Answers are indicated in Red.
Explanations for the Answers are given in Red as well.

1. Which of the following is **not** found in or on a prokaryotic cell?

A. DNA.
B. ribosomes.
C. pili.
D. lysosomes.
E. nucleoid.

Refer to Chapter 2 and compare eukaryotic and prokaryotic cell structure (Figs 2.15 and 2.18).

---

2. Which of the following is **not** part of the endomembrane system?

A. mitochondria
B. Golgi apparatus
C. rough endoplasmic reticulum
D. lysosomes
E. tonoplast

Refer to Chapter 2 and compare eukaryotic and prokaryotic cell structure (Section 2.5a and 2.5b)

---

3. An animal secretory cell and a photosynthetic leaf cell are similar in all of the following ways **except**

A. They both have a Golgi apparatus.
B. They both have mitochondria.
C. They both have a plasma membrane.
D. They both have a nucleolus.
E. They both have chloroplasts.

Both of these cells have A, B, C, and D. Animal cells do not have chloroplasts.

---

4. Which organelle is involved in the energy production of a prokaryotic cell?

A. chloroplast
B. mitochondrion
C. nucleus
D. cilia
E. The entire cell is involved in energy production.

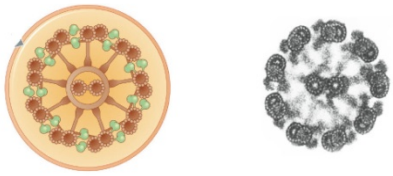
---

5. Biologists can isolate and purify ribosomes from mammalian cells by the use of the

A. transmission electron microscope.
B. scanning electron microscope.
C. ultracentrifuge.
D. light microscope.
E. Golgi apparatus.

In order to isolate cell components Biologists would disrupt (break open) cells and then spin the components, the heaviest pelleting at lower speeds – using an ultracentrifuge.

6.The following diagram and electron micrograph show



A. the cross section through a flagella.
B. a nuclear pore.
C. the cross section through a mitochondria.
D. sister chromatids in crossover.
E. the cross section of a bacterial cell.

Refer to text book Figure 2.25.

---

7. The centromere is a region in which

A. chromatids are attached to one another.
B. metaphase chromosomes become aligned.
C. chromosomes are grouped during telophase.
D. the nucleus is located prior to mitosis.
E. new spindle microtubules form.

Refer to text book page 184.

---

8. Cytokinesis usually, but not always, follows mitosis. If a cell completed mitosis but not cytokinesis, this would result in a cell with

A. a single large nucleus.
B. a high concentration of actin and tubulin.
C. one abnormally large nucleus and one abnormally small nucleus.
D. two nuclei.
E. two nuclei but with half the amount of DNA.

Refer to Fig. 9.6

---

9. Replication of DNA occurs during

A. S phase.
B. G_1 phase.
C. G_0 phase.
D. prophase.
E. cytokinesis.
Refer to Fig 9.4

---

10. A group of cells is assayed for DNA content immediately following mitosis and is found to have an average of 8 picograms [10^{-12} of a gram] of DNA per nucleus. Those cells would have _____ pictograms at the end of the S phase and ____ pictograms at the end of G_2.

A. 8; 8
B. 8; 16
C. 16; 8
D. 16; 16
E. 8; 4
So in G_1 there is 8 picograms of DNA, after S there will be double or 16 and the amount remains the same in G_2.

---

11. A nucleus has 11 chromosomes. What is the only valid conclusion from this observation?

A. The cell is diploid.
B. The cell is haploid.
C. The cell is in G_0.
D. Each chromosome has only one chromatid.
E. The cell is able to undergo meiosis.
All we can deduce from this is that this is a haploid cell.

---

12 During which phase(s) of mitosis do we find chromosomes composed of two chromatids?

A. from interphase through anaphase
B. from G_1 of interphase through metaphase
C. from metaphase through telophase
D. from anaphase through telophase
E. from G_2 of interphase through metaphase
From the end of S phase to metaphase chromosomes are actually composed of two sister chromatids.

---

13. In meiosis at what stage are tetrads of chromosomes aligned at the centre of the cell and independent assortment soon follows.

