

Appendix B

Evolution Concept Inventory given in WEI-1010 in fall 2004*

Correct answers in bold.

Question: When comparing plants and animals, why are there many similarities at the sub-cellular levels and great diversity at higher levels of organization? In 1 -4, choose “a” if the statement correctly answers the question, or choose “b” if it does not.

1. Both animals and plants have a common energy metabolism based on ATP (a high energy compound), but they have different tissue organizations. a or **b**
2. While contractile proteins have a role in intracellular movement in both plants and animals, contractile proteins are highly organized in muscle tissues only in animals. a or **b**
3. **Although both plant and animal cells evolved from common cellular ancestors, they have evolutionarily diverged since becoming multicellular.** a or **b**
4. Both animals and plants have differentially permeable membranes. Animal bodies are, however, supported by skeletal systems, while plants depend upon cell walls and fluid pressure against permeable membranes for support. a or **b**
5. The unifying idea in biology that enables us to explain the formation of Earth’s diverse life forms is that
 - a. **a spontaneous process of organic change has occurred over time.**
 - b. all life forms require energy to maintain the structures and functions inherent in being alive.
 - c. patterns of embryonic development in organisms that appeared earlier in Earth’s history (e.g., fish and frogs) are repeated in the embryonic development of more recent organisms (e.g., mice and humans).
 - d. organic change occurs when organisms acquire traits in one generation and pass them on to subsequent generations.

Statement: A species of guppy (small fish), found in streams in Venezuela, has males that exhibit a genetically determined range of coloration from brightly colored to dull gray. Brightly colored males are seen easily and consumed by predators, but plain males are not chosen by females for mating. In a stream with no predators, the proportion of brightly colored males is high. If a few predators are added to the same stream, the proportion of brightly colored males decreases within five months (3-4 generations).

What accounts for the changes in male coloration after predators are added? In 6-9, choose “a” if the statement correctly answers the question, or choose “b” if it does not.

6. The traits of some guppies gradually changed as they encountered predators, so that they became less brightly colored. The offspring of these individuals inherited these changes. a or **b**
7. When predators were introduced into the stream, females stopped choosing brightly colored males and chose dull males since dull males had traits that would now benefit the females' offspring. a or **b**
8. The presence of predators led to mutations in the genes responsible for coloration, and, as a result, the proportion of brightly colored males gradually decreased. a or **b**
9. **The proportion of guppies with genes that cause bright coloration decreased due to strong selection by predators, even though females still preferred brightly colored mates.** a or **b**
10. Fitness is a term used by biologists to define the evolutionary success of an organism. Below are data on four female lizards.

	Lizard A	Lizard B	Lizard C	Lizard D
Body length	20 cm	12 cm	10 cm	15 cm
Total offspring surviving to adulthood	19	28	22	26
Age at death (years)	4	5	4	6
Comments	Lizard A is very strong, healthy, and clever.	Lizard B is red and has small legs.	Lizard C is dark and very quick.	Lizard D has the largest territory & has mated with many lizards.

Which lizard would be considered the most fit?

- a. Lizard A **b. Lizard B** c. Lizard C d. Lizard D

(This question was taken from Anderson, D., Fisher, K., and Norman, G (2002) Development of the conceptual inventory of natural selection. *J. Res. Sci. Teach* 39:952-978.)

Question: Which of the following statements about natural selection are generally true? In 11-14, choose “a” if generally true or “b” if not generally true.

11. Natural selection acts directly on an individual's genetic make-up and thereby decreases or increases the survival probability of the individual. a or **b**
12. Natural selection acts on individuals by changing their genes so they are better able to withstand selection pressure. a or **b**

13. Natural selection generally acts on groups of organisms causing extinction of some groups and survival of other groups. a or b
14. **Within a population, natural selection acts via the structures, physiologies, and behaviors expressed by individuals.** a or b
15. From the list of sentences below, pick the one that makes the following paragraph the best summary of Darwin's proposed mechanism for evolution.
- All organisms produce many more offspring than can possibly survive. Those that do survive are a little different from their parents. (INSERT SENTENCE HERE FROM THE LIST BELOW) Differential survival leads to some types of offspring leaving more progeny than others. Over long periods of time new species are formed in this manner.
- a. This differential survival is due to limited food supplies.
 - b. This differential survival is due to many organisms competing with each other.
 - c. This differential survival is due to a constantly changing environment.
 - d. **This differential survival is due to heritable differences among the offspring.**
16. The boll weevil is an insect that destroys crops in the southern United States. Farmers use pesticides to kill these weevils. Over the past forty years, the farmers have noticed that fewer and fewer weevils are killed by pesticides. Which of the following statements is the best scientific explanation for this observation?
- a. The species became more fit and stronger due to exposure to pesticides. As a result, individual weevils within the species were better at adapting to their environment and surviving selection pressures such as those due to insecticides, diseases, predation, and competition. Thus, fewer and fewer weevils died each year from pesticide exposure.
 - b. Individual weevils tried to breed with the strongest mates available and develop a better gene pool for their population. This prevented the species from becoming extinct since, as the gene pool gradually improved, fewer and fewer weevils died from repeated pesticide exposure.
 - c. **The Weevils exhibited variation in their response to pesticides. Some of this variation was genetic. Weevils that could tolerate more pesticide had more offspring, which inherited the beneficial gene variants. Through this process, the proportion of pesticide resistant variants increased in the population and fewer and fewer weevils died from pesticide exposure.**
 - d. The presence of the pesticide caused some weevils to develop genetic mutations enabling them to tolerate more pesticide. These mutations were inherited by their offspring, who developed additional beneficial

