

1. if a population is not in Hardy-Weinberg equilibrium it means that:

- a. One of the assumptions is not met (diploid organism, sexual reproduction, same allele frequencies in both sexes, random mating)
- b. One evolutionary mechanism is acting on the population and causing a change of the allele frequencies through the generations.
- c. Genotype frequencies cannot be calculated from allele frequencies as p^2 , $2pq$ and q^2
- d. The three previous answers are correct.

2. The shorthorn is a breed of cattle originated in the North East of England known for having short horns. Their skin can be white, colored or roan (a mixture of white and pigmented). In a farm with 2,820 cows, 260 are white, 1,430 red, and 1,130 roan. if skin color is controlled by a single autosomal gene with two alleles, indicate the false answer.

- a. The frequency of the allele causing red skin is 0.7074.
- b. This population is not in Hardy Weinberg's equilibrium
- c. The frequency of homozygotes for the white allele is 0.092.
- d. The expected proportion of heterozygotes is 0.414.

3. How can you calculate allele frequencies in a population? Indicate the correct answer:

- a. From genotype frequencies or counts of individuals with each genotype.
- b. Assuming that the population is in Hardy-Weinberg equilibrium in the case of two alleles with dominance
- c. Answer a and b are both correct
- d. Answers a and b are both false

4. Indicate which of the following statements about natural selection is false:

- a. The result of the natural selection process depends on the fitness values of the different genotypes
- b. Natural selection is the only evolutionary mechanism able to achieve an adaptation of the population to the environment.
- c. Natural selection always fixes one allele in the population.
- d. The more different the biological efficiencies of the different genotypes, the greater the intensity of natural selection and the faster the new equilibrium will be reached.

5. Indicate the false answer. (Why the recessive alleles that causes severe disease have not been already eliminated completely from human population by natural selection? A severe disease refers to those that affect greatly or completely prevent transmission of alleles to the next generation)

- a. Because humans have a large population size and these alleles have not been eliminated by genetic drift yet
- b. Because natural selection is not efficient to eliminate recessive alleles at lower frequency
- c. Because defective alleles causing disease are being generated continuously by mutation
- d. Because these alleles can be beneficial in heterozygotes

6. Indicate the true sentence. An allele with frequency 0.12 in a population of 50 individuals:

- a. Is more likely to be fixed than lost by genetic drift.
- b. Will have the same allele frequency in the next generation.
- c. Has a probability of fixation of 12%.
- d. None of the other answers are true.

7. Two alleles, A and a, are found for a given gene in a population. Allele frequency of allele A is 0.7. If due to an environmental change, relative fitness values of genotypes AA, Aa and aa become respectively 1, 1 and 0.52, which of the following statements is false?

- a. Allele a is recessive and detrimental.
- b. After the first round of selection, the frequency of allele A will be 0.7316.
- c. After the first round of selection, the frequency of heterozygotes will be 0.5121
- d. When a new equilibrium is reached, allele frequencies will be 1 for allele A and 0 for allele a.

8. Ross's goose is a small Arctic nesting goose. Goslings (baby geese) exist in two color morphs: grey and yellow. Color is controlled by two alleles at a single locus with grey being dominant. There is no difference between yellow and grey goslings once they become adults. However, yellow goslings are at an increased risk of predation by a predatory bird, the Arctic skua. A study of goose nests in a population in Canada found 263 yellow goslings and 413 grey goslings. if 303 grey goslings survive to adulthood, but only 150 yellow ones do, indicate the false answer:

- a. The absolute fitness value of the yellow goslings is 0.57.
- b. The relative fitness value of the yellow phenotype relative to the grey one is 0.78.
- c. Relative fitness values cannot be calculated from the available data.
- d. The relative fitness values will be the same for heterozygotes and homozygotes for the grey gene

9. Indicate the false answer. According to the neutralist theory of molecular evolution:

- a. The amount of polymorphism observed in a population is determined by the balance between mutation and genetic drift.
- b. Neutral mutations cannot fix in a population.
- c. Most variants found in DNA sequences are neutral.
- d. Advantageous mutations will get fixed faster than neutral mutations.

