Circle the best single letter choice for each of the following questions before transferring your answers to your computer sheet. Note: *Questions may have 3, 4 or 5 choices.*

1. All of the following are found inside mitochondria. Which could readily diffuse across the membranes and "escape" into the cytoplasm?

A. H^+
B. $C0_2$
C. glucose
D. ATP synthase

---

2. Dr. Maxwell in the Biology department studies a single-celled alga isolated from an Antarctic lake. This organism grows well at very low temperature but dies at room temperature.

   Imagine that you work in this lab and you grow this organism at low temperature and also at a higher temperature. You then compare the fatty acid composition of the membrane lipids for each culture.

   Which characteristics of the lipids would you expect to be **higher in the culture grown at low temperature**?

A. Phosphate concentration
B. Electronegativity
C. Double bonding
D. Polarity

---

3. Which of the following do mitochondria and chloroplasts have in common?

   1. prokaryotic origin
   2. contain ribosomes
   3. contain DNA
   4. present in plant cells

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

---

4. If a mitochondrion "died" inside a cell, it would be broken down by enzymes. Where would such enzymes likely be located?

A. In the cytoplasm
B. In a lysosome
C. In a secretory vesicle
D. In the smooth endoplasmic reticulum

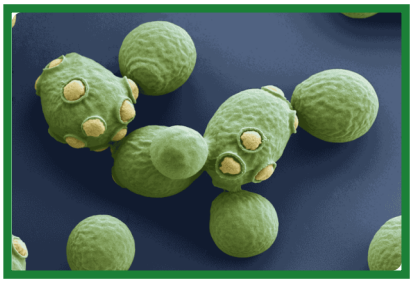
---

5. If you observed hundreds of cells in plant meristem tissue, which type or phase of cell division would you find most of them engaged in?

A. mitosis
B. interphase
C. G_0
D. meiosis

---

6. This image of budding yeast was used in class to illustrate cell division in unicellular organisms. The original image was false coloured to show green cells and yellow "bud scars".



What sort of technology generates such images?

A. Immunofluorescence light microscopy
B. Standard light microscopy
C. Transmission electron microscopy
D. Scanning electron microscopy

---

7. A mule is the hybrid offspring of a male donkey (2n = 62) and a female horse (2n = 64).

If you stained a mitotic metaphase mule cell with a dye that bound to chromatin, what would you expect to see in a light microscope?

A. A diffuse tangle threads within the nucleus.
B. 126 replicated chromosomes, arranged in pairs.
C. 126 chromatids.
D. A network of fibres attached to kinetochores

---

8. The drug colchicine binds to tubulin, thus preventing it from polymerizing to form part of the cytoskeleton.

Which aspect of dividing white blood cells would you expect to be disrupted by colchicine?

A. Cell shape and mobility
B. Segregation of chromosomes
C. Cytokinesis
D. Distribution of organelles to daughter cells

---

9. *Cannabis* is a diploid flowering plant with 2n = 20. Imagine one of your friends is looking down a microscope at meiotic cells in the stamens.

How will she identify the metaphase II cells?

A. They will have 10 chromosomes, all different, lined up at the center of the cell.
B. They will have 5 pairs of chromosomes; all chromatids paired, at the center of the cell.
C. They will have 5 pairs of chromosomes, all chromosomes lined up individually at the center of the cell.
D. They will have 20 unreplicated chromosomes, all lined up individually at the center of the cell.

---

10. Recall that, in budding yeast, cycling cells do not divide in half to produce two daughter cells of equal size. Although two cells are created, one is quite small (the "bud") and the other is quite large (the "mother").

    Recall also that adenine is one of the nitrogenous bases used by cells to make new DNA

    Assume that you have a culture of budding yeast that are all starting in G1 and you provide them with radioactive adenine for **one full cell cycle.**

    Where will the radioactive adenine end up?