mutations. Thus, pesticide sensitivity was gradually reduced, and fewer and fewer weevils died each year from pesticide exposure.

17. A field has annual pea plants in it and no other fields in the area have pea plants. Fifty percent of the plants have purple flowers and 50% have white flowers. Flower color is determined by a single gene in each of the plants' two sets of chromosomes and this means each plant has two copies of a gene for flower color. If a plant has one white and one purple copy, or two purple copies, its flowers are purple. If it has two white copies, its flowers are white. A rabbit family, that eats just purple pea flowers, moves into the field. When a rabbit finds a purple-flowered plant, it eats all the flowers on that plant. Although the plant survives, it produces no seeds. After many years,.... (Choose the letter of the correct outcome)
- only white-flowered pea plants remain in the field.**
 - only purple-flowered pea plants remain in the field.
 - about 50% of the pea plants have purple flowers and about 50% have white flowers.
 - it is not possible to predict exactly what happens.

Question: The result in question 17 illustrates which of the following? Choose "a" if the statement correctly answers the question, or choose "b" if it does not.

- Evolution occurred in the plant population because the rabbits' eating preference changed the genes of the plants whose flowers they ate. a or **b**
- Evolution occurred in the plant population because the relative number of purple and white genes changed.** a or **b**
- The rabbits exerted a selection pressure that produced better pea plants compared to other pea plants in other fields outside this area. a or **b**
- The individual plants whose flowers were eaten did not evolve, although they did survive the selection pressure exerted by the rabbits.** a or **b**
- The individual plants whose flowers were not eaten evolved because they were better able to survive in that field. a or **b**

Mark as true any of the following statements that provide evidence for the evolutionary origin of species and not the unique creation of each species.

- Pandas have 5 fingers but do not have opposable thumbs. They do have an enlarged wrist bone that serves as a thumb for grasping and stripping leaves from bamboo.** True (a) or False (b)
- When the insecticide DDT is first used in an area, most flies are killed, but after several years of use, most of the flies survive the DDT treatment.** True (a) or False (b)

25. **The anatomy of the vertebrate eye leads to blind spots and detached retinas.** True (a) or False (b)
26. **The bat wing, the salamander forelimb, and dinosaur forelimb are composed of the same set of bones but radically modified in size and shape.** True (a) or False (b)

Mark as true, any of the following statement that provides evidence for the evolutionary origin of species and not the unique creation of each species.

27. The bill length of humming birds in the West Indies precisely matches the depth of the floral tubes of the flowers on which they feed.
True (a) or False (b)
28. **When one sickle cell gene is present with a normal gene, the sickle cell gene protects the person from malaria. But, when the other gene is also a sickle cell gene, the person is severely anemic and usually dies.**
True (a) or False (b)
29. The oldest fish fossils, amphibian fossils, and primate fossils are the same age.
True (a) or False (b)
30. **Humans, fish, and turtles develop tails in their embryos. Adult fish and turtles have tails, but adult humans do not.** True (a) or False (b)
31. If a subpopulation of a species is isolated on the Hawaiian Islands, what is the probability that evolution will occur in that population?
- Over any period of time much longer than one generation, the probability is 100%.**
 - Although the probability differs among species, it is usually between one in a million and one in a billion.
 - Although it depends upon the circumstances and the strength of the selection pressure, the probability is usually around 50%.
 - It depends upon the species. For fruit flies the probability would be close to 100% while for humans the probability would be very small, essentially 0%.
 - The probability cannot be determined.

Task: For each scenario, choose the bird population which would, in theory, have a greater capacity to respond to intense selection pressures and better adapt to major climatic changes over the next 50,000 years (25,000 generations).