10. You have genotyped the two alleles (standard -std and inverted - Inv) of a polymorphic inversion in a sample of 45 humans and you have calculated and allele frequency $p=0.678$ for the std allele. You have also genotyped a SNP variant with two alleles (G and C) located close to the inversion with and allele frequency $p= 0.789$ for G. You have found the haplotype counts shown in the following table. Indicate the true option.

Haplotype	Count
Std G	61
Inv G	10
Std C	0
Inv C	19

- a. There is no linkage disequilibrium between the inversion and the SNP alleles
- b. There is linkage disequilibrium with a value of $D' = 1$
- c. There is a linkage disequilibrium with a value of $r^2 = 1$
- d. There is linkage disequilibrium but with a low D' value

11. Indicate the false answer. Population subdivision:

- a. Causes a decrease of the number of private alleles (found in a single subpopulation)
- b. Causes a heterozygote deficiency with respect to the proportion of heterozygotes we would find if all individuals were part of a single population
- c. Results in a big F_{st}
- d. Implies a low migration rate among subpopulations

12. Which of the following statements about migration is false?

- a. Migration rate is the proportion of alleles in the receptor population that come from another
- b. If migration is the only acting evolutionary force, all populations receiving alleles from other population will reach the alleles frequency of the population distributing more alleles to the rest.
- c. In the continent-island model, the island will have the same allele frequencies than the continent in the equilibrium.
- d) Migration can counteract the effects of drift on the allele frequencies of different populations.

13. Pingelap is atoll in the Pacific Ocean that is part of Micronesia, Approximately 5% of the population of 3000 people have complete achromatopsia, an autosomal recessive disorder characterized by photophobia, low visual acuity and total inability to distinguish colors. In the rest of the world, only 1 in 30,000 people are affected by this disorder. The genetic base of achromatopsia in the Pingelap population is the change of a single nucleotide in gene CNGB3 that exchanges a serine by a phenylalanine in position 435 of the protein, a highly conserved position within a protein domain that is important for protein function. Which of the following explanations for these observations do you think that is more likely?

- a. Allele frequency increase of the achromatopsia allele in this island due to natural selection
- b. Allele frequency increase in this island due to a founder effect or a bottleneck
- c. Balance between mutation and purifying selection
- d. Migration from another population with high frequency of this allele.

14. In a DNA substitution models:

- a. The probability of change among nucleotides depend on the length of the gene.
- b. The probability of having a particular nucleotide at time. "t+1" depends only on the nucleotide existing in time "t", and not on previous states.
- c. We use conserved domains in proteins to establish the rates of change across nucleotides.
- d. Equal nucleotide frequencies are always assumed.

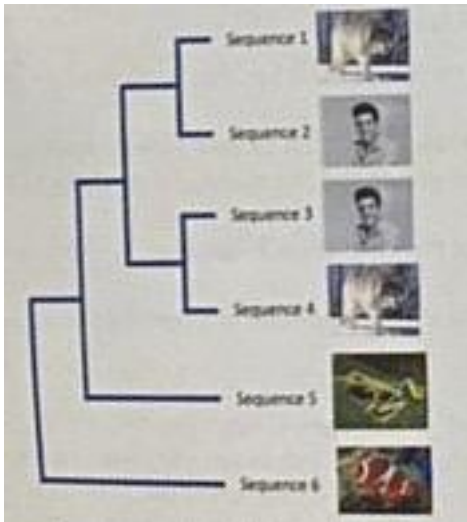
15. Lateral gene transfer:

- a. Has only been demonstrated in bacteria.
- b. Only occurs through hybridization.
- c. Has only been described in laboratory conditions.
- d. Evidence shows that it may occur between highly divergent organisms.

16. After a gene duplication:

- a. There are multiple potential evolutionary trajectories of the new locus, acquiring a new function is just one of them.
- b. The new locus immediately acquires a new function.
- c. The new locus often replaces the old locus, since it is a more evolved version of it.
- d. The consequence is a polygenic trait.

