

Section A

Select the **BEST** answer to the question provided and mark it on your Test Score Answer Sheet. A correct answer is worth one mark. Section A is worth a **total of 40 marks**.

- The presence of circular chromosomes in the mitochondria and chloroplasts of eukaryotic cells suggests

B

 - that chromosomes are only stable in a circular configuration.
 - that these organelles evolved from prokaryotic cells.
 - that mitochondria are maternally inherited.
 - that the genetic code is different in mitochondria.
- A sample of DNA is found to contain 27% deoxycytidine. This same sample contains

A

 - 23% deoxyadenosine
 - 27% deoxyadenosine
 - 23% deoxyguanosine
 - 27% deoxythymidine
- Which of the following proteins is a non-chromatin nuclear component?

A

 - cytochrome c
 - histone 2A
 - lamin
 - cohesin
- A DNA strand has the sequence 5'- GTACGGTATCATAG - 3'. The complementary strand will be:

B

 - 5'- CTATGATGTCGTAC -3'
 - 5'- CTATGATACCGTAC -3'
 - 5'- GTACGGTATCATAG -3'
 - 5'- CATGCCATAGTATC -3'
- Centromeres

C

 - prevent fusion of chromosomes.
 - help DNA polymerase replicate the whole chromosome.
 - provide the site of chromosomal attachment to the mitotic spindle.
 - protect chromosomes from attack by deoxyribonucleases.

6. Identify the **correct** statement.

- C**
- a) During mitotic cell division, nuclear chromosomes are duplicated exactly and distributed more or less equally between daughter cells.
 - b) Mitochondria are fragmented at the time of mitosis and reformed in daughter cells.
 - c) It does not matter if daughter cells receive unequal numbers of chloroplasts as a result of mitosis.
 - d) Daughter cells are always genetically identical to their mother cell.

7. A single base pair mutation that results in premature termination of translation of the corresponding mRNA is called a _____ mutation.

- A**
- a) nonsense
 - b) missense
 - c) non-conserved
 - d) silent

8. Which statement is **true** regarding the nuclear envelope?

- A**
- a) it is structurally supported by a 'meshwork' of lamin protein
 - b) it is supported from inside by a network of microtubules
 - c) it contains keratin filaments
 - d) the inter-membrane space is continuous with the nucleoplasm

9. During meiosis, homologous chromosomes move towards opposite poles of the spindle during

- A**
- a) anaphase I
 - b) metaphase I
 - c) anaphase II
 - d) metaphase II

10. How many of the following statements are **true**?

- I. Meiosis can be interrupted for a period of many years before completion.
- II. Meiosis II is known as a reduction division.
- III. Oogenesis produces one mature gamete for every meiosis, whereas spermatogenesis produces four mature gametes for every meiosis.
- IV. Primary spermatocytes are diploid.

- B**
- a) 1
 - b) 2
 - c) 3
 - d) 4

11. Consider a short mature mRNA molecule with the sequence:
 $^m\text{GUAGACUAGAGCCAUGAUGAUGAUGUUUACGAUUCAGUCAUAGAGAUACAGAA}_n$

(where ^mG indicates the 5' cap and A_n indicates a 3' polyA tail)

How many amino acids would be in the encoded polypeptide?

- C
- a) 2
 - b) 4
 - c) 8
 - d) 16

12. Identify the **incorrect** statement about gene expression in eukaryotic cells.

- D
- a) Transcription occurs in the nucleus, translation occurs in the cytoplasm.
 - b) Primary mRNA transcripts are usually spliced before they are exported from the nucleus.
 - c) Processed mRNA molecules leave the nucleus through nuclear pore complexes.
 - d) Ribosomes are positioned on mRNAs by interacting with the Shine-Dalgarno sequence.

13. Identify the best order for the following mutations with respect to the likelihood that they will represent a null allele in a protein-coding gene, least likely first.

- D
- a) missense, frameshift, silent
 - b) frameshift, silent, missense
 - c) silent, frameshift, missense
 - d) silent, missense, frameshift

14. Mutations in DNA

- B
- a) are silent.
 - b) are random.
 - c) reduce genetic diversity.
 - d) don't occur in somatic cells.

15. In a monohybrid cross, if the P generation consists of plants that are true breeding then the F₂ generation will consist of organisms that exhibit what ratio of dominant phenotypes to recessive phenotypes?

- D
- a) 3:2
 - b) 1:2
 - c) 1:3
 - d) 3:1

16. In a monohybrid cross, if the P generation consists of plants that are true breeding then the F₂ generation will consist of organisms that exhibit what ratio of homozygous dominant individuals to heterozygous individuals to homozygous recessive individuals?