A. Both the "mother" and "bud" cell would have radioactive adenine in their DNA.
B. Only the bud would have radioactive adenine in its DNA.
C. Radioactive adenine would only be found in the nucleus of any given cell.
D. Radioactive adenine would only be found in one of the two sister chromatids of a given replicated chromosome.

---

11. In researching questions for this test, Tom read the following unfortunate passage about dividing lily cells on a website called *Suite 101*.

    "The cell cycle has a DNA synthesis phase (S phase) which doubles the normal full number of chromosomes from diploid (2n) to tetraploid (4n). This is followed by a G2 cell phase that biochemically prepares the cell for the mitotic or M phase, which includes cytokinesis."

    In what way is the author of this passage mistaken (whacked)?

A. DNA synthesis does not occur in S phase.
B. S phase does not increase ploidy from 2n to 4n.
C. G2 does not follow S phase.
D. Cytokinesis is not part of mitotic cell division.

---

12. The goldenrod gall was dissected in class to reveal a white insect larva. This larva grew from a fertilized egg (zygote) into a multi-cellular organism through repeated cell divisions designed to ensure the "inheritance of sameness" in all cells.

    Which of the following mechanisms likely contributed to the larval cells all having the same DNA?

A. Very precise cutting and pasting of DNA backbones during recombination
B. Replicating the same locus at the same time in homologous chromosomes
C. The S phase "checkpoint" ensuring that all chromatids attach to spindle microtubules before replication
D. Semi-conservative replication that uses an "old" DNA strand to specify the "new" strand by complementary base pairing

---

13. You will likely recall that DNA replication in both eukaryotes and prokaryotes is bi-directional, semi-conservative and semi-discontinuous.

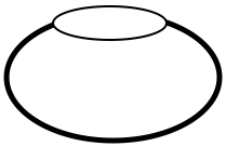
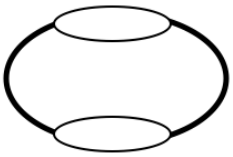
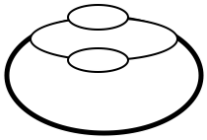
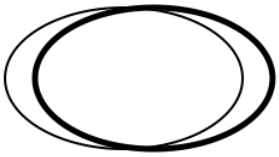
    What does "bi-directional" mean in the case of DNA replication?

A. Once initiated at an "origin", a given replication fork moves out along a chromosome; another one moves out in the opposite direction.
B. Once initiated at an "origin", a given replication fork moves along both strands of DNA, reading one strand in the 3' to 5' direction, reading the other strand in the 5' to 3' direction.
C. Once initiated at an "origin", a given replication fork replicates one strand of DNA to the end of the chromosome and then returns to replicate the other strand in the other direction.
D. Once initiated at an "origin", a given replication fork replicates all the way around a "bubble", starting in one direction, ending in the other.

---

14. Under optimum conditions, *E. coli* cells can double in number in about 20 minutes even though it takes longer than that to replicate their chromosomes. This paradox is solved by noticing that the single replication origin on the *E. coli* chromosome initiates a new round of replication before the previous round is complete.

    Which of the following diagrams summarizes this process? (Note that the thick line represents the original chromosome. The thin lines represent newly synthesized DNA.)

A. 
B. 
C. 
D. 

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15. Consider a penguin gamete. The amount of DNA in this gamete is defined as "1C". The number of chromosomes in this gamete is defined as "1n". That is, the value of C and the value of n are equal in penguin gametes.

    During which stage of penguin cell division would the value of C and the value of n be **equal**?

A. During G1 of a skin cell; both n and C equal 2
B. During G2 of a liver cell; both n and C equal 4
C. During metaphase of Meiosis II; both n and C equal 1
D. During metaphase of mitosis; both n and C equal 2

---

16. Recall that generalized transduction involves transferring DNA (inside the head of a lytic virus) from a bacterial donor to a recipient.

    Imagine that you discover that two particular alleles (bio^+ and gal^+) are very frequently transferred together by transduction. What could you conclude?

