

Appendix A

Concepts, Ideas, and Understandings in Evolution*

General concepts

1. Commonalties are found below the cell level, and diversity is found at and above the cell level. Below the cell level commonalties include DNA as the genetic material, universal genetic code, ATP as energy intermediate, L-amino acids in proteins, D-sugars in carbohydrates, and proteins as catalysts. At and above the cell level immense diversity in morphology, behavior, and physiology is observed.
2. Evolution, as the process that produced life and biological diversity on Earth, is relatively new. In Western thought, from at least the time of Aristotle (384-322 BCE) through the 18th century, life forms were considered to be created by God and to be unchanging. After the publication of the Darwin and Wallace papers in 1858, the evidence accumulated in the second half of the 19th century to establish that life forms were formed and constantly changed by the process of evolution.
3. Evolution is the major unifying idea in biology.

Essential observations and conclusions of evolutionary theory

4. Lots of individuals die before reproducing. All organisms have the potential for exponential growth, but the sizes of populations are relatively constant. Therefore, many organisms die before reaching reproductive age, or produce fewer or less adapted offspring.

5. Some individuals are better at surviving than others and are thereby naturally selected for survival. Individuals in a population differ in their capacity to obtain resources and survive the environmental conditions they experience. Therefore some individuals are naturally selected because they are better adapted to the current situation and produce more progeny.

6. Natural selection acts on the structures, physiologies, and behaviors expressed by an individual. The phenotype of the individual (actual structures, physiologies, and behaviors expressed by an individual) results from the interaction of the genotype (all of the alleles present in an individual) with the environment.

7. Some of the variation in ability to survive is inherited.

8. Because of the above processes, the selected for traits become more common in subsequent generations of a population and this process is called evolution. Evolution occurs when differential reproduction, among individuals with different genetic make-ups, changes the overall genetic composition of a population (allele frequencies change).

9. Evolution is an emergent property of a system with the above characteristics. This self-contained process of natural selection leading to changes in allele frequencies in a population is random and directed by ever changing selection pressures, as well as chance.

10. Evolution does not optimize for the best organism. Evolution results in an organism that survives in an existing environment but not the “best” organism that can survive in all environments.

11. Natural selection does not cause genetic change in individuals, but rather acts on phenotypic differences that exist and that result from underlying genetic differences.

12. Natural selection acts on individuals, but they do not evolve.

13. Populations of organisms evolve.

Evidence for evolution

14. Structures like the panda's enlarged wrist bone, that function as a thumb to strip bamboo leaves, illustrate evolution well.

15. Fossils show extinct species and the changes to earlier species that in turn led to present species.

16. Comparative anatomy elucidates homologous structures that have a common evolutionary lineage but may have different functions, while analogous structures have a common function but are not inherited from common ancestors.

17. Embryology shows common patterns of development that are observed in different species but for some structures like gills, legs, tails, etc. only residual patterns of early development of these structures are present in more recently evolved species, while the structures themselves are either rudimentary or absent.

18. Biochemistry reveals sequences of amino acids in proteins and nucleic acids in DNA that have a number of differences that is positively correlated with the time since the species under consideration last had a common ancestor.

19. Human-caused selection pressures have enhanced particular character traits in many organisms including domesticated plants and animals.

20. Present-day evolution includes human mediated selection pressures that have changed allele frequencies in many species.

Mechanisms of evolution

21. On Earth, evolution is a scientific law like gravity. Evolution is an inevitable consequence of the nature of living things on Earth making the probability of evolution occurring equal to 1.0.

22. Natural selection acts on phenotypic variation that is created by mutations (random changes in DNA) and by new genetic arrangements, usually resulting from sexual reproduction.

23. Chance events can change the course of evolution: an asteroid hitting the planet, being in a particular place at a specific time, etc.

24. Natural selection through evolution changes the degree of expression of a character trait in a population: longer or shorter neck, thicker or thinner beak, wider or narrower leaf blade, longer tooth, etc.

25. Coevolution is the interactive evolution between two organisms.

26. The end result of natural selection and evolution is the adaptation of a population to a particular environment that is composed of nonliving (abiotic) and living (biotic) elements.

27. Extinction is an outcome of natural selection with more than 99% of all species having gone extinct.

28. Extinctions result from population and species characteristics in combination with environmental conditions. Localized distribution and over specialization predispose a species to extinction while competition among species, novel predators and parasites, and habitat loss are usually the immediate causes of extinction.

