

Circle the best single letter choice for each of the following questions before transferring your answers to your computer 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. Which of the following statements about retroviruses is correct?
1. Drugs that treat retroviruses generally have more severe side effects than drugs that treat DNA-based viruses.
 2. Retroviruses earned their name because they evolve 'backward'; their genomes have become smaller and simpler over evolutionary time.
 3. Immediately after a retroviral particle (virion) fuses with a host cell, the retroviral RNA is translated into proteins to assemble new virions.
 4. Retroviruses tend to have higher mutation rates than DNA-based viruses.
- 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.
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2. The use of antiviral drugs suffers from a paradox: the more we use them, the less effective they become in controlling viral infections. Why?
- A. Antiviral drugs put a selection pressure on the virus, favouring the spread of drug-resistant strains.
 - B. Antiviral drugs stimulate viral populations to grow faster.
 - C. Antiviral drugs increase viral mutation rates; some of the resulting mutations make viruses more drug-resistant.
 - D. Antiviral drugs promote horizontal gene transfer (HGT) of drug-resistant alleles into drug-sensitive strains.
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3. The CCR5- Δ 32 allele, which provides protection against HIV, is more common in some human populations than others. However, the geographic distribution of this allele probably **cannot** be explained by selection imposed by HIV. Why not?
1. The human populations with the highest frequency of CCR5- Δ 32 are not the ones that have been most heavily affected by HIV.
 2. HIV is not truly "alive", so it cannot influence the evolution of living organisms.
 3. HIV has only been infecting humans for a few (human) generations, so there has not been time for much of an evolutionary response.
 4. The CCR5- Δ 32 mutation may have first occurred long before HIV began infecting humans.
- 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.
-

4. What is the main advantage of treating a viral infection with a "cocktail" of multiple drugs at the same time, instead of with a single drug?
- A. Drug cocktails reduce the viral mutation rate, making it unlikely that the virus will experience a mutation that improves its resistance to any of the drugs used.
 - B. Drug cocktails allow each drug to be taken at a lower dose, so the risk of side effects is lower compared with taking high doses of a single drug.
 - C. Drug cocktails trains the patient's immune system to recognize a variety of viral coat proteins, so they are better able to deal with the virus than if the patient took a single drug.
 - D. Drug cocktails are more likely than a single drug to remain effective, because a given virion is unlikely to experience a mutation that improves its resistance simultaneously to all the drugs in the cocktail.
-

5. Which of the following would be a consequence of reductive evolution?

- 1. Smaller genome size.
- 2. Increased amount of junk DNA.
- 3. Decrease in time taken to complete the cell cycle.
- 4. Inability to adapt to extreme environments.

- 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
-

6. Which of the following statements about the Last Universal Common Ancestor (LUCA) is correct?

- 1. It had only ribozymes to catalyze reactions.
- 2. It was the first form of life, developing about 4 billion years ago.
- 3. It probably had an RNA genome.
- 4. It possessed peptidyl-transferase activity.

- 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
-

7. The Miller-Urey experiment was a huge breakthrough in our understanding of the evolution of life. However, creationists argue that the biochemistry of life is distinctly different from that of the Miller-Urey experiment.

Which of the following statements supports the creationist's argument?

- A. Life requires energy while the Miller-Urey experiment did not.
 - B. Water is required for all life but was not required for the Miller-Urey experiment.
 - C. The amino acids produced by the Miller-Urey experiment are not required for life.
 - D. The Miller-Urey experiment produced two forms of each sugar while all life produces only one.
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8. Both DNA and RNA are nucleic acids that contain genetic information.

Which of the following statements accurately compares DNA and RNA?

- A. Tautomeric shifts occur only in DNA, not RNA.
 - B. Phosphodiester bonding is identical in DNA and RNA.
 - C. DNA contains a 6 carbon sugar while RNA contains a 5 carbon sugar.
 - D. Hydrogen bonding is important for maintaining the structure of RNA, but not DNA.
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9. If you are registered in this course, you are a human. From which of the following groups are you *descended*?

- A. LUCA
 - B. Gorillas
 - C. Both A and B are correct.
 - D. Neither A nor B is correct.
-

10. To which of the following groups are you (a human) *related*?

- 1. Bacteria
 - 2. Marsupials (e.g. kangaroo)
 - 3. Plants
 - 4. Chimpanzees
- 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.
-

11. Until fairly recently, living things were classified as belonging to either the Plant Kingdom or the Animal Kingdom. What is the main problem with this system of classification?

