

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. Guppies are small fish that cannot survive if the water temperature becomes too warm. However, certain mutations can increase heat-resistance and thus improve individuals' ability to survive in warm water.

Imagine two populations of guppy, one (#1) living in relatively cool water and the other (#2) living in an area where water temperatures are becoming warmer.

In which population is heat-resistance most likely to increase, and why?

- A. Population #2, because a heat-resistant mutation is more likely to occur in response to a warm environment.
- B. Population #2, because any heat-resistant mutations that do occur will be favoured by selection in a warm environment.
- C. Population #2, because both (a) and (b) contribute to increasing heat-resistance.
- D. In either population, because a heat-resistant mutation is equally likely to occur and equally likely to be selectively favoured in either population.

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2. It is possible to stain chromosomes such that only the kinetochores are visible as bright red spots under the microscope.

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

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

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3. 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

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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 spore cell in G2?

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

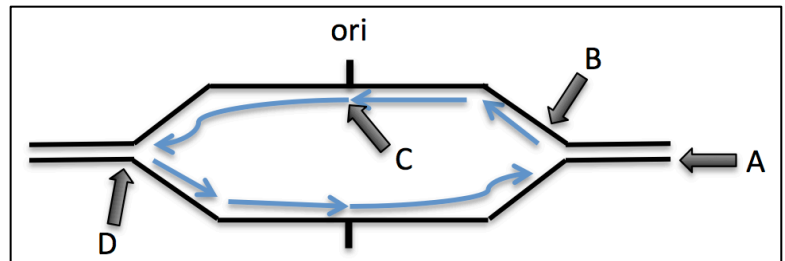
5. As an important enzyme in DNA replication, ligase is strongly expressed during S phase of the cell cycle in insects.

If you detected ligase activity in G_1 rather than S phase, which of the following activities would it likely be involved in?

1. Excision repair of mismatches.
 2. Unequal crossing over.
 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.

6. The sketch at right shows a typical replication bubble near one end of a mouse chromosome.

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. The base indicated by Arrow C, the first DNA base to be added of this leading strand, was added by DNA polymerase III.
3. Arrow A identifies a 3'OH.
4. The strand indicated by Arrow B will be used as template DNA for replication of the entire chromosome.

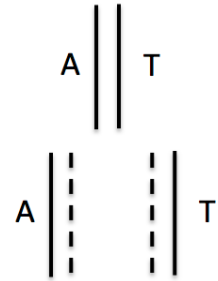
- A. 1, 2 & 3 only
 B. 1 & 3 only
 C. 2 & 4 only
 D. 4 only
 E. All of 1, 2, 3 & 4 are correct.

7. Imagine that you notice in a karyotype that one arm of Chromosome 4 is inverted with respect to that of its homologue.

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.

8. The sketch at right represents a typical AT base pair in DNA being replicated. During the first round of replication, imagine that a hypothetical purine, called shautamine, is incorporated into the growing DNA backbone as the original AT pair is replicated. During the second round of replication, shautamine undergoes a tautomeric shift and therefore attracts the "wrong" base.



Continuing the diagram in this pattern, which of the following SNPs will be present instead of the original AT pair following the third round of replication?

- A. AT
B. GC
C. CG
D. TA

9. Mendel's careful analysis of controlled crosses was able to show the random segregation of the two alternative alleles of the seed colour gene, **Y** and **y**.

During which of the following stages of the life cycle of the pea plants did this random segregation take place?

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

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

Which of the following elements is most likely to be a retrotransposon?

Mobile Element	Enzyme Coded	Repeat Sequences?	Host Genes?	<i>gag</i> 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

