Circle the best single letter choice for each of the following questions before transferring your answers to your Scantron sheet. Note, for "multiple-multiple" style questions, more than one option may be correct (e.g. 1, 2 & 3 only). Part marks may be available for choosing some of the correct answers but choosing any incorrect answer earns a grade of "0".

1. Although many people accept that one of the classic characteristics of living systems is that they evolve, there is often confusion about what term evolution actually means.

   Which of the following levels of organization of living systems evolves?

A. populations
B. individuals
C. genotypes
D. alleles

---

2. Emerald ash borers are invasive insects, currently spreading into Canada from more southerly (warmer) environments. In general, these insects die if the surrounding temperature becomes too cold. However, certain mutations can improve cold-tolerance and thus improve the ability to survive cold winters.

   Imagine two populations of emerald ash borers, one (A) living in a cold environment and another (B) living in a warm environment. Both populations are equal in size and reproduce at equal rates.

   In which population is a mutation that improves cold-tolerance more likely to occur?

A. Population A (cold environment)
B. Population B (warm environment)
C. The mutation will not occur in either population since mutation mechanisms are not directed to "respond to need" in particular environments.
D. The mutation is equally likely to occur in either population.

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3. It is possible to stain chromosomes such that only the telomeres are visible as bright pink spots under the microscope.

   For an organism with 2n = 16, how many pink spots would be present at anaphase of Meiosis II?

A. 64
B. 32
C. 16
D. 8
E. 4

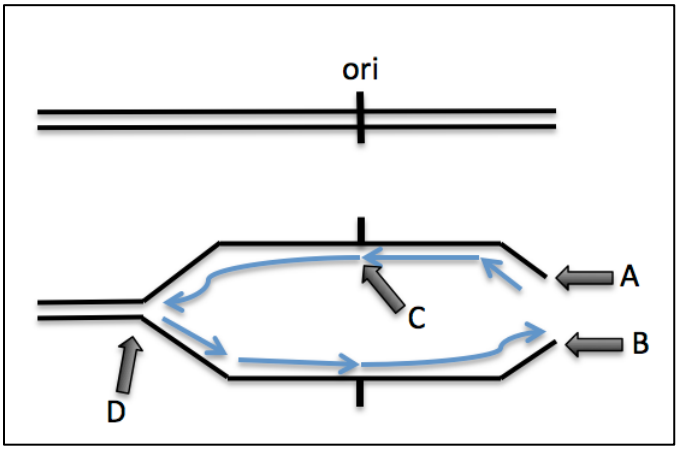
---

4. *Ammophila brevigulata* is a species of diploid plant with a C-value of 480 Mb (million base pairs).

   How much DNA would be in the nucleus of a gametophyte cell in G2?

A. 240 Mb
B. 480 Mb
C. 960 Mb
D. 1920 Mb

5. The sketch at right shows the last origin of replication (ori) at the end of a mouse chromosome and the last replication bubble that would result.



Which of the following statements about this situation is correct?

1. The fork at Arrow D will proceed all the way to the other end of the chromosome.
2. Arrow B identifies a 3'OH.
3. The base indicated by Arrow C, the first base to be added of this leading strand, was added by DNA polymerase III.
4. Arrow A identifies where telomerase would begin adding DNA bases.

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2 ,3 & 4 are correct.

---

6. Hopefully you recall that the enzyme ligase is essential in DNA replication. However, ligase is also involved in other aspects of DNA biochemistry.

Which of the following mechanisms would likely require ligase activity?

1. Excision repair of mismatches.
2. Proof-reading by DNA polymerase.
3. Non-homologous end joining of broken chromosomes.
4. Photolyase repair of thymine dimers.

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2 ,3 & 4 are correct.

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7. Imagine that you notice in a karyotype that a part of one Chromosome 8 is exchanged with part of one Chromosome 22.

Which of the following mechanisms is the most likely cause of such a chromosomal rearrangement?

A. Errors in recombination during meiosis.
B. Repair of double strand breaks.
C. Movement of retrotransposons.
D. Improper attachment of spindles to kinetochores during mitosis.

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8. The Table below summarizes characteristics of 4 mobile elements found in the human genome.

Which of the following elements is most likely to be HIV?