Origin of species

29. A species consists of all individuals in all populations that do not exchange genes with other populations, thus genes do not flow between species. Because gene flow is not easily assessed or is just not assessable in fossils, different species are usually identified by differences in anatomy, behavior, physiology, and DNA sequences. The species concept is very “leaky” but it does describe an important and real level of biological organization.

30. Species arise via mechanisms that prevent gene flow between populations.

31. Allopatric speciation is when a population is separated spatially into two or more groups. Over time changes evolve in the separated groups that prevent gene flow when they once again are in contact.

32. Sympatric speciation is when a population in the same location evolves traits that prevent gene flow.

33. Chromosomal changes can lead to a new species in a single generation with polyploidy being an example as well as a major speciation mechanism in plants.

History of life on Earth

34. Life arose from the inorganic, most likely on Earth. Evolution of life required emergence of a capacity for metabolism as well as a capacity for reproduction in the same entity.

35. The oceans of the Earth became rich with organic molecules that combined to form the first life. With the input of energy in the form of UV light, heat, or electrical discharge, elements and simple compounds like hydrogen, nitrogen, carbon monoxide,

carbon dioxide, methane, hydrogen sulfide, and ammonia can combine to form simple and complex organic molecules. Many of the organic molecules may have come from meteors that showered down on Earth from 4 to 3.5 billion years ago (BYA).

36. Ribonucleic acid (RNA) molecules can catalyze chemical reactions (metabolism) and can undergo base pairing to make copies of themselves. These properties of RNA make it a candidate for the first molecule in the central dogma of DNA to RNA to protein for all extant life, except RNA viruses, if they are considered alive.

37. Earth became solid and cool enough to support carbon based life about 4 BYA and life was certainly present by 3.5 BYA. The oldest rocks are about 4.1 BY old and fossils of microorganisms are found in rocks dated to be about 3.5 BY old.

38. The first life forms obtained energy from compounds in the organic soup.

39. All life appears to be derived from the first cells that arose between 4.0 and 3.5 BYA.

40. Photosynthesis arose around 3.5 BYA and became the primary source of energy for life.

41. We are a very recent species. Life arose about 3.5 BYA and modern humans arose about 0.0002 BYA. Basic time line of major evolutionary events: eukaryotic cells about 1.7 BYA as a symbiotic association of several prokaryotic cell types, multicellular organisms arose in the water about 0.6 BYA, land plants about 0.4 BYA, land invertebrates about 0.38 BYA, land vertebrates about 0.35 BYA, dinosaurs and mammals about 0.19 BYA, flowering plants about 0.14 BYA, hominids about 0.007 BYA, human line split from apes about 0.005 BYA, anatomically modern humans about 0.0002 BYA, literacy 0.000005 BYA, and industrial revolution 0.0000002 BYA. This time line is well illustrated with a time period of a day or a year.

42. Some animals evolved the capacity for culture and modern humans have excelled in this capacity. Capacity for language may be the character trait that distinguishes modern humans from other animals and language has permitted modern humans to excel at culture.

43. Evolution is genetically based and proceeds at a pace that is much slower than cultural change.

44. Human behaviors have an evolutionary basis. High places, vicious animals, snakes, spiders, etc. have been with us from our beginning and are dangerous. We have innate fear responses to them. Culturally introduced dangers like guns, electric wires, concentrated radioactive materials, dioxin, etc. have not been present long enough for genetically based aversions to have arisen.

45. We are an animal and like all extant animals we evolved to survive successfully in a dangerous world. The human brain was the organ that evolved to permit the survival of a physically impoverished ape in a dangerous world.

46. The human brain evolved a strong propensity to believe in spirits, gods, and other explanations of things not otherwise accessible to the senses provided to humans by evolution. This was apparently an adaptive trait.

47. We know our animal origins. There are no missing links from us to our common primate ancestors and on back to fishes.

* This list of evolution concepts was developed only for use at Rensselaer. A number of faculty contributed concepts taken from their personal files and perhaps from published sources. Since we had no intention of publishing these concepts (it was requested by reviewers and editor), we did not keep records as to who contributed which concepts and

their sources. The concepts themselves are clearly not original, but rather derived from the work of others, and we have no way of identifying sources. We acknowledge that some may be from unknown published sources.