- A. It does not reflect evolutionary relationships: some animals are more closely related to plants than they are to other animals.
 - B. It does not reflect the diversity of life on earth: some living things are neither plants nor animals.
 - C. It does not account for convergent evolution: some plants are carnivorous, and some animals use photosynthesis.
 - D. The term "kingdom" is both sexist and un-democratic.
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12. DNA sequence data suggest that modern humans last shared a common ancestor with Old World monkeys about 25 million years ago. In contrast, we last shared a common ancestor with New World monkeys about 40 million years ago.

What can you conclude about evolutionary relationships among these groups?

- A. Humans are more closely related to Old World monkeys than to New World monkeys.
 - B. Old World monkeys are more closely related to New World monkeys than to humans.
 - C. Both A and B are correct.
 - D. Neither A nor B is correct.
-

13. *Arabidopsis* is a model diploid plant species. The value of C for *Arabidopsis* is 110 Megabases (Mb). (1Mb = 1 million base pairs)

How much DNA would there be in the nucleus of an *Arabidopsis* gametophyte cell during prophase of mitosis?

- A. 55 mB
 - B. 110 mB
 - C. 220 mB
 - D. 440 mB
-

14. Birds have a relatively low value of C relative to related organisms such as turtles. Small genome size is believed to be the result of the high metabolic demands of flight - favouring smaller cells that must therefore have smaller nuclei.

Which of the following would you predict to be dramatically less common, or fewer, in the genome of birds relative to turtles?

- A. genes
 - B. chromosomes
 - C. transposable elements
 - D. single nucleotide polymorphisms
-

15. Which of the following statements most accurately summarizes a relationship between genome size and organismal complexity?

- A. On average, humans have the largest genome size of all animals.
 - B. On average, animals have larger genome sizes than plants.
 - C. On average, multi-cellular eukaryotes have larger genome sizes than uni-cellular eukaryotes.
 - D. On average, eukaryotic organisms have larger genome sizes than prokaryotic organisms.
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16. Which of the following sequences in the human genome is classified as "junk" DNA?

- 1. retrotransposons
- 2. telomeres
- 3. proviruses
- 4. centromeres

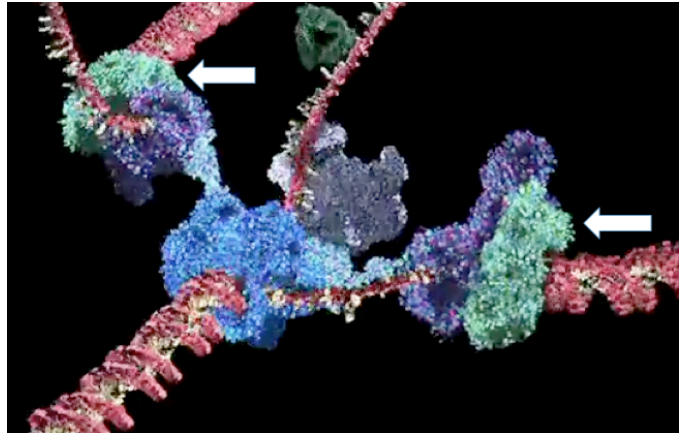
- A. 1,2 & 3 only
 - B. 1 & 3 only
 - C. 2 & 4 only
 - D. 4 only
 - E. All of 1,2,3 & 4 are correct.
-

17. This screen shot from an animation shown in class shows the structure of a replisome.

The template DNA is approaching from the bottom left; the leading strand is leaving toward the right and the lagging strand is at the top left.

The arrows identify a protein complex called the "sliding clamp".

What is the function of the sliding clamp?



- The sliding clamp prevents unwound single-stranded regions on the template strand from binding with themselves before the polymerase can replicate them.
- The sliding clamp triggers proof-reading if DNA polymerase creates a mismatch by mistake.
- The sliding clamp holds newly synthesized Okazaki fragments in place until ligase can seal any remaining "nicks".
- The sliding clamp helps DNA polymerase III stay attached to the template strand.

18. Meselson and Stahl used bacterial cells for their famous experiment involving the incorporation of heavy nitrogen into DNA during replication followed by separation of different DNA into distinct bands in cesium chloride gradient tubes.

What difference would you expect in the banding pattern in the tubes if you repeated the Meselson and Stahl experiment using eukaryotic cells instead of bacteria?

- Since eukaryotes have the same fundamental mechanism of DNA replication as prokaryotic cells, there would be no difference in the banding patterns in the tubes.
- Since eukaryotes have larger genomes, all the bands would travel further down the tubes.
- Since eukaryotes have more chromosomes, there would be more bands in the tubes.
- Since eukaryotes have faster polymerases, more DNA would be produced and the bands would be wider.