A. Prophase I
B. Metaphase I
C. Interphase
D. Metaphase II
E. Telophase II
So since we are asked about tetrads this must refer to Metaphase I. Refer to Fig. 10.11

---

14. In meiosis synapsis of homologous chromosome pairs occurs and crossing over may follow.

A. Prophase I
B. Metaphase I
C. Interphase
D. Prophase II
E. Metaphase II
Synapsis occurs in Propahse I and crossing over may occur (usually does , however it does not have to)

---

15. In meiosis centromeres of sister chromatids uncouple and chromatids separate at which phase?

A. Metaphase I
B. Anaphase I
C. Prophase II
D. Anaphase II
E. Metaphse II
Again refer to Fig. 10.11

---

16. A cross between homozygous purple-flowered and homozygous white-flowered pea plants results in offspring with purple flowers. This demonstrates

A. the blending model of genetics.
B. true-breeding.
C. dominance.
D. a dihybrid cross.
E. linkage which was unknown to Mendel.
One of Medel's classic experiments, which ever trait shows is dominant to the other.

---

17. Alleles

A. are the result of hybridization.
B. are present only in the F_1 generation.
C. occur in a 3 : 1 ratio.
D. are alternate forms of a gene.
E. don't affect the phenotype until the F_2 generation.

---

18. In a cross **AaBbCc** x **AaBbCc**, what is the probability of producing the genotype **AABBCC**?

A. 1/4
B. 1/8
C. 1/16
D. 1/32
E. 1/64

P(AA) ½ x ½ xP(BB) ½ x ½ x P(CC) ½ x ½ = ¼ x ¼ x ¼ = 1/64

---

19. In a cell in which 2n=6, the independent assortment of chromosomes during meiosis can by itself give rise to ___ genetically different gametes.

A. 1
B. 4
C. 5
D. 8
E. 12

Remember we said in lecture that we can use the formulae 2^n, where n is the haploid number. In this case $2^3 = 8$.

Use the following information to answer Questions **20, 21** and **22**.

Albinism (lack of skin pigmentation) is caused by a recessive autosomal allele. A man and woman, both normally pigmented, have an albino child together.

---

20. What is the probability that their next child will be phenotypically normal?

A. 0 %
B. 25%
C. 50 %
D. 75 %
E. 100 %

Since they are normal but have an albino child, which must be homozygous recessive, they must be heterozygous for the allele. So from a standard cross of say Aa x Aa there is a 75% chance of getting AA or Aa – or phenotypically normal offspring.

---

21. For this trait, what is the genotype of the albino child?

A. homozygous dominant
B. homozygous recessive
C. heterozygous
D. hemizygous
E. Unknown because not enough information is provided

Refer to explanation above.

---

22. The couple decides to have a second child. What is the probability that this child will be albino?

A. 0
B. 1/4
C. 1/2
D. 3/4
E. 1

It must be ¼ to get an aa child.

---

23. A 9:3:3:1 phenotypic ratio is characteristic of

A. a monohybrid cross.
B. a dihybrid cross.
C. a trihybrid cross.
D. linked genes.
E. epistasis.

Refer to Fig. 11.9

---

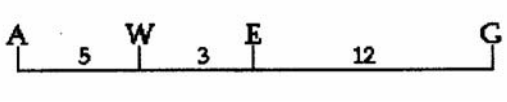
24. Which of the following is an example of polygenic inheritance?

A. pink flowers in snapdragons.
B. the ABO blood groups in humans.
C. sex linkage in fruit flies.
D. white and purple colour in pea plant flowers.
E. height in humans.

Text book section 11.2e

---

25. The following is a map of four genes on a chromosome. Between which two genes would you expect to find the highest frequency of recombination?



A. A and W
B. W and E
C. E and G
D. A and E
E. A and G

On this map A and G are the farthest apart and so we would expect the highest frequency of recombination between them.

---

26. New combinations of linked genes are due to

A. nondisjunction.
B. crossing over.
C. independent assortment.
D. mixing of sperm and egg.
E. mutations.

The only way to get new combinations of linked genes is by crossing over. Text Book Chapter 12

---

27. **AaBbccDdEe** x **AABbCcDdee**
From this cross, what is the probability of obtaining the genotype **AabbCcDDEe** in the progeny?

A. 1/16
B. 1/32
C. 1/64
D. 1/128
E. 1/256

P(Aa) ½ x P(bb) ¼ x P(Cc) ½ x P(1/4) x P(Ee) ½ = 1/128

---

28. A recessive allele on the X chromosome is responsible for red-green colour blindness in humans. A woman with normal vision whose father is colour-blind marries a colour-blind male. What is the probability that couple's son will be colour-blind?

A. 0
B. 1/4
C. 1/2
D. 3/4
E. 1

$? \text{ ---------} X^aY$

$\downarrow$

$X^AX^a \text{ ---------} X^aY$

Worman with normal vision colour blind male

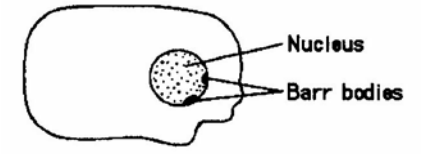
$\downarrow$

X^aY

For son to be colouor biind must inherit Xa from mother of which there is a 0% chance.