Mobile Element	Enzyme Coded	Repeat Sequences?	Host Genes?	*gag* Gene?
A	T	Yes	No	No
B	T	Yes	Yes	No
C	RT	Yes	No	No
D	RT	Yes	No	Yes

T = transposase; RT = reverse transcriptase; *gag* = protein associated with RNA

---

9. Make a sketch of a typical GC base pair in DNA about to be replicated. During the first round of replication, imagine that a hypothetical purine, called shautamine, is incorporated into the growing DNA backbone as the original GC pair is replicated. During the second round of replication, shautamine undergoes a tautomeric shift and therefore attracts the "wrong" base.

After the third round of replication, which of the following SNPs will be present instead of the original GC pair?

A. AT
B. AG
C. CG
D. TA

---

10. Mendel's careful analysis of controlled crosses was able to show the independent assortment of the alleles of two different genes: eg. short vs. tall plants and green vs. yellow seeds.

During which of the following stages of the life cycle of the pea plants did this independent assortment take place?

A. spore
B. gametophyte
C. zygote
D. sporophyte

---

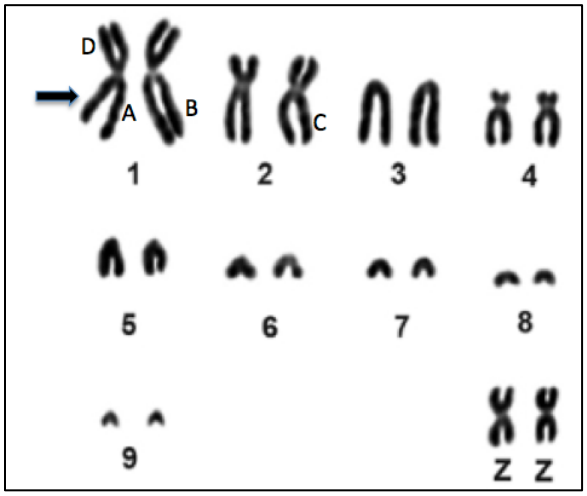
11. Imagine that a gene duplication on chromosome 12 in frogs results in excessive gene product giving rise to a dominant disorder of limb formation.

Now imagine that this CNV is present on one homologue of an affected offspring but it is absent from the somatic genome sequence of either parent.

In which of the following cells did such a "*de novo*" mutation likely arise?

A. meiocyte of one parent
B. meiocyte of both parents
C. zygote
D. each somatic cell of offspring

12. In domestic chickens, birds that are homozygous for the recessive alleles of the Lavender gene lack feathers. The karyotype at right is from a heterozygous bird (**LI**). (The sex chromosomes in birds are called Z.)



The arrow shows the location of the dominant allele (**L**) of the Lavender gene on Chromosome 1.

Which of the letters indicates the location of an **I** allele?

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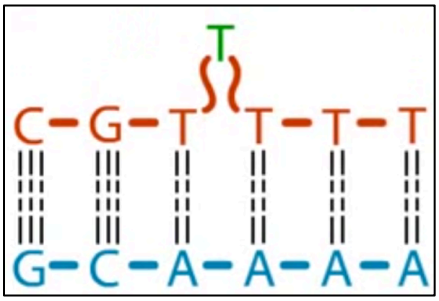
13. Imagine you are a chemist and you have synthesized a new compound for colouring fabric. However, during testing you discover that your new compound stabilizes the loop in the structure shown below, making the loop more likely to occur.



Which of the following types of genomic variation will your compound likely promote?

A. aneuploidy
B. indel
C. SNP
D. CNV
E. translocation

---

14. Pigs are mammals and females inactivate extra X chromosomes during somatic development just as humans do. So female pigs are mosaics for X chromosome expression.

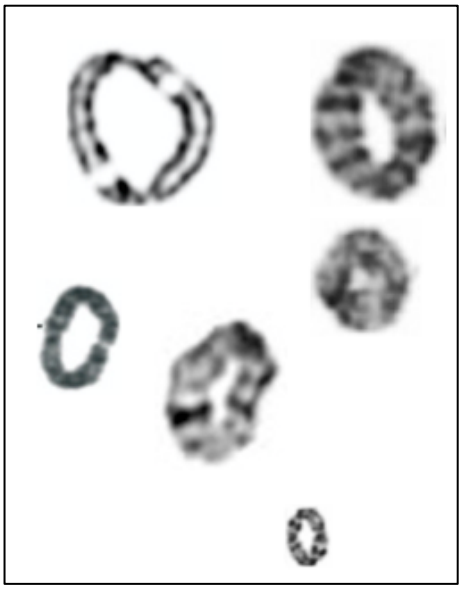
Recall that the "spotted" **S** allele of MC1R in pigs results from an unstable mutation such that back-mutations occur in several cells during somatic development. Each of these cells then makes black melanin and gives rise to a patch of black-pigmented tissue called a "spot" on an otherwise red background. Spotted pigs are, therefore, also a kind of genetic mosaic.