17. According to the evidence provided by the following gene:

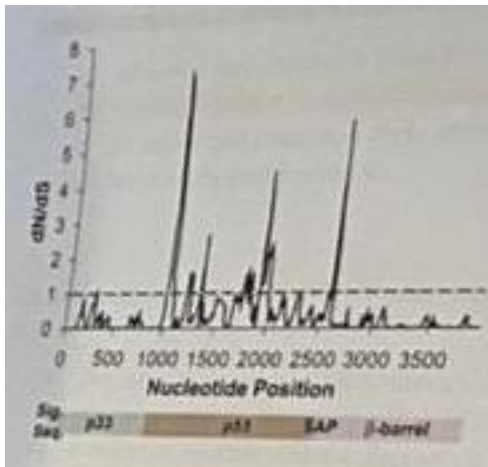


- a. Sequence 3 and 4 are paralogous.
- b. Sequence 3 and 5 are paralogous.
- c. Sequence 2 and 3 are orthologous.
- d. Sequence 2 and 5 are orthologous

18. Orthologous genes:

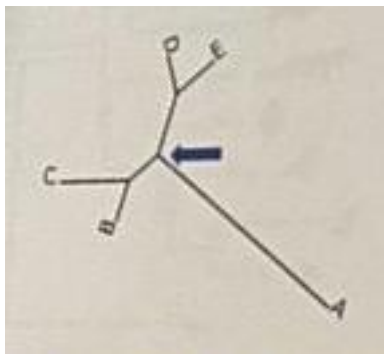
- a. When used in phylogenetic, always replicate the species tree.
- b. Originate through duplication events
- c. Often show a high degree of sequence and functional similarity
- d. Derive from lateral gene transfer

19. The following graph shows the variation of dN/dS along a DNA fragment in a species of prokaryote. Which statement is consistent with the evidence?



- a. All sites of all genes evolve neutrally.
- b. Positive selection is acting on multiple sites in the gene p33
- c. Positive selection is acting on multiple sites within gene p55.
- d. All sites are affected by negative selection.

20. What can we say from the tree below:

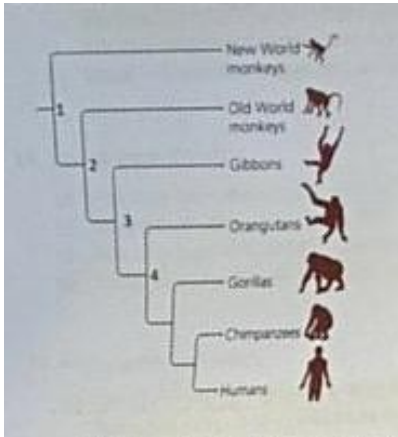


- a. The tree is an unrooted phylogram
- b. Species A is ancestral to all other species.
- c. The arrow indicates the root of the tree.
- d. E and A are more closely related than D and E.

21. A significant negative Tajima's D:

- a. Provides clear evidence supporting the action of natural selection
- b. Rejects the null hypothesis of mutation-drift equilibrium
- c. Indicates that the population has undergone drastic demographic changes
- d. Indicates that the population is evolving neutrally

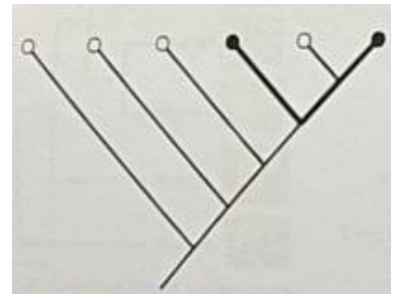
22. Sivapithecus is a primate fossil that lived approximately 12 Ma (Mega-annum) ago. By its anatomical features, this fossil is closely related to the present-day orangutans (it can be associated with the lineage leading to the orangutan). Which statement is true according to the combined evidence provided by this fossil and the following tree?



- This evidence shows that the ancestor of gorillas, chimpanzees and human lived 12 Ma ago
- This fossil indicates that 12 Ma ago, orangutans and the ancestors of the gorilla, chimpanzee and human, had already diverged (node 4 must be older than 12 Ma)
- This fossil indicates that humans and orangutans diverged 5 Ma ago
- This fossil shows that gorillas and chimpanzees diverged 12 Ma ago

23. The lineages highlighted in dark in this phylogenetic tree:

- Form a paraphyletic clade.
- Form a monophyletic clade.
- Form a polyphyletic clade.
- Form a supraphyletic clade.