---

29. The figure below represents the stained nucleus from a cheek epithelial cell of an individual whose genotype would probably be

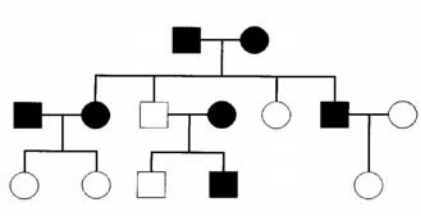


A. XX
B. XY
C. XXY
D. XXX
E. XXY

Barr bodies are inactive X chromosomes, anyone having more than one X with have all the rest inactivated and they will appear as Barr bodies.

---

30. Examine the pedigree in the figure below, where individuals that have the genetic condition being tested are marked with filled squares or circles. Which of the following inheritance patterns is **most likely** correct for this condition?



A. autosomal dominant
B. X-linked recessive
C. X-linked dominant
D. mitochondrial
E. autosomal recessive

Ok first the trait appears equally in males and females so it is not sex linked. The trait shows up in every generation and so is probably dominant.

---

31. Individuals with extra or missing copies of some of their chromosomes are called

A. polyploids.
B. haploids.
C. aneuploids.
D. triploids.
E. diploids.

Refer to text book Fig. 12.12

---

32. One possible result of chromosomal breakage is for a fragment to join a nonhomologous chromosome. This is called

A. a deletion.
B. a disjunction.
C. an inversion.
D. a translocation.
E. a duplication.

Refer to text book. Fig. 12.11

---

33. "Some dogs have three legs". This statement is:

A. verifiable and falsifiable.
B. verifiable but not falsifiable.
C. falsifiable but not verifiable.
D. neither verifiable nor falsifiable.
E. scientific, according to Karl Popper's criterion.

What evidence would you need to verify this statement? Find ONE dog with three legs. This is definitely possible, and therefore the statement is verifiable.
What evidence would you need to falsify this statement? You would have to prove that NO dogs have three legs. In which case, you would need to find all dogs--this is not possible. Therefore the statement is not falsifiable.

---

34. Which of the following pairs is **mismatched**?

A. Le Comte du Buffon – hypothesized that the apparently non-functional traits which some organisms have were once functional in an ancestral species.
B. Aristotle – suggested than all matter could be ranked in a hierarchy of increasing perfection.
C. Charles Darwin – argued that organisms have an innate tendency that directs their evolution towards perfect adaptation to their environment.
D. Jean-Baptiste Lamarck – argued that species evolved in response to their environment.
E. All of A, B, C and D are **correctly** matched.

D is NOT mismatched. Lamarck did think that species evolved in response to their environment. The difference between Lamarck and Darwin is the mechanism by which species evolved (use/disuse with acquired traits versus natural selection).
C is mismatched; in no way did Darwin think that organisms had a perfecting principle; this was the concept of orthogenesis which was a characteristic of Lamarckian evolution.

35. Which of the following statements distinguishes between Darwin's and Lamarck's theories of evolution?

A. Darwin's theory assumed inheritance of favourable traits; Lamarck's theory did not.
B. Darwin's theory predicted adaptation to local environments; Lamarck's theory did not.
C. Darwin's theory assumed that species evolve through differential reproductive success; Lamarck's did not.
D. Darwin's theory incorporated particulate inheritance; Lamarck's theory did not.
E. All of the above statements distinguish between Darwin's and Lamarck's theories.

A. Both Darwin and Lamarck assumed inheritance of favourable traits; however, the mechanism for inheritance differed.
B. both Darwin and Lamarck predicted that populations evolved local adaptation; again, it is just the mechanism by which this occurs is what differs between their theories of evolution.
D. Darwin didn't know about particulate inheritance; this was Mendel's contribution.

36. A population of cats has individuals varying in fur colour; there are white cats (**bb**), black cats (**BB**), and grey cats (**Bb**). White cats typically have a smaller litter of kittens compared to the other coloured cats. If black cats have, on average, 8 kittens, while grey cats have 2 kittens on average, what is the relative fitness of white cats?

A. 1.0
B. 0.6
C. 0.30
D. 0.25
E. 0.125

The key to this question is the statement: "white cats typically have a smaller litter of kittens compared to the other coloured cats". This means they have the lowest absolute fitness of the other genotypes/phenotypes. You can calculate the relative fitness of black cats (8/8 = 1.0) and grey cats (2/8 = 0.25). Since white cats have the lowest absolute fitness, they must have the lowest relative fitness, lower than 0.25. The answer, thus, is 0.125.