A. These two alleles are very close together on host bacterial chromosome.
B. These two alleles are the same length (of bacterial chromosome sequence).
C. These two alleles are part of the viral chromosome.
D. These two alleles are each carried inside two different viruses.

---

17. Which of the following events turns F^+ cells into Hfr (high frequency recombination) cells?

A. Replication of the F Factor by "rolling circle" replication.
B. Transposition of the F Factor to a new plasmid.
C. Transfer of the F Factor to a recipient cell.
D. Integration of the F Factor into the host chromosome.

---

18. Imagine that you mix two different auxotophic strains of bacteria together and plate them on minimal medium in Petri plates. Some wild type colonies grow.

However, if you add an enzyme that degrades DNA to the mix before plating, no colonies grow.

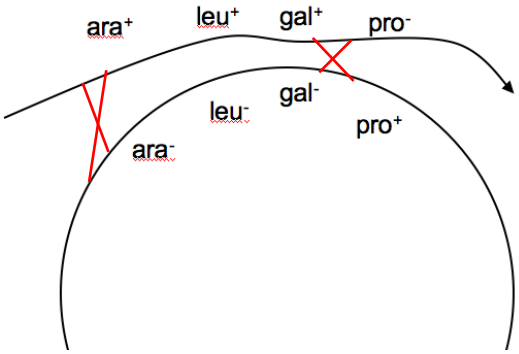
Which type of genetic exchange is most likely happening in this case?

A. Conjugation
B. Transduction
C. Transformation
D. Transposition

---

19. This figure represents linear bacterial donor DNA in close proximity to a circular recipient chromosome.

How many recombination events would be required to create a totally wild type recipient (**ara^+ leu^+ gal^+ pro^+**)?



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

---

20. Which of the following events turns F^- cells into F^+ cells?

A. Replication of the F Factor by "rolling circle" replication
B. Transposition of the F Factor to a new plasmid
C. Transfer of the F Factor to a recipient cell
D. Integration of the F Factor into the host chromosome

---

21. Which of the following would be true of the gametes made from one particular gametophyte?

A. Some would be male; some would be female.
B. They would have the same genes as one another, but different alleles.
C. They would be identical to one another.
D. They would have half the number of chromosomes relative to the gametophyte.

---

22. Imagine that you go home for a visit and help your younger brother with his high school Biology homework. You notice that he has written down in his notes that "Plants are haploid and make gametes by mitosis; animals are diploid and make gametes by meiosis."

    What should your response be?

A. Yes, plants make gametes by mitosis and animals make gametes by meiosis but both plants and animals have a haploid and a diploid stage of their life cycle.
B. Brother, you are whacked! Both plants and animals make gametes by meiosis. The difference is that plant gametes divide by mitosis but animal gametes do not.
C. People often get mixed up on the difference between plant and animal life cycles. Yes, your notes are correct.

---

23. When one observes cells going through meiosis I, it is clear that the pairing and segregation of any given pair of homologues is not affected by that of any other pair of homologues.

    What genetic phenomenon does this chromosome behaviour give rise to?

A. A map distance greater than 50 cM separating genes on the two different homologues
B. Random segregation of the alleles of a given gene
C. Independent assortment of the alleles of unlinked genes
D. Epistatic interactions between the genes on the two homologues

---

24. Some "seedless" watermelon plants are triploid (3n).

    Which of the following characteristics would you expect such plants to show?

    1. Progeny from a cross of a tetraploid strain (4n) with a diploid strain (2n).
    2. Mitosis would be normal.
    3. Meiosis would show abnormal pairing of homologues.
    4. Karyotype would show three copies of each chromosome.

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

---

25. The cutting and pasting of DNA backbones giving rise to recombinant chromatids is a fundamental aspect of meiosis and the sexual life cycles of eukaryotes.

    When does this process occur?