19. All biology students learn that cells require nucleotides for DNA replication during S phase of the cell cycle. But what if you discovered cells taking up nucleotides outside of S phase?

What process might require nucleotides to be taken up **outside** of normal S phase in somatic cells?

- Replacing primers.
 - Movement of mobile elements.
 - Adding telomeres.
 - Excision repair of thymine dimers.
- 1,2 & 3 only
 - 1 & 3 only
 - 2 & 4 only
 - 4 only
 - All of 1,2,3 & 4 are correct.

20. Bakers yeast, *Saccharomyces cerevisiae*, is a single-celled eukaryote with linear chromosomes. The sequence of the telomere repeat on the end of yeast chromosomes is

5'TGTGGGTGTGGTG TGTGGGTGTGGTG TGTGGGTGTGGTG 3'
3'ACACCCACACCAC ACACCCACACCAC ACACCCACACCAC 5'

What must be the sequence of the RNA template carried by yeast telomerase?

- A. 3'ACACCCACACCAC5'
- B. 5'UCUCCCUCUCCUC3'
- C. 5'ACACCCACACCAC3'
- D. 3'UCUCCCUCUCCUC5'

21. Assume that this screen shot from an animation shown in class shows the general structure of a replisome in a horse.

The template DNA is approaching from the left; the leading strand is leaving toward the bottom and the lagging strand is looping out to the right.



Which of the following statements about this replisome is correct?

- 1. Both leading and lagging template strands are "read" in the same "direction" ie. 3' to 5'
- 2. The two new strands, leading and lagging, will become sister chromatids.
- 3. A replisome like this would be present at each end of a replication "bubble".
- 4. If proofreading fails to correct a mismatch made by DNA polymerase III, this damage will appear at the same location on both the leading and lagging strands.

- 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.

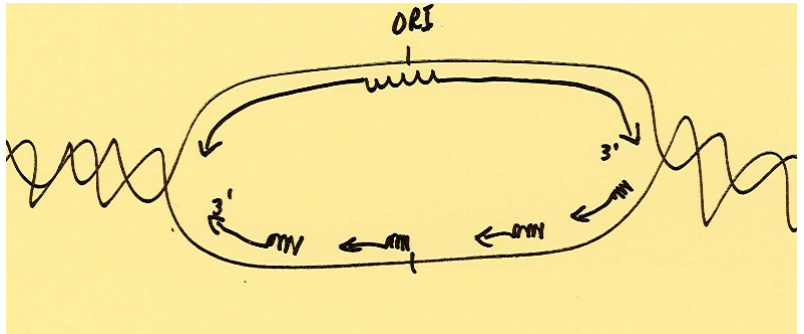
22. There is an enzyme called "separase" that degrades the protein cohesin during the cell cycle. Separase has been suggested as a possible target for cancer drug therapy.

What would be the effect of a drug that blocked the action of separase in actively cycling cells?

- A. Cells would replicate and divide their chromosomes normally but cytokinesis would be prevented.
- B. Cells would fail to replicate their DNA during S phase because replication bubbles could not get started.
- C. Cells would be produced with many more mutations due to lack of repair of mismatches during G1.
- D. Cells would be produced with the wrong number of chromosomes due to failure of sister chromatids to go to the opposite pole during anaphase.

23. Image that one of your colleagues in your study group showed you this sketch of a replication bubble.

How should you respond?



- A. Perfect! Overall this image is correct.
- B. Close! This image is generally correct, but the 3' labels should be 5'.
- C. Whacked! This image incorrectly shows the top strand as the leading template at both forks.
- D. Whacked! This image incorrectly suggests that both leading and lagging strand synthesis requires primers.

24. Modern microscopy allows us to visualize various components of cells by making antibodies that target specific proteins. These antibodies carry a fluorescent "tag" that lights up the location of the target proteins.

Which of the following proteins should you target if you want to see the distribution of microfilaments in a cell?

- A. actin
- B. keratin
- C. tubulin
- D. cohesin

25. Although you know that vertebrate telomeres are added by telomerase, telomeres in other organisms are maintained in other ways. For instance, in insects like *Drosophila*, telomeres are maintained by a kind of retrotransposon!

Why is it not so surprising to hear that a retrotransposon is associated with making telomeres?

- A. Both retrotransposons and telomeres are DNA made from an RNA template.
- B. Both retrotransposons and telomeres code for reverse transcriptase.
- C. Both retrotransposons and telomeres have repeated sequences at their ends.
- D. Both retrotransposons and telomeres are in the category of "junk DNA".