37. Which of the following statements is/are example(s) of trade-offs?

1. A turtle laying its eggs in a swamp where eggs will not be at risk of drying out instead of on a beach where eggs are available to predators.
2. During the summer when food availability is high, a hungry squirrel at risk of starvation caches (hides) nuts in order to survive the winter despite the probability of the nuts rotting or being lost.
3. A larger leaf increases the rate at which photosynthesis can occur (increasing the energy available to the plant), while also increasing the rate of water loss.

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

A trade-off necessarily requires that both choosing a particular option comes at a cost. In statement 1, there are only benefits to laying eggs in a swamp (reduced desiccation) while there are only negative impacts of laying eggs on the beach (desiccation AND predation).

38. Which statement best defines evolution?

A. A predictable change from simple to complex organisms
B. Difference between individuals in survival and reproduction
C. The generation of new traits in a population
D. Organisms developing the characteristics they need to be successful in their environment
E. A process of change over generations

39. In a mouse population at Hardy-Weinberg equilibrium, hair colour is controlled by a gene with two alleles, **D** and **d**, which are expressed by simple dominance. The **D** allele occurs with a frequency of 20%. What is the predicted frequency of the dominant phenotype in this population?

A. 0.64
B. 0.36
C. 0.04
D. 0.32
E. 0.20

The population is at equilibrium, so we can assume that $f(DD) = p^2$, $f(Dd) = 2pq$, and $f(dd) = q^2$.

The question tells us that the frequency of the D allele is 20%. This, therefore, is $p = 0.20$.
That means that $q = 1 - p = 1 - 0.2 = 0.8$.

The question wants the predicted frequency of the dominant PHENOTYPE. Since this trait is expressed via simple dominance, individuals who show the dominant phenotype are either DD or Dd.
$f(DD) = p^2 = (0.2)^2 = 0.04$
$f(Dd) = 2pq = 2(0.2)(0.8) = 0.32$

So, the total frequency of dominant phenotype is 0.04 + 0.32 = 0.36.

---

40. The following table summarizes the number of individuals of each genotype for four populations, labeled 1, 2, 3, and 4. Which of the four populations are at Hardy-Weinberg Equilibrium?

Population	AA	Aa	aa
1	20	40	20
2	10	50	30
3	6	48	96
4	5	40	5

A. 1 only
B. 2 and 4 only
C. 1 and 4 only
D. 1, 2, and 3 only
E. 2 and 3 only

Removed from exam.

---

41. In a city of 150,000 people, there are 50 deaths annually due to a rare lethal recessive allele. What is the probability of meeting a **male** who carries this allele?

A. 0; the disease is lethal.
B. 0.003
C. 0.018
D. 0.036
E. 0.500

This question was made a bonus question.
People who have the disease must be homozygote recessives (otherwise, the phenotype associated with the recessive allele is not expressed—this is the nature of recessive alleles). Therefore, $q^2 = 50/150000 = 0.0003$. That makes the frequency of the recessive allele $q = \text{sqrt}(0.0003) = 0.018$. That means that $p = 1 - 0.018 = 0.982$.
Carriers are individuals who have the allele, but do not express it (if they did, they would die). These individuals are heterozygotes. Based on the HW-equilibrium, these individuals occur with a frequency of $2pq = 2(0.982)(0.018) = 0.036$
As with all assumptions you have made in genetics during this course, males represent half of the population. Since heterozygotes occur with a frequency of 0.036, half of them should be predicted as males: $0.5(0.036) = 0.018$.

---

42. Consider the statement "Evolution would cease in any population in which all mutations were prevented." This statement is

A. true, because mutations are the source of all genetic variation.
B. false, because mutations have only a minimal effect in shifting allelic frequencies compared to the effects of natural selection.
C. false, because altered expression of Homeotic genes (like the *Hox* gene) can create variation.
D. true, because the rate of natural selection depends directly on the rate at which mutations occur.
E. false, because some modes of natural selection maintain genetic variation.

This question was removed from the exam.

---

43. Fish and salamanders that live in caves where it is completely dark do not have eyes, although it is thought that they evolved from ancestors that had eyes. Which of the following is the best explanation for this?

A. Darkness caused mutations in the genes that control eye development, resulting in the eyes of these species being lost.
B. These animals responded to the darkness by increasing their other senses (e.g. hearing) to compensate for not being able to see in the dark; these enhanced senses required more energy, and crowded out the eyes.
C. These fish and salamanders are eyeless populations of fish and salamanders with eyes that do not live in caves.
D. In a dark environment, individuals with smaller eyes save energy because eyes are energetically expensive to maintain. Those individuals with smallest eyes subsequently had the most energy to allocate to reproduction and passing on their genes in greater proportion to subsequent generations.
E. In the absence of light, there was no selection for eyes, so eyes were slowly lost from the dark environment populations.