C

- a) 3:2:1
- b) 1:3:1
- c) 1:2:1
- d) 3:1

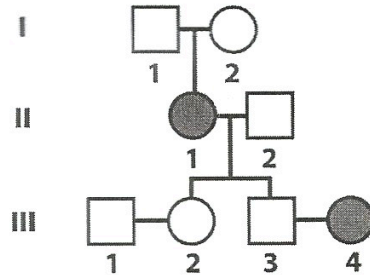
17. In a mitotically dividing cell, will an allele on one sister chromatid match the allele on the other sister chromatid?

A

- a) Yes, if no errors have been made during DNA synthesis.
- b) Yes, but only if both sister chromatids are inherited from the same parent.
- c) Yes, or the chromatids won't disjoin during anaphase.
- d) Yes, but only when an individual is homozygous for that allele.

18. Using the pedigree below, and bearing in mind that this is a rare condition, what is the chance that the couple III-3 and III-4 will have an affected child?

D



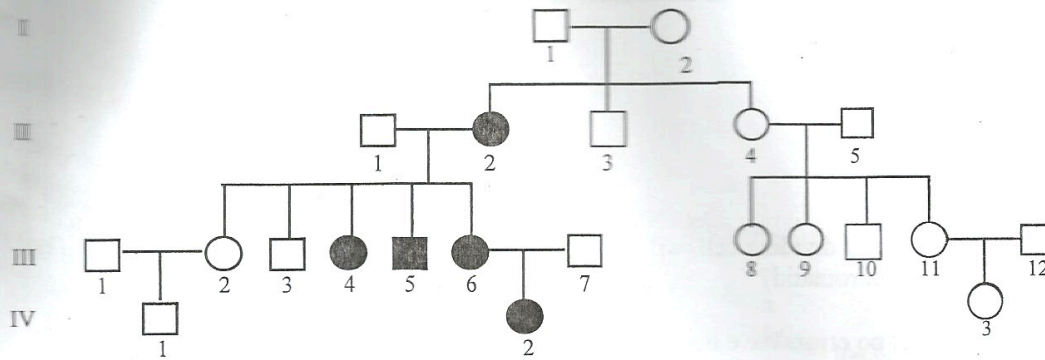
- a) 0
- b) 1/4
- c) 1/3
- d) 1/2

19. Referring to the pedigree in question 17, what is the chance that a child of couple III-1 and III-2 will have an affected child?

A

- a) 0
- b) 1/4
- c) 1/3
- d) 1/2

The next three questions refer to the following pedigree:



20. What is the most probable mode of inheritance for the rare trait indicated in this pedigree?

- B**
- a) sex-linked
 - b) recessive
 - c) rapidly mutating
 - d) dominant

21. Which of the following options best explains why no one is affected in the first generation?

- C**
- a) The couple in the first generation were related.
 - b) The allele must have switched from a recessive to a dominant mode of inheritance at generation II.
 - c) The mutant allele must have arisen in a gamete in someone from the first generation.
 - d) The couple in the first generation died before they could display the trait.

22. What is the probability that the next child born to individuals III-6 and III-7 is affected?

- C**
- a) 0
 - b) 0.25
 - c) 0.5
 - d) 0.75

23. Which of the following cellular processes would be disrupted by Nocadazole, a drug that interferes with the polymerization of tubulin?

1. chromosome disjunction, 2. translation, 3. transcription, 4. dynein-mediated intracellular transport, 5. ribosome assembly

- A**
- a) 1 and 4
 - b) 1, 2, and 5
 - c) 1, 4, and 5
 - d) 2 and 4

24. Epistasis influences

- C**
- a) genotypic ratios.
 - b) segregation of alleles.
 - c) the phenotypic ratio.
 - d) the kinds of gametes formed.

25. A medical technician is analyzing a blood sample in a clinical lab. In determining the blood type the technician determines that the red blood cells have A antigens present on the surface but not B antigens. In this case, is it possible for the technician to unambiguously assign a genotype to the patient?

- C**
- a) No, because I^A is dominant over I^B .
 - b) No, because there are three genotypes that specify this phenotype.
 - c) No, because there are two genotypes that specify this phenotype.
 - d) No, because human blood type alleles show co-dominance.

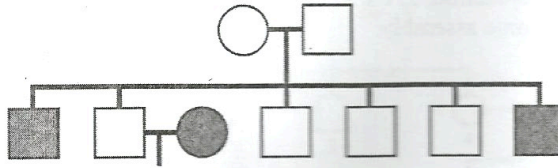
26. A woman who is blood type A has a child who is blood type O. Which of the following individuals could not be the father of this child?

- B**
- a) type A
 - b) type AB
 - c) type B
 - d) type O

27. During a typical cell cycle, S phase is followed by

- C**
- a) G1.
 - b) mitosis.
 - c) G2.
 - d) interphase.