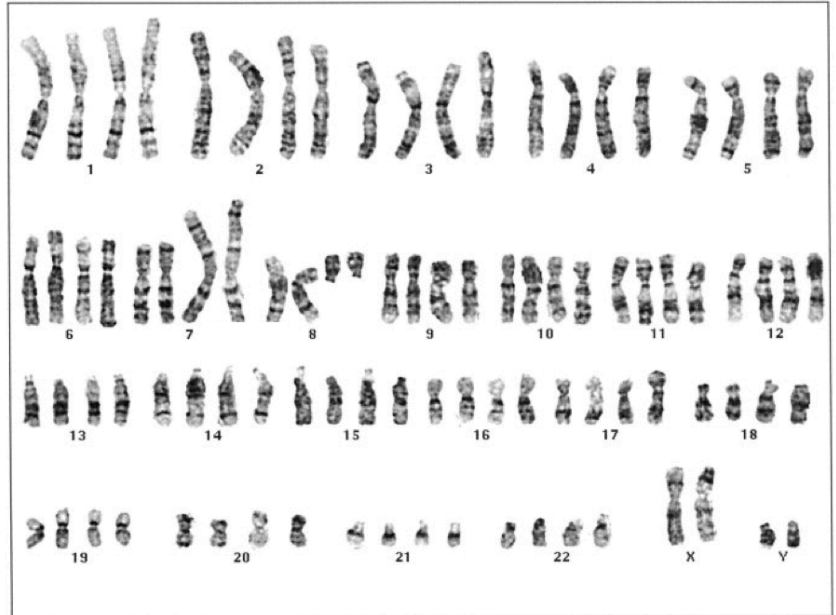
11. Identical twins arise when a single embryo splits into two independent embryos that develop into two independent offspring. Imagine twin male organisms, Thing One and Thing Two, who both carry the same novel SNP in their somatic genomes. However, neither of their parents carries this SNP in their respective somatic genome.

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

- A. meicyte of both parents
B. meicyte of one parent
C. zygote giving rise to Thing One and Thing Two
D. each somatic cell of Thing One and Thing Two



12. Polyploid plants are often larger and more vigorous than diploids. Following this logic, a mad scientist has created a polyploidy "super human" with the karyotype shown at right.



Which of the following statements about this person is likely correct?

1. Cells contain one Barr body.
2. Carries a translocation.
3. Male.
4. Not viable.

- 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.

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 interferes with kinetochore motor protein activity.

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

- A. aneuploidy
- B. indel
- C. SNP
- D. CNV
- E. translocations

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?

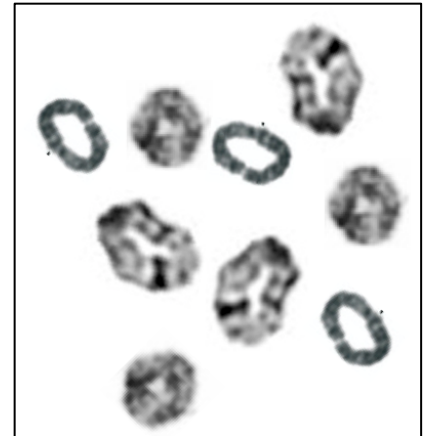
- A. Following initial X inactivation, each descendent cell makes an independent inactivation choice; however, following changes in pigmentation, each descendent cell is the same as the parent cell.
- B. For X inactivation, the two alternatives are initially equally likely to occur; however, in pigmentation 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.

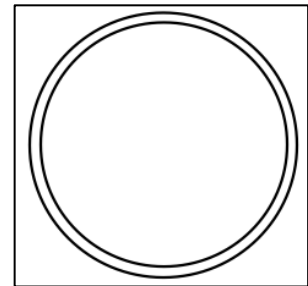
Imagine that you have discovered a new species of very unusual unicellular eukaryote in which the nuclear genome is composed entirely of circular "ring" chromosomes. Subsequent analyses show that the ring chromosomes are simply linear chromosomes with their ends attached; the overall chemistry and replication 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)?

<p>A.</p>	<p>B.</p>	<p>C.</p>	<p>D.</p>
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17. 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 respective mothers are not. Also imagine the fun you can have at parties by shining a bright light on your kids to make them sneeze on demand.

What is the likelihood that all of your four children will be sun sneezers like you?

- A. $(\frac{1}{4})^4$
 B. $\frac{1}{4} \times 4$
 C. $1 - (\frac{3}{4})^4$
 D. $(\frac{3}{4})^4$

18. The diagram at right shows the relative location of the alleles of three genes along the maternal homologue of chromosome 9 in panda cells in G_1 .



Which of the following statements is correct concerning a heterozygote (**Ee Bb Gg**)?

- The organism would make 8 different gamete genotypes.
- The **eBG** gamete would be rare, relative to **EBG**.
- During G_2 , the **b** allele would be on the paternal homologue.
- During meiosis I, this chromosome could align, and then disjoin, in three different combinations.

- 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.

19. 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.

Assuming that the XXX karyotype results from a single error in chromosome partitioning, in which of the following stages of meiosis might the error occur?