A. During integration of transposons into chromosomes
B. During S phase of the cell cycle
C. During metaphase of Meiosis II
D. During prophase of Meiosis I

---

26. In humans, colour blindness is a recessive trait carried on the X chromosome. Imagine that a couple, Barak and Oprah, have a colour-blind daughter with the unusual karyotype of 45, X. That is, she has only one X chromosome instead of the usual two.

Although Barak and Oprah both have normal colour vision and normal karyotypes, Oprah's father was colour-blind.

Where could an error in meiosis have occurred that would have given rise to this colour-blind daughter with only one X chromosome?

1. Non-disjunction in Barak at Meiosis I
2. Non-disjunction in Oprah at Meiosis I
3. Mis-division in Barak at Meiosis II
4. Mis-division in Oprah at Meiosis II

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

---

27. Recall that a "geep" is a chimeric organism that is partly goat and partly sheep.

How could a geep arise in nature?

A. It could not. Such chimeras require technical intervention by humans.
B. Geeps could arise from the mating of a male goat and a female sheep; you would just need two sheep eggs to be fertilized.
C. Geeps could arise when a goat embryo fused with a sheep embryo in the uterus of a female sheep.

---

28. If two human tetragametic chimeras met in an on-line chimera chat room and eventually met and conceived a child, would this child likely also be a chimera? Why (not)?

A. NO; chimeras are infertile and would not conceive a child in the first place.
B. YES; the zygote from the woman, and the one from the man, would give rise to morulas that would fuse to give a chimeric child.
C. NO; chimeras make normal gametes that fertilize to give normal offspring.
D. YES; the child would be a "double chimera" having traits from both of the cell lines in each of its parents.

---

29. Older mothers have a higher risk of chromosomal anomalies among their children. Why might this be?

A. Older mothers have time for many more cell divisions before meiosis occurs. Perhaps this provides more opportunity for mistakes.
B. Older mothers are exposed to environmental hazards for a longer time. Perhaps this damages DNA.
C. Older mothers tend to mate with older fathers. Perhaps such fathers have high proportions of aneuploid sperm.
D. Older mothers are releasing eggs that started meiosis before the women were born. Perhaps the cytoskeleton has broken down.

---

30. Imagine that you run a fertility clinic and see a couple, Bart and Angelina, who have a young daughter they call "Lady Gaga" since she sings and covers herself with food.

    The sad news is that Lady Gaga has leukaemia and needs a tissue transplant from a compatible donor - neither of her parents is a match. Therefore, Bart and Angelina want you to use their gametes to create several embryos. Then the couple wants to become pregnant only with an embryo that is both female and a tissue match for Lady Gaga.

    Assuming that Bart has HLA haplotypes 3 and 17; and Angelina has HLA haplotypes 3 and 29; what fraction of their total embryos would likely be female **and** a tissue match for Lady Gaga? (You don't need to know Lady Gaga's genotype to answer this question.)

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

---

31. In cats, the Manx allele (**M**) causes a short tail while the recessive allele (**m**) confers a long tail. Cats with the homozygous dominant genotype (**MM**) die as embryos before birth.

    If two short tail cats mate, what is the probability that each **surviving** kitten will have a long tail?

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

---

32. Imagine that a plant was grown in a greenhouse from a seed collected in the wild. The plant flowered, showing orange petals with black spots. The plant was self-pollinated and gave rise to the following progeny:

    88 orange with spots; 34 yellow with spots; 32 solid orange (no spots); 8 solid yellow (no spots).

    What can you conclude regarding the genetics of flower colour in this plant?

    1. There are two genes involved
    2. This was a dihybrid cross
    3. All dominant alleles are completely dominant
    4. Two genes affecting flower colour are linked

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

---

33. Tay-Sachs disease causes nerve cells to malfunction and is usually lethal by age 4. Two healthy parents know from genetic testing that they are both carriers of the recessive allele responsible for this disease on chromosome 15.

    If this couple conceives two children, what is the likelihood that they will both be healthy **and** male?

