species evolve from other existing species in an area

17. **Describe the various pieces of evidence that support Darwin's theory of evolution and how/why the pieces of evidence support the theory.**
    a. Pieces of evidence supporting Darwin's theory of evolution:
        i. fossil record
            1. shows the variety of structures of life
            2. shows organisms with intermediate features
            3. shows that there were changes over time to structures
            4. shows complex species originated from simpler ones
        ii. comparative anatomy
            1. species have similar structures
            2. shows that species originated from common ancestor with that structure
        iii. comparative embryology
            1. same as above (but in embryos, because they are not needed when we develop)
        iv. vestigial structures
            1. shows that we originated from species with those structures
            2. shows that natural selection has weeded those unnecessary structures out
        v. biogeography
            1. shows that communities of plants and animals evolve (in isolation) from common ancestors of the area (and do not just come to be)
        vi. comparative DNA (biochemistry)
            1. shows that all cells have similar molecular structures
            2. shows that closer-related species have more similar DNA
    b. Acronym for the six pieces of evolution: ABVDEF (V, not C):
        i. Anatomy
        ii. Biogeography
        iii. Vestigial structures
        iv. DNA
        v. Embryology
        vi. Fossils
18. **Describe how biology, technology, and society are connected.** New advances in technology related to biology (medicines, surgery) are drastically improving the standard of living and average life span in our modern society. Technology is also allowing us to create many new experiments with biology, such as cloning, which may change our society in the future. Society is changing, which is one environmental factor that may affect our evolution (biology) and our technology. The goal of science is to understand natural phenomena. The goal of technology is to apply scientific knowledge.
19. **Describe how evolution is connected to our everyday life.** Evolution is related to our current lives because it is how our life became this way. Without evolution, we would all be the same, primitive cell. There would be no diversity in life. It shows that we are also always changing in response to our environment, even if that doesn't seem so. We may not be *homo sapiens* in the future, but something else

that has adapted to a more modern world. It also helps us fight disease and lead conservation efforts. Researching genes' purposes has allowed genetically modified crops. DNA can be used to identify individuals. We speed up natural selection and evolution in "bad" (insects, pests, parasites, and bacteria) organisms when we use chemicals against them.

20. **Explain why and how evolution is a core theme of biology.** Evolution is a core theme of biology because it *makes sense of the unity and diversity of all life*. Without the theory of evolution, we would not know why some species are similar to other species, and why some are so very different. We would not understand that everything is changing, because it happens so slowly, and is very hard to notice.

Extra Notes

Section 1.5: Unity of life based on DNA and a common genetic code (explained above)

Section 1.6: The diversity of life can be arranged into three domains

- There are two main "dimensions" in the world of biology:
    - The "vertical" dimension is the size scale that stretches from molecules to the biosphere.
    - The "horizontal" dimension spans across the great diversity of organisms existing now and over the long history of life on Earth. -(Chapter 1 Evolution Powerpoint)
- taxonomy is the branch of biology that names and classifies species, arranges species into a hierarchy of broader and broader groups, from genus, family, order, class ,phylum, kingdom
- life divided into three domains:
    - bacteria
        - most widespread, diverse prokaryotes
    - archaea
        - prokaryotes that live in Earth's extreme environments
    - eukarya
        - have a nucleus and organelles
        - divided into four subdomains
            - protists (prokaryotes)
                - multiple kingdoms
            - plants (eukaryotes)
            - fungi (eukaryotes)
            - animals (eukaryotes)

Section 1.7: Evolution explains the unity and diversity of life (explained above)

Section 1.8: Scientific inquiry is used to ask and answer questions about nature (explained above)

- science is a way of knowing - an approach to understanding the world around us

Section 1.9: Scientists form and test hypotheses and share their results

- controlled experiment is important to compare an experimental group with a control group. Without the control group, researchers cannot rule out other variables.
- science is a social activity
- science seeks scientific, supported causes for natural phenomena
- science is necessarily repetitive

Section 1.10: Biology, technology, and society are connected in important ways (explained above)

- science has become such a powerful aspect of society that every citizen should be scientifically literate

Section 1.11: Evolution is connected to our everyday lives (explained above)

Section 13.1: A sea voyage helped Darwin frame his theory of evolution (explained above)

- Aristotle, who had a major influence on Western thought, believed that species were perfect and permanent
- idea that the Earth is 6,000 years old and all species were individually designed was a common belief

Section 13.2: Darwin proposed natural selection as the mechanism of evolution (explained above)

- first two reasons of natural selection are observations, other two are inferences based on the observations
- individuals do not evolve but species evolve as bad traits get weeded out and the good traits accumulate
- evolution is not chosen - it is random

Section 13.3: Scientists can observe natural selection in action (explained above)

- it is shown that pesticides can kill 99% of insects on first usage, but become less and less effective

Section 13.4: The study of fossils provides strong evidence for evolution (explained above)

- paleontologists dig and find fossils
- some fossils are mineral casts when empty spaces in organisms once were
- trace fossils are footprints, burrows, and other remnants of an ancient organism's behavior
- some fossils retain organic material, when it is covered by a material in which bacteria cannot get to it

Section 13.5: Many types of scientific evidence support the evolutionary tree of life (explained above)

Section 13.6: Homologies indicate patterns of descent that can be shown on an evolutionary tree

- scientists can form an evolutionary tree of life similar to a family tree, with ancestors and descendants
    - tree is usually sideways

Section 13.7: Evolution occurs within populations

- microevolution is when gene frequencies in a population change
- no individual can evolve

Section 13.8: Mutation and sexual reproduction produce the genetic variation that makes evolution possible (explained above)

- new alleles originate by mutation
- a mutation that alters a protein's function will probably be harmful
- mutation rates in animals and plants average about 1 in every 100,000 genes per generation
- in organisms that reproduce sexually, most variation results from unique combinations of inherited alleles

Section 13.12: Natural selection is the only mechanism that consistently leads to adaptive evolution (explained above)

- relative fitness is the contribution an individual makes to the gene pool of the next generation relative to the contributions of other individuals
- fittest individuals produce the largest amount of viable, fertile offspring, and therefore pass the most genes on to the next generation

Section 13.14: Sexual selection may lead to phenotypic differences between males and females

- Darwin first to examine sexual selection, form of natural selection, in which individuals with certain traits are more likely to attract mates, not necessarily survive better
- the distinction in appearance between the sexes is called sexual dimorphism
- sometimes, individuals within the same sex compete with each other, called intrasexual selection
- in intersexual selection, or mate choice, individuals of the other sex choose their mates

Section 13.15: The evolution of antibiotic resistance in bacteria is a serious public health concern (explained above)

Section 13.17: Natural selection cannot fashion perfect organisms (explained above)

- selection acts only on existing variations

- evolution is limited by historical constraints
- adaptations are often compromises
- chance, natural selection, and and the environment interact