Which of the following statements accurately distinguishes the "spotted" mosaicism from the X-inactivation mosaicism in female pigs?

A. Following initial X inactivation, each descendent cell makes an independent inactivation choice; however, following changes in pigmentation, each descendent cell is the same as the parent cell.
B. For X inactivation, the two alternatives are initially equally likely to occur; however, in pigmentation the two alternatives are not initially equally likely to occur.
C. Changes in X-linked gene expression do not involve altering the DNA sequence; however, changes in pigmentation gene expression do involve changes in DNA sequence.
D. Both B and C are correct.

Use the information below to answer the following 2 questions.

Imagine that you have discovered a new species of very unusual unicellular eukaryote in which the nuclear genome is composed entirely of circular "ring" chromosomes. Subsequent analyses show that the ring chromosomes are simply linear chromosomes with their ends attached; the overall chemistry and replication of DNA is usual for eukaryotes. Telomerase activity is never expressed. The chromosomes attach to spindle tubules and segregate as expected during mitosis.

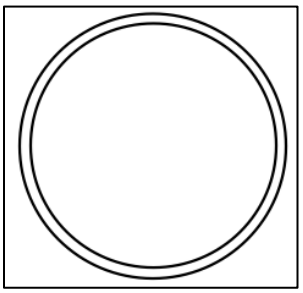


15. What is the likely ploidy level of this dividing cell?

A. 1n
B. 2n
C. 3n
D. 6n

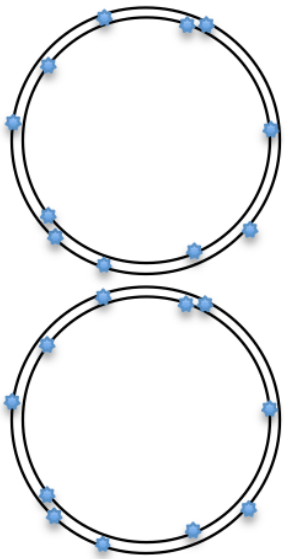
---

16. Each line in this sketch represents one backbone of the double helix of a ring chromosome in G_1 of the cell cycle. Imagine that you are able to add a fluorescent dye to thymine and then feed it to cycling cells in S phase.

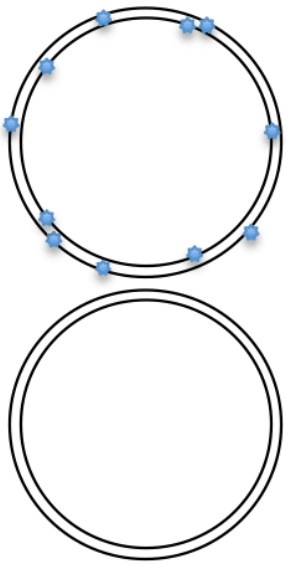


Which of the following diagrams best conveys the relative location of the dyed thymine (stars) in the two ring chromosomes that would result from replication (ie. in G_2)?

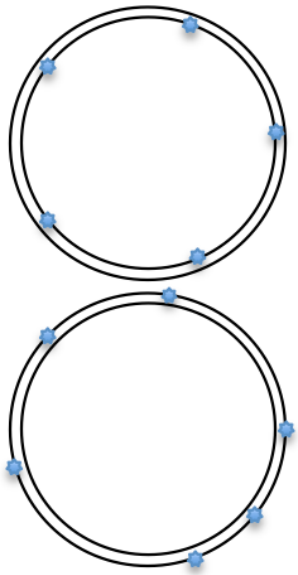
A.