24. We sequenced and aligned the protein-coding region of two orthologous genes from two closely related species. Using the software DnaSP, we estimated that the number of synonymous and non-synonymous substitutions are 140 and 140, respectively.

- a. All amino acid changes in these proteins are deleterious.
- b. Positive selection is a plausible option for the evolution of these proteins.
- c. All amino acid changes in these proteins are selectively neutral.
- d. None of the above is correct.

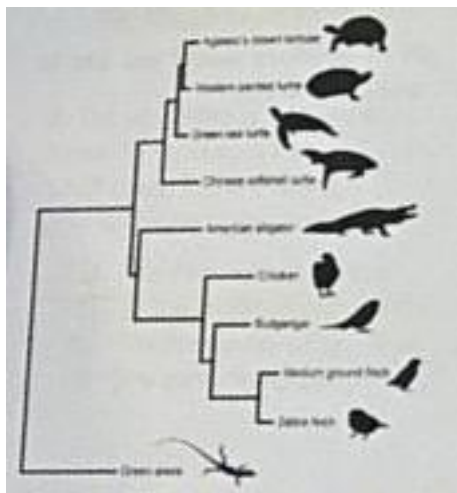
25. What can we say about a substitution model if the rates from A to G and from G to A are both 0.470?

- a. The *Jukes and Cantor (JC69)* model is a candidate.
- b. We cannot discard the *Kimura 2P (K2P 80)* model.
- c. A model compatible with the data would be the *Hasegawa-Kishino-Yano*.
- d. All the other answers are true.

26. According to the evidence provided by the following molecular phylogeny:

- a. The American alligator is more closely related to the chicken than to turtles.
- b. The green anole is the ancestor of all other species.
- c. The American alligator is more closely related to the turtles than to the chicken.
- d. Turtles and tortoises form a polyphyletic clade.

27. We used the McDonald and Kreitman test to study the role of natural selection in the molecular evolution of a human olfactory receptor. The p-value of the test was $P=0.0026$.



- a. Some amino acid changes in this olfactory receptor were fixed by positive selection.
- b. This protein evolves under neutrality.
- c. Natural selection has played a relevant role in the evolution of this protein, although we cannot know if it is positive or negative.
- d. The McDonald and Kreitman test is not useful to detect the footprint of natural selection in protein-coding genes.

28. After comparing two orthologous introns from two species separated 4 million years ago, we observed 34 nucleotide differences. If the total analysed sites region (excluding gaps) is 2,400 bp, and no multiple hits occurred during its divergence, what will be the estimated evolutionary rate of this intron?

- a. 2×10^{-9}
- b. 0.5×10^{-9}
- c. 1×10^{-9}
- d. 0.25×10^{-9}

29. In a codon substitution model the probability of a synonymous transversion that changes a *i* codon to a *j* codon is:

- a. The frequency of the *j* codon \times the omega ratio.
- b. The frequency of the *j* codon \times the transition/ transversion ratio.
- c. The frequency of the *j* codon
- d. The p-value of the IRT.

30. According to what you have seen in the practices, what type of positions would you use to reconstruct the phylogeny necessary to calculate the evolutionary rate of a protein.

- a. Non-synonymous sites
- b. All sites.
- c. Introns or synonymous sites
- d. All the other answers are false.

- 1.d)
- 2.b)
- 3.c)
- 4.c)
- 5.a)
- 6.c)
- 7.c)
- 8.c)
- 9.b)
- 10.b)
- 11.a)
- 12.b)
- 13.b)
- 14.b)
- 15.d)
- 16.a)
- 17.d)
- 18.c)

- 19.c)
- 20.a)
- 21.b)
- 22.b)
- 23.a)
- 24.b)
- 25.d)
- 26.a)
- 27.c)
- 28.a)
- 29.c)
- 30.c)