26. Recall that RNA primers are needed to initiate DNA synthesis. Recall also that bases can exist in both their "usual" or "unusual" tautomeric forms. If an adenine in the DNA template strand made the shift to its unusual tautomer during creation of an RNA primer, which incorrect base would be inserted by primase?

- A. uracil
- B. cytosine
- C. thymine
- D. guanine

27. The rate at which new mutations appear in coding genes varies quite widely from one species to another.

Which of the following mechanisms is a sensible explanation for why some species have more mutations in coding genes than other species?

1. Some species have less strict control on the G1/S checkpoint of the cell cycle.
 2. Some species have particularly sloppy telomerase that creates many mismatches.
 3. Some species are less able to repair UV damage than others.
 4. Some species suffer more tautomeric shifting of their bases than other species.
- 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 base analogue, such as 5 bromo-uracil (5BU) is incorporated into a replicated DNA strand instead of a thymine, this step creates "damage" but not a mutation.

What is the next step in the process toward creating a mutation?

- A. The 5BU is removed by excision repair and replaced with thymine.
B. The 5BU becomes bonded to the next base, creating a dimer.
C. The 5BU changes into thymine, calling an A in the next round of replication.
D. The 5BU changes its tautomeric form, calling a G instead of an A in the next round of replication.
-

29. STR sequences are variable regions in the human genome that can be used to create unique "DNA fingerprints" for individuals.

Which of the following characteristics of STR sequences is variable from one person to another?

- A. Orientation relative to surrounding sequences. (i.e. inverted or not)
B. Location in the genome.
C. Base sequence.
D. Copy number.
-

30. Ultraviolet radiation (from sunlight) and gamma radiation (from radioactive decay) are just different wavelengths of electromagnetic energy. However, they interact with DNA quite differently.

Which of the following statements about electromagnetic radiation as a physical mutagen is true?

- A. Both UV and gamma radiation create damage resulting from breaks in the DNA backbone.
B. Damage caused by UV radiation would not be randomly distributed in all DNA sequence.
C. Reactive oxygen species (ROS) can be used to repair the effects of gamma radiation on DNA.
D. Photolyase removes thymine dimers and replaces them with undamaged thymines.
-

31. Which of the following mechanisms creates copy number variation (CNV)?

1. Unequal crossing-over during meiosis.
 2. Repair of double-strand breaks in chromosomes.
 3. "Slippage" during DNA replication.
 4. 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.
-

32. Several lines of evidence suggest that meiotic cell division evolved from mitosis. Many of the characteristic features of meiosis were likely already present in early eukaryotes. For instance,

- i) recombination enzymes are found in all three modern Domains of life and were therefore likely also present in the earliest eukaryotic cells;
- ii) although the process is relatively rare, sections of homologous chromosomes can pair and recombine during mitosis in somatic cells;
- iii) chromatids do not replicate so long as they are held together.

So then, what **was** the major new evolutionary innovation that was necessary in order for meiosis to be distinct from mitosis?

- A. Crossing over.
B. Synapsis.
C. Disjunction of replicated homologues to opposite poles.
D. Preventing S phase before meiosis II.
-

33. Sharks are diploid organisms that replenish skin tissue by mitotic cell division of cells called fibroblasts and make gametes by meiotic cell division in cells called meiocytes.

Picture a shark fibroblast in metaphase of mitosis.

When would a shark meiocyte have half the amount of DNA **and** half the number of chromosomes, compared to a shark fibroblast in metaphase of mitosis?

- A. In G1, before DNA replication leading into meiosis.
B. In G2, just before meiosis begins.
C. At the end of meiosis I.
D. At the end of meiosis II.
E. Never; chromosome number and amount of DNA are not the same in mitosis and meiosis.
-

34. A seed is a biological package containing a small multi-cellular plant "baby" as well as food in the form of starch or oil etc. Therefore, "seedless" fruits are defective in some aspect of seed production.

Seedless watermelons have been developed as follows: A diploid plant ($2n = 22$) was treated to double its chromosome number to tetraploid. Then this tetraploid plant was crossed to a diploid parent to create triploid offspring. These triploid plants make the watermelon fruit but are unable to make seeds; they are "seedless".

Which of the following statements about this situation is true?