A. $(3/4 \times 1/2)^2$
B. $(3/4 \times 1/2) + (3/4 \times 1/2)$
C. $1 - (3/4 \times 1/2)^2$
D. $2 \times (3/4)^2$

---

34. Squash is an abundant vegetable in the Fall in Ontario. Squashes come in three different colours: white, yellow and green. Two genes are involved, each with one dominant and one recessive allele. The dominant allele of the Green gene (**G**) codes for an enzyme that converts yellow pigment to green pigment. However, the dominant allele of the White gene (**W**) codes for an enzyme that degrades all pigment – resulting in white fruit. The recessive alleles code for a non-functional enzyme in both cases.

    If yellow was your favourite colour of squash, what proportion could you expect among the offspring from a dihybrid cross? (**GgWw x GgWw**)?

A. 1/16
B. 3/16
C. 6/16
D. 7/16
E. 9/16

---

35. A geneticist once discovered an autosomal mutation in *Drosophila* that caused affected females to lay elongated eggs. This new egg shape reminded the geneticist of her favourite vegetable so she named the gene "zucchini" (true story). Female flies that carry both the mutant and wild type alleles of the zucchini gene lay eggs that are of normal shape. (Males, of course, carry the alleles of the zucchini gene but do not express them.)

    What would be the proper notation for the **dominant** allele in this system?

A. zuc
B. zuc^+
C. Zuc
D. Zuc^+

---

36. Imagine you are a genetic counsellor, routinely advising couples about the risk of genetic disease in their families. You are working with an engaged man, Yousef, and woman, Priti, both of whom are phenotypically normal. However, one of Yousef's brothers died of muscular dystrophy, an X-linked recessive disorder that is lethal before reproductive age. There is no incidence of this disorder in Priti's family.

    Priti has asked about the family she wants to have with Yousef. She wonders if it would be their sons, or their daughters, that would be at higher risk of being affected by this disease. What should be your response?

A. "Sons must express the trait if they inherit the recessive allele; in your future family, the risk is higher for your sons than your daughters."
B. "This is a recessive trait; in your future family, there is no risk of either sons or daughters being affected."
C. "Fathers give X chromosomes to daughters, not to sons; in your future family, Yousef is the carrier so the risk is higher for your daughters than your sons."
D. " In a population, sex-linked disorders more commonly affect males than females; in your future family, the risk is higher for your sons than your daughters."

---

37. For the organism of genotype **AABbCcDDEe**, (homozygous for 2 genes, heterozygous for 3 genes), how many different types of gametes will be made if the 5 genes are all on different chromosomes?

A. 2
B. 3
C. 4
D. 8
E. 9

---

38. For the organism of genotype **AABbCcDDEe**, (homozygous for 2 genes, heterozygous for 3 genes), how many different types of gametes will be made if the **C** gene and the **E** gene are linked on the same chromosome while the remaining genes are all on different chromosomes?

A. 2
B. 3
C. 4
D. 8
E. 9

---

39. In recombination frequency mapping, a parent that is dihybrid for the genes in question is crossed with a homozygous recessive parent and the resulting offspring are classified and counted.

Which of the following is always true of the "non-recombinant" offspring?

A. They have the same phenotype as one parent or the other.
B. They have the same genotype as one parent or the other.
C. They inherit a chromosome with the same cis vs. trans arrangement as the dihybrid parent.
D. They are relatively rare.

---

40. Consider the following cross.

In *Drosophila* the mutation **vg** causes small wings. The mutation **bl** causes black body. The wild type alleles for these mutations, **vg**$^+$ and **bl**$^+$, are both dominant giving long wings and grey bodies respectively.

Imagine that a dihybrid wild type female fly (**vg vg**$^+$ **bl bl**$^+$) was test-crossed with a small black male (**vg vg bl bl**). The following progeny resulted:

Number	Phenotype
415	black body, long
92	grey body, long
88	black body, short
405	grey body, short

Which of the following conclusions could you draw from these data?