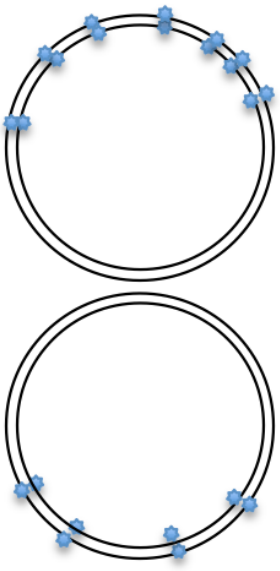
B.



C.



D.



17. Roughly one in every 1,000 girls is born with three copies of the X chromosome. Although the extra X chromosomes are inactivated in somatic cells, "triple X" females often exhibit lower IQ, motor coordination problems and delayed language development.

Imagine a triple X girl, Alisha, who shows an X-linked recessive form of the blood clotting disorder, hemophilia. That is, she carries the mutant allele on all three of her X chromosomes. Alisha's father and brother are also hemophiliac but her mother is not.

Assuming that her XXX karyotype resulted from a single error in chromosome partitioning, in which of the following stages of meiosis might the error have occurred?

1. Meiosis II in the father.
2. Meiosis I in the mother.
3. Meiosis II in the mother.
4. Meiosis I in the father.

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2, 3 & 4 are correct.

---

18. About 25% of humans exhibit the autosomal dominant phototic sneeze reflex (PSR) that causes them to sneeze a given number of times (often twice) when suddenly facing directly into full sun. (You know who you are.)

Imagine that you and your partner are both sun sneezers but your mothers are not. Given the poor outcomes of summer photos of affected individuals, you hope that none of your children will be sun sneezers.

What is the likelihood that none of your four children will be sun sneezers like you?

A. $(¼)^4$
B. ¼ x 4
C. $1-(3/4)^4$
D. $3/4)^4$

---

19. The diagram at right shows the relative location of three genes along chromosome 9. Imagine a heterozygote (**Ee Bb Gg**) with all dominant alleles on the maternal homologue. Such an organism could produce 8 different combinations of alleles, therefore producing 8 different possible genotypes among gametes.

Which of the following genotypes would be expected to be least frequent among the gametes of such heterozygotes?

A. EBg
B. EBG
C. eBG
D. ebg
E. All gametes will be equally frequent.

---

20. Recall that the **S** allele of the MC1R gene is responsible for black spotting as modeled in the Simutext module on pig pigmentation. Imagine that you use Mate-O-Matic to cross true breeding heavily spotted males with red females to create an F1 generation.

    If you then cross these F1 animals together, which of the following phenotypes will be most frequent among the resulting F2 generation?

A. lightly spotted
B. heavily spotted
C. red
D. black

---

21. The concept of randomness comes up a lot in Biology, often with reference to situations in which alternative events are equally likely.

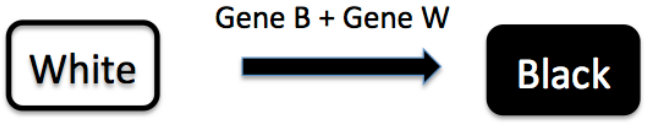
    Which of the following statements describes two alternative events that are equally likely to occur?

    1. Segregation of **H** vs. **h** into any given gamete in a (**Hh**) heterozygote.
    2. Sons with red eyes vs. sons with white eyes from a heterozygous *Drosophila* mother.
    3. Segregation of **HB** vs. **Hb** into any given gamete in a dihybrid (**HhBb**; with the two genes on separate chromosomes).
    4. The appearance of a SNP at a particular location on Chromosome 3 vs. a particular location on Chromosome 6.

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2 , 3 & 4 are correct.

---

22. The diagram below shows the biochemical conversion of a white compound to a black compound. The action of the products of two genes results in epistasis: the dominant allele of Gene B codes for the enzyme that does the conversion. However, this enzyme only works if it is first activated by the product of the dominant allele of Gene W. For both genes, the recessive alleles are not expressed at all.



    Which of the following ratios would be expected among offspring from a dihybrid cross of BbWw x BbWw?

A. 12 Black: 4 White
B. 8 Black: 8 White
C. 9 Black: 7 White
D. 1 Black: 15 White

---

23. In *Drosophila*, the *scalloped* gene contributes to wing shape and neural development. Homozygous ***sc sc*** flies die as embryos. The *paralytic* gene is involved in nerve transmission such that flies lacking a dominant allele become reversibly paralyzed at elevated temperatures. The *scalloped* gene is on Chromosome 1 while the *paralytic* gene is on the X chromosome.