1. The triploid offspring don't have seeds because they can't make proper spores (and therefore can't make gametes).
 2. The tetraploid parent makes diploid spores by meiosis.
 3. In prophase of mitosis, cells of the seedless plants are $6C$.
 4. The "treatment" to double chromosome number most likely applies during S phase.
- 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.
-

35. Which of the following statements about a homologous pair of chromosomes is true?

1. Each member of the pair is inherited from different parents.
 2. Each member of the pair assort independently of other homologous pairs in meiosis I.
 3. Each member of the pair is pasted up beside the other in a karyotype.
 4. Each member of the pair carries the same mobile elements in the same places.
- 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.
-

36. Mitch and Gogi met at a conference of "Little People". They both have a genetic condition called achondroplasia that results in shortening of the long limb bones. A genetic counselor at the conference explained that this trait is inherited as a single gene autosomal dominant trait where homozygotes for the achondroplasia allele are not viable.

Mitch and Gogi are determined to have four children and want them all to be "little" like their parents.

What is the likelihood that Mitch and Gogi's four (living) children would all have achondroplasia?

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

37. "Factor VIII" is a protein necessary for proper blood clotting in the event of wounding. People missing this Factor suffer from Hemophilia. The Factor VIII gene is coded on the X chromosome. Recall that the ABO blood type gene is autosomal.

Consider a hemophiliac man, Anwar, with Type A blood. Anwar's father has Type O blood.

What fraction of Anwar's gametes carry the Type A blood type allele but do **not** carry the defective Factor VIII allele?

- A. 0
- B. 1/2
- C. 1/4
- D. 1/8
- E. 3/4

38. The gene coding for the protein dystrophin is the largest human gene known (over 2 million base pairs). It is coded on the X chromosome. Muscle cells lacking dystrophin gradually weaken and die, giving rise to the characteristic symptoms of the disorder called muscular dystrophy. The disorder is therefore inherited as a sex-linked recessive trait.

Humans with 1 X chromosome, but no Y chromosome, develop as females with 45 chromosomes rather than the usual 46. Consider one such woman, Betty, who has muscular dystrophy.

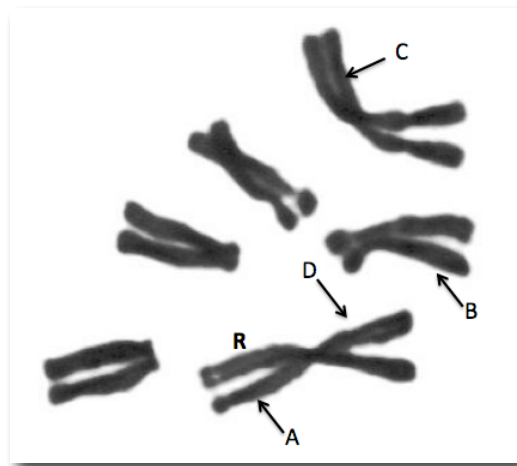
If Betty's father and mother were phenotypically and karyotypically normal, identify which stage of meiosis, in which parent, was a likely site of the error in chromosome movement that resulted in Betty's unusual chromosome number.

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

39. The Indian Muntjac deer is famous for being the mammal with the lowest number of chromosomes, $2n = 6$. This image is a real micrograph showing Muntjac metaphase chromosomes from white blood cells.

This particular animal is heterozygous for the "red coat" alleles, **R** and **r**.

The location of the **R** allele is labeled on the diagram with an "R"; which arrow indicates the location of the **r** allele?



40. Linda samples 2 different populations of a single fish species and wants to use the chi-square test to determine if there is a difference in schooling behaviour between the two populations.

Using a 5% rejection level, which critical chi-square value should she use from the table below?

Critical values of Chi-square			
Degrees of freedom	$p=0.50$	$p=0.05$	$p=0.01$
1	0.46	3.84	6.64
2	1.39	5.99	9.21
3	2.37	7.82	11.35
4	3.37	9.49	13.28
5	4.35	11.07	15.09
6	5.35	12.59	16.81
7	6.35	6.35	18.48

- A. 0.46
 B. 3.84
 C. 5.99
 D. 9.49
 E. None of these values are appropriate in this case.

41. After the lab, you overhear Linda saying that she failed to reject the null hypothesis in the fish behaviour experiment to determine if there is a difference in schooling behavior between the two populations of fish species.

Which of the following statements is **true** based on this information?

- There was a difference in the behaviour among the populations.
- Her calculated chi-square value was less than the critical value.
- She should repeat the experiment with many more populations.
- The variation in behaviour among populations was just due to chance or sampling error.

- 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.

42. Given the following information, what would be the length of the specimen in mm?

Ocular lens = 10x
 Objective lens = 10x
 1 stage division = 10 μ m
 diameter of the field = 3.5mm
 length of the specimen = 25 ocular divisions
 25 ocular division = 20 stage divisions

- A. 0.16
 B. 0.20
 C. 1.6
 D. 2.0
 E. 3.5