32. All members of population “a” have an enzyme that corrects any change to their DNA. Population “b” does not have this ultra-efficient repair enzyme and continues experiencing changes in its genes due to mutations.

a or b

33. Population “a” experiences 10 times the immigration rate of individuals from surrounding populations than population “b”. Population “b” remains fairly isolated and experiences a constant, very low influx of genes from other populations. a or b
34. Due to periodic plagues, population “a” exhibits large fluctuations in number of birds with total population size often plummeting to 5-10 individuals before slowly climbing back to higher levels. Population “b” maintains a steady abundance of moderate size. a or b
35. Due to its proximity to the ocean, population “a” has evolved in a very stable climate with constant rainfall and temperature. Population “b” lives further inland and has evolved in a very seasonal and unpredictable climate. a or b

Statement: Evidence from the fossil record indicates that at least 99% of all species of multicellular organisms that have lived on Earth are now extinct and that the organisms living together during a given era are essentially unique. For example, the plant and vertebrate species alive today are different than those 100 million years ago, and those existing 100 million years ago were different from those 300 million years ago, and so on. These observations indicate which of the following about the evolutionary process? Choose “a” if the statement correctly answers the question, or choose “b” if it does not.

36. **Earth had a diverse set of species both 300 and 100 million years ago, because extinction and speciation tend to have about the same rate over long periods of time.** a or b
37. Evolution acts to continually improve organisms so as to produce the best possible species. a or b
38. **The fate of almost all species over many millions of years is extinction.** a or b
39. Our species, Homo sapiens, evolved to be the pinnacle of evolution on Earth and is not vulnerable to extinction. a or b

Task: Select from the following list those changes in humans that are attributable only to cultural change. Choose “a” if only cultural or “b” if not cultural.

40. Walking upright. a or b
41. Use of agriculture. a or b
42. Use of fire. a or b
43. Fine motor skills required to type on a computer. a or b

Task: Select from the following list those changes in humans that are attributable only to cultural change. Choose “a” if only cultural or “b” if not cultural.

44. Communicating with facial expressions like smiles. a or b

45. Ability to speak. a or **b**
46. **Writing.** a or b
47. Using language with grammar. a or **b**
48. **Fear of guns.** a or b

Statement: In a large bioregion we have, among many other species, the following four species with the listed characteristics.

- a. *Eatone* eats only lupin flowers, lives in almost all major habitats in the bioregion, and produces several offspring per year during its 10-year life-span.
- b. *Eatmany* eats lupin, lily, lilac, and many other flowers, requires cool, moist habitats that are very rare in the bioregion, and produces many offspring during its one year lifespan.
- c. *Eatall* is an omnivore that eats many plants, lives in all major habitats in the bioregion, and produces large numbers of offspring during its several-year lifespan.
- d. *Pickypoo* specializes in eating dogwood leaves, hibernates only in cool caves that are rare in the bioregion, and produces two or three offspring over a lifespan of many years

Fill in the letter(s) of the species

49. that has/have the highest probability of going extinct in this bioregion. **d**
50. that has/have an intermediate probability of going extinct in this bioregion. **a, b**
51. that has/have the lowest probability of going extinct in this bioregion. **c**

Question: When an asteroid slammed into the Gulf of Mexico sixty-five million years ago, most of western North America was incinerated by temperatures of several thousand degrees centigrade. A huge tidal wave that flooded half the continent followed. Hundreds of species in that area went extinct in a period of minutes to hours. This was a major event in the evolutionary history of North America. This event illustrates what important aspects of the mechanism of evolution? Choose “a” if the statement correctly answers the question, or choose “b” if it does not.

52. Species that are poorly adapted to their environment eventually go extinct. a or **b**
53. **Selection pressure can be so extreme that essentially no life can survive.** a or b
54. Highly specialized organisms often go extinct when environmental conditions change. a or **b**
55. **Chance or luck (good and bad) plays a major role in evolution.** a or b

Statement: In his famous 1859 book, *The Origin of Species by Means of Natural Selection*, Darwin proposed that natural selection is the primary mechanism for evolution, but he had little direct evidence for how species originated. We now understand how species are produced.

56. Pick the fewest statements possible from the five below to illustrate the general process for the evolution of species.
- A major mutation has to occur that makes the individuals with this genetic change radically different and unable to mate with other individuals of their original species.
 - Mutations and new gene combinations arise in individuals, sometimes quickly and sometimes over extended periods, that make mating between individuals in this subpopulation with other members of the species less possible.
 - When the populations are reproductively isolated, they are separate species and further genetic changes make them more and more different.
 - A previously existing species has to go extinct to open-up ecological space for a new species to form.
 - A subpopulation of a species becomes physically, behaviorally, or in some other way isolated or partly isolated from other populations of the species.