If a dihybrid female (***sc sc*$^+$ *para para*$^+$***)*** is crossed to a homozygous wild type male (***sc*$^+$ *sc*$^+$ *para*$^+$ *Y***), what fraction of the surviving offspring would be paralyzed at high temperature?

A. 1/8
B. 3/4
C. 1/2
D. 1/4

---

24. The dominant allele at the "white" coat colour gene in domestic cats masks the effects of other pigmentation genes. That is, cats with at least one W allele are pure white, regardless of their ability to make pigment. White cats are also very likely to have blue eyes and to be deaf.

Which of the following statements about this dominant allele (**W**) is likely correct?

1. The **W** allele is more common than the **w** allele in wild cat populations.
2. The **W** allele is pleiotropic.
3. The **W** allele codes for a product that inhibits the product coded by the **w** allele.
4. The **W** allele would cause deviation from 9:3:3:1 ratios that are usual among progeny from a dihybrid cross.

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2 , 3 & 4 are correct.

---

25. In Andalusian chickens, feather colour is determined by the **B** locus. Chickens with genotype **BB** have black feathers; chickens with genotype **Bb** have blue-gray feathers; and chickens with genotype **bb** have white feathers.

A flock of 100 chickens has escaped their farm and become wild. After several generations, the population is composed of 4 individuals with black feathers (genotype **BB**), 32 with blue-gray feathers (**Bb**), and 64 with white feathers (**bb**).

Which of the following processes is most likely to be occurring at this locus?

A. disassortative mating
B. heterozygote disadvantage
C. selection favouring the b allele
D. random mating

---

26. Which of the following processes takes populations out of Hardy-Weinberg equilibrium?

1. heterozygous disadvantage
2. inbreeding
3. heterozygote advantage
4. disassortative mating

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2, 3 and 4 are correct.

---

27. Which of the following alleles is most likely to disappear from a population, that is, to reach an allele frequency of zero?

A. A harmful dominant allele.
B. A harmful recessive allele.
C. An allele at a locus subject to heterozygote advantage.
D. An allele at a locus that is not related to fitness.
E. Harmful dominant and harmful recessive alleles are equally likely to disappear from a population.

---

28. Which of the following processes results in evolution?

1. heterozygous disadvantage
2. inbreeding
3. heterozygote advantage
4. disassortative mating

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only.
E. All of 1, 2, 3 & 4 are correct.

---

29. Which of the following situations results in selection maintaining both alleles, A1 and A2, such that neither allele completely replaces the other in a population? (Assume that the population is so large that genetic drift can be ignored.)

1. $w_{A1A1} < w_{A1A2} < w_{A2A2}$
2. $w_{A1A1} < w_{A2A2} < w_{A1A2}$
3. $w_{A1A1} = w_{A2A2} > w_{A1A2}$
4. $w_{A1A1} = w_{A2A2} < w_{A1A2}$

A. 1, 2 & 3 only
B. 1 & 3 only
C. 2 & 4 only
D. 4 only
E. All of 1, 2, 3 & 4 are correct.

---

30. In a population of lizards, tongue shape is controlled by the **T** locus. You capture 100 lizards, and count 49 individuals with deeply-forked tongues (genotype **TT**), 42 with slightly forked tongues (genotype **Tt**) and 9 with unforked tongues (genotype **tt**).

    What can you reasonably conclude about tongue shape and fitness in this population?

A. wTT > wTt > wtt
B. wTT < wTt < wtt
C. wTT = wtt > wTt
D. wTT = wtt < wTt
E. wTT = wTt = wtt

---

31. After the practical skills session, you overhear Farida saying that she rejected the null hypothesis in the fish behaviour experiment designed to determine if there is a difference in predation behavior between the 5 populations of fish species.

    Which of the following statements is correct based on this information?

A. The experiment did not have the proper control population.
B. Her calculated chi-square value was less than the critical value.
C. She should repeat the experiment with only two populations.
D. There was a difference in the behavior among the populations.

---

32. The specifications given below describe a light microscope.

    Ocular lens = 10x
    Objective lens = 100x (oil immersion)
    1 stage division = 10µm
    diameter of the field = 3.5mm

    Which of the following magnifications would be achieved by this microscope?

A. 1X
B. 10X
C. 100X
D. 1000X