1. All wild-type progeny are homozygous.
2. The dihybrid parent was linked in cis.
3. The test cross parent makes two types of gametes, equally frequent.
4. These two genes are separated by 18 cM.

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

---

41. The hypothesis that "life exists on other planets" is

A. verifiable but not falsifiable.
B. falsifiable but not verifiable.
C. neither verifiable nor falsifiable.
D. both falsifiable and verifiable.

---

42. Fitness in an evolutionary sense is

A. a measure of muscle tone and cardiovascular stamina.
B. a measure of the population's adaptations to the local environment.
C. a measure of the offspring contributed by an individual.
D. what determines whether an individual will survive and compete successfully.

---

43. Lamarck published his ideas about evolution some 50 years before Darwin and Wallace. How did Lamarck's ideas differ from those of Darwin and Wallace?

Lamarck proposed _____, whereas Darwin and Wallace proposed _____.

A. Species become increasingly simple with time; species become increasingly complex with time
B. Inheritance of acquired characteristics; descent with modification
C. Species are fixed and unchanging; all species are derived from a common ancestor
D. Species become increasing perfect over time; species gradually decline from a perfect beginning

---

44. Which level of biological organization evolves by natural selection?

A. alleles
B. genotypes
C. phenotypes
D. individual
E. populations

---

45. Which of the following ideas would Darwin **NOT** have agreed with?

A. Individuals are potentially capable of producing many more offspring than can survive.
B. The Earth is old enough for sea sediments to be raised into mountains.
C. Organisms around the world are related by descent from a common ancestor.
D. Organisms become increasingly complex as they become better adapted to their environments.
E. Artificial selection by breeders of domestic animals can lead to changes in populations over time.

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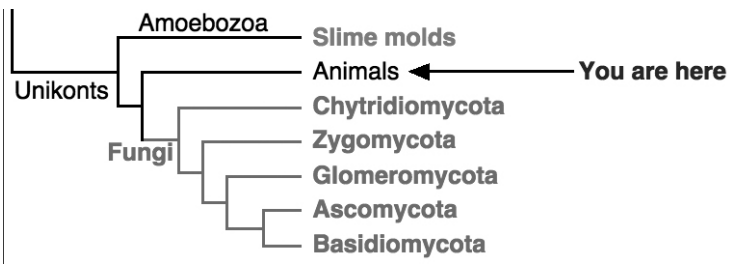
46. The illustration here shows that



A. Animals evolved from fungi.
B. Fungi evolved from animals.
C. Fungi and animals are closely related.
D. Slime molds evolved from fungi and animals.

---

47. Why would human height have **greater** heritability in Europe of 2010 than in 1410?

A. The environment of Europe in 2010 is much more affected by human activity than in 1410.
B. Europeans of all heights have a better chance of survival in 2010 than 1410.
C. Europeans have a better diet in 2010 than in 1410.
D. Tall people were selected against in 1410 because of the short doorways in castles.
E. B and C are both correct.

---

48. The Medium Ground Finch (*Geospiza fortis*) is one of fifteen species of "Darwin's Finches" that live in the Galapagos Islands. In 1839, Darwin wrote about these: "*Seeing this gradation and diversity of structure in one small, intimately related group of birds, one might really fancy that from an original paucity of birds in this archipelago, one species had been taken and modified for different ends.*"

In modern scientific language, what process was Darwin referring to?

A. Natural selection
B. Artificial selection
C. Convergent evolution
D. Adaptive radiation

---

49. Which of the following is the correct expression of heritability?

A. V_P / V_G
B. VG /(VG + VE)
C. $V_P = V_G + V_E$
D. $H' = - \sum p_i * \ln p_i$

---

50. Which of the following represents a case of microevolution?

A. Rapid development of penicillin-resistant bacteria following widespread use of penicillin
B. Evolution of Darwin's finches
C. Evolution of birds from dinosaurs
D. Evolution of really small organisms