---

44. The temperature of Northern Canada has been progressively warming overtime. The polar bear population living there has been decreasing in size, and the population has been developing a lighter fur coat over successive generations. This is an example of

A. stabilizing selection.
B. directional selection.
C. disruptive selection.
D. negative frequency-dependent selection.
E. positive frequency-dependent selection.

---

45. A balanced polymorphism may be maintained by all of the following **except**

A. negative frequency-dependent selection.
B. a spatially variable environment.
C. positive frequency-dependent selection.
D. disruptive selection.
E. All of A, B, C and D maintain balanced polymorphisms.

---

46. Which of the following scenarios regarding the mode of selection is **mismatched**?

A. Extinct early ancestors of horses are smaller than modern horses—disruptive selection because the ancestor is small and the modern living descendent is large.
B. Madagascar hissing cockroaches lives in a woodpile and experience heavy predation from lizards. The lizards are unable to eat the very largest adult cockroaches, and instead prey upon small and medium sized cockroaches—directional selection.
C. As a poisonous morph of tree frogs becomes more abundant in the area, it is less likely to be eaten by snakes—positive frequency-dependent selection.
D. A rare version of plant is visited by fewer pollinators; pollination is required for successful plant reproduction—positive frequency-dependent selection.
E. None of A, B, C and D is mismatched.

Horses are progressively getting bigger, according to this statement. This means that it is better to be bigger, which is selection for ONE extreme. This is an example of DIRECTIONAL selection, not disruptive selection.
D is incorrect; Positive frequency-dependent selection is when the common phenotype is selected FOR (and the rare phenotype is selected against). Since is it bad to be a rare version of the plant, this is consistent with positive-frequency dependent selection.

---

47. Which of the following are **necessary** for evolution by natural selection to take place?

    1. Offspring resemble their parents more than other individuals in the population.
    2. Differences among individuals exist and lead to different numbers of successful offspring being produced.
    3. Individuals adjust their development depending on the environment.
    4. Every individual has a desire to have many offspring.

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

If traits are heritable (evidenced by similarity between parents and offspring—statement 1) and there is differential reproductive success (i.e. statement 2), this is really all that is necessary for natural selection from this list. Part marks (0.5) were given for choosing C, nevertheless. An organism's DESIRE for offspring is irrelevant. The part marks were given for the interpretation that there needs to be a 'struggle for existence' for evolution by natural selection.

---

48. The reason spontaneous mutations do not have an immediate effect on allele frequencies in a large population is that:

A. mutations are random events, and mutations may be either beneficial or harmful.
B. many mutations exert their effects after an organism has stopped reproducing.
C. mutations are so rare that mutated alleles are greatly outnumbered by non-mutated alleles.
D. mutations usually occur in males and have little effect on eggs.
E. spontaneous mutations are not expressed in phenotypes, only genotypes.

---

49. A new chemical was discovered and introduced into a culture containing one species of bacteria. Within a day, most of the bacteria were dead, but a few remained alive.

    Which statement best explains why some of the bacteria survived?

A. They had a genetic variation that gave them resistance to the chemical.
B. They were exposed to the chemical long enough to develop a resistance to it.
C. They mutated and became a different species after exposure to the chemical.
D. They absorbed the chemical and broke it down in their digestive systems.
E. They needed to survive and reproduce in order to maintain high fitness, and subsequently, acquired the resistance.

---

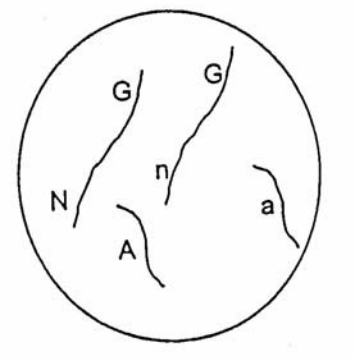
50. What level of biological organization evolves by natural selection?

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

This is NOT the same question as the clicker question asked in class. Populations (and/or species) evolve.

Bonus Question

51. The figure below is the nucleus of a cell taken from a diploid, sexually reproducing, multicellular animal.
What are all the kinds of gametes that this organism can produce?



A. AaGGNn
B. AGN, AgN, Agn, AGn, aGN, agN, agn
C. AGN, aGN
D. GN, Gn, A, a
E. AGN, AGn, aGN, aGn