- Meiosis I in the mother.
- Meiosis II in the father.
- Meiosis II in the mother.
- Meiosis I in the father.

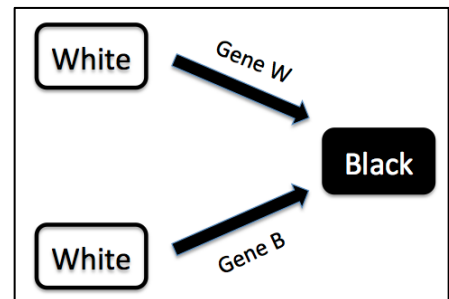
- A. 1, 2 & 3 only
 B. 1 & 3 only
 C. 2 & 4 only
 D. 4 only
 E. All of 1, 2, 3 & 4 are correct.

20. 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.
-

21. The diagram at right shows two parallel biochemical pathways for the conversion of two different white compounds to a black compound. The action of the products of these two genes results in epistasis since the dominant alleles of either Gene B or Gene W will result in black phenotype. 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. 4 Black: 12 White
 B. 8 Black: 8 White
 C. 15 Black: 1 White
 D. 9 Black: 7 White
-

22. 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 to create the F2 generation, which of the following phenotypes will not be expected?

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

23. 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 involving pigmentation.

- 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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24. In a hypothetical population of badgers, claw length is determined by the **C** locus. Badgers with genotype **CC** have long claws; badgers with genotype **Cc** have medium claws; and badgers with genotype **cc** have short claws.

In a colony of 50 badgers, 32 individuals have long claws (genotype **CC**), 16 have medium claws (**Cc**), and 2 have short claws (**cc**).

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

- A. gene flow (the two **cc** individuals have probably immigrated from another colony)
 - B. heterozygote disadvantage
 - C. selection favouring the **b** allele
 - D. random mating
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25. In *Drosophila*, the *Notched* gene contributes to wing shape and neural development. Flies affected by this dominant mutation die as larvae at high temperatures. The *paralytic* gene is involved in nerve transmission such that flies lacking a dominant allele become reversibly paralyzed at elevated temperatures. The *Notched* gene is on Chromosome 3 while the *paralytic* gene is on the X chromosome.

If a dihybrid female (***NN⁺ pp⁺***) is crossed at high temperatures to a homozygous wild type male (***N⁺N⁺ p⁺Y***), which of the following fractions of their offspring would be phenotypically normal (ie. alive and not paralyzed)?

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

26. Which of the following alleles is most likely to become completely fixed in a population, that is, to reach an allele frequency of one?

- A. A beneficial dominant allele
 - B. A beneficial 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. A and B are both equally likely to become completely fixed
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27. Which of the following processes results in adaptive evolution (ie. a population becoming better fit to its environment)?

- 1. genetic drift
- 2. inbreeding avoidance
- 3. assortative mating
- 4. selection favouring a recessive allele

- 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.
-

28. If a population is in Hardy-Weinberg equilibrium at the R locus (alleles R and r), which of the following conclusions can you draw?

- 1. Allele frequencies of R and r will not change.
- 2. Individuals mate randomly with respect to their genotype at the R locus.
- 3. Genotypes RR, Rr, and rr all have equal relative fitness.
- 4. Frequency of R = frequency of r = 0.5.

- 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.
-

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

What can you reasonably conclude about relative fitness of genotypes **TT**, **Tt** and **tt**?

- A. $w_{TT} < w_{Tt} < w_{tt}$
 - B. $w_{TT} = w_{Tt} = w_{tt}$
 - C. $w_{TT} = w_{Tt} < w_{tt}$
 - D. $w_{TT} < w_{Tt} = w_{tt}$
-

30. In a large population, the starting frequencies of alleles **A1** and **A2** are 0.8 and 0.2, respectively.

Which of the following situations will result in allele **A1** going to fixation (i.e., completely replacing allele **A2**)?

Assume that the population is so large that you can ignore the effects of genetic drift.

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

- 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.
-

31. The specifications given below describe a light microscope.

Ocular lens = 10x

Objective lens = 10x

1 stage division = 10 μ m

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
-

32. After the practical skills session, you overhear Farida saying that she accepted 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 more than the critical value.
 - C. She should repeat the experiment with only two populations.
 - D. There was no difference in the behavior among the populations.
-