Answer using letters from the statements above:

 b, c or b, c, e

Question. You have joined a team of biologists studying the fruit fly, *Drosophila fruit eater*. This species began laying its eggs on bananas in the 1920s. At your first research meeting, the geneticists reveal that they have discovered three genetically different forms of the fly. You suggest that speciation is taking place in *D. fruit eater* despite the fact all individuals in this species are living together in the same habitat. Your hypothesis is loudly rejected and you decide to gather more evidence. Which of the following data would provide support (a) for your hypothesis? Which would weaken (b) your hypothesis?

57. New ecological data indicate that, besides bananas, *D. fruit eater* eats only two other fruits: papayas and mangos.

support (a) weaken (b)

58. Geneticists, working in the lab, show that hybrids amongst the three types of *D. fruit eater* survive and reproduce just as well as their parents.

 support (a) **weaken (b)**

59. The entomologists show that each genetic type prefers a different fruit and that there is a very strong tendency for each type to lay its eggs on only one type of fruit.

support (a) weaken (b)

60. In the wild, female *D. fruiteater* seem to mate randomly and indiscriminately with male *D. fruiteater*.

support (a) **weaken (b)**

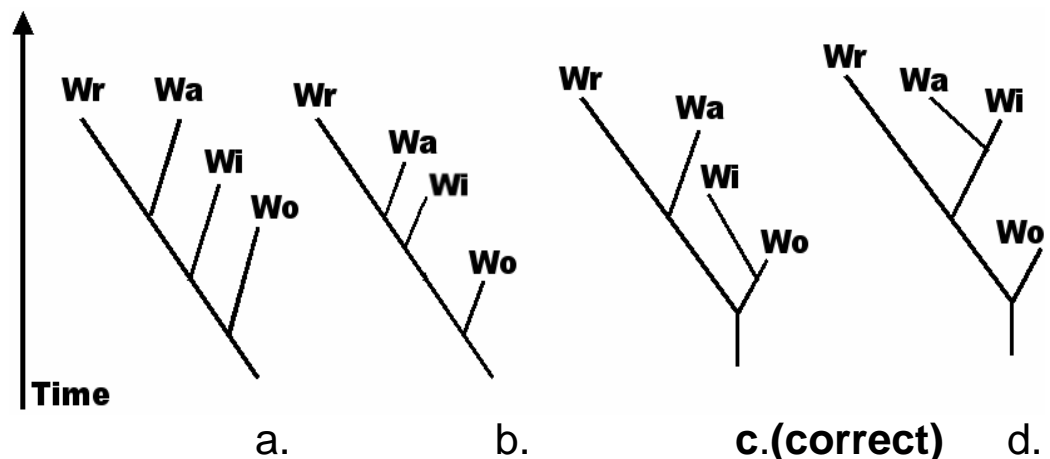
61. Which of the following is the correct chronological order for the evolution of photosynthesis and the major groups of organisms listed?

- a. bacteria, photosynthesis, land plants, eukaryotic cells, mammals, dinosaurs
- b. bacteria, eukaryotic cells, photosynthesis, land plants, dinosaurs, mammals
- c. eukaryotic cells, bacteria, photosynthesis, land plants, mammals, dinosaurs
- d. **bacteria, photosynthesis, eukaryotic cells, land plants, dinosaurs, mammals**

62. The stratigraphic section below shows the location of fossils for a group of extinct hominids. The cytochrome c genes for all 4 species were sufficiently preserved that they could be sequenced. The sequence data are given in the table. Only the base positions that have undergone substitutions are shown for all four species. Given this information, choose the letter of the phylogenetic tree that best summarizes evolution in this group of species.

Figure shows eight stratigraphic layers (top layer is 1 and bottom layer is 8) with *Wo* skull in layer 7; *Wi* skulls in layers 7, 6, 5; *Wa* skulls in layers 5, 4; and *Wr* skulls in 6, 5, 4, 3, 2.

<i>W. recentus</i>	(<i>Wr</i>)	CACAATA	TGAGC	GAAGAGATG
<i>W. antecedentus</i>	(<i>Wa</i>)	A A	G C	G CG
<i>W. intermedius</i>	(<i>Wi</i>)	C G	T A	T AT
<i>W. originalus</i>	(<i>Wo</i>)	C C	T A	C AT



* This concept inventory was developed only for use at Rensselaer. A number of faculty contributed questions taken from their personal files, test banks, and perhaps from other published sources. Since we had no intention of publishing these questions (it was requested by reviewers and editor), we did not keep records as to who contributed which questions and their sources. Some of the questions are likely not original, but we have no way of identifying them. We acknowledge these possible unknown published sources.