28. In the following pedigree for a recessive trait, what is the likelihood that individual II-4 is homozygous?



- A
- 1/3
 - 1/2
 - 1/4
 - 0
29. b denotes blue eyes in humans and B for brown eyes is completely dominant over b. b is partially dominant over bg (green eyes) and bh (hazel eyes); and bh is completely dominant over bg (green eyes) What is the best representation of the dominance hierarchy for this trait?
- B
- $B > b > bg > bh$
 - $B > b > bh > bg$
 - $b > B > bg > bh$
 - $B > bg > bh > b$
30. A monohybrid cross between heterozygous rabbits produces progeny in two phenotypic classes, in a ratio of 2:1 instead of the usual 3:1. What is a likely explanation for this altered ratio?
- A
- Homozygous recessive individuals die during embryonic development due to the presence of a lethal mutation.
 - Heterozygous individuals are physiologically more able to adapt to the birth process.
 - Homozygous individuals occur more frequently in nature.
 - Heterozygous individuals have increased fitness.
31. Which of the following statements regarding the components of the cytoskeleton is **false**?
- D
- All three cytoskeleton components are polymers.
 - Microfilaments are polar.
 - Microtubules are polar.
 - Intermediate filaments are polar.

32. Which of the following statements regarding gene activity is **true**?

- D**
- a) One gene can influence multiple traits.
 - b) Gene activity can be modified by environmental conditions.
 - c) Genes act in networks with other genes.
 - d) All of these statements are true.

33. When two or more genes influence a trait, an allele of one of them may have an overriding effect on the phenotype. When an allele has such an overriding effect, it is said to be:

- D**
- a) Dominant
 - b) Recessive
 - c) Penetrant
 - d) Epistatic

34. In a mating between individuals with the genotypes $I^B i$ and ii , what percentage of the offspring are expected to have the O blood type?

- C**
- a) 10%
 - b) 25%
 - c) 50%
 - d) 100%

35. A daughter of the mating in question 33 has a child with a man with type O blood. What is the probability that they will have two children with type B blood?

- B**
- a) $1/2$
 - b) $1/4$
 - c) $1/8$
 - d) $1/16$

36. In which of the following locations would you expect to find ribosomal subunits in various stages of assembly?

B

- a) nuclear matrix
- b) nucleolus
- c) nuclear pore complex
- d) cytoplasm

37. Which of the following accurately describes intermediate filaments?

C

- a) they are found only in epithelial cells and neurons
- b) they are larger than microtubules, but smaller than F-actin filaments
- c) the monomers of which they are made contain a central α -helical domain
- d) they form highly unstable polymers

38. A tall pea plant has green, wrinkled peas. If the dominant alleles for these three traits are D, Y, and W respectively, what is the genotype of the plant that would be used in a test cross?

A

- a) dd yy ww
- b) Dd Yy Ww
- c) DD YY WW
- d) Unable to determine, based on the information given

39. Tissue-specific enhancers are found in

C

- a) genes that encode metabolic enzymes essential for core cellular functions.
- b) all genes.
- c) genes that encode regulatory transcription factors.
- d) ribosomal RNA genes.

40. What process must always happen in order for a gene to be expressed?

A

- a) transcription
- b) translation
- c) nuclear export of RNA
- d) correct protein folding

Section B

Record your answers to the questions below in the provided spaces. **DO NOT USE ACRONYMS.** Section B contains **13 questions** for a **total of 16 marks**.

Circle true or false to each of the following four questions [1 mark each]

1. $(A + C) / (G + T) = 1$ True False

TRUE

2. DNA compaction is reversible. True False

TRUE

3. Homologous chromosomes pair during meiosis. True False

TRUE

4. All translation occurs on the rough endoplasmic reticulum. True False

FALSE

5. Noncoding sequences in mature mRNAs of eukaryotes are called [1 mark]

EXONS

6. Does crossing over occur before or after metaphase I in cells undergoing meiosis? [1 mark]

BEFORE

7. If the diploid number for cats is 38, how many chromatids are found in:

(i) a primary oocyte in prophase I [1 mark]

76

(ii) an egg [1 mark]

19

8. Together with ribosomal proteins, what is used to make ribosomal subunits? [1 mark]

mRNA

9. Spontaneous mutations can arise as a result of DNA replication errors made during S phase. Provide one example of a type of DNA sequence that gives rise to mutation "hot spots" in the genome. [1 mark]

Simple repeat AAA

10. A fragment of a polypeptide, Met-Leu-Ala-Gly, is encoded by the following sequence of DNA:

Strand A - G T T A C A A C C G G C C A -
Strand B - C A A T G T T G G C C G G T -

- (a) Which strand is the template strand for transcription? [1 mark] a
- (b) Indicate, on the above figure, the 3' and 5' ends of the non-template strand only of the DNA. [1 mark]
11. Arrange the following events in the correct temporal sequence, starting with 1 at the earliest. [2 marks]
- | | | |
|--|-------|------|
| (A) duplication of the chromosomes | _____ | A) 1 |
| (B) formation of the nuclear membrane | _____ | B) 4 |
| (C) attachment of microtubules to the kinetochores | _____ | C) 3 |
| (D) crossing over between homologous chromosomes | _____ | D) 2 |
12. What type of motor protein is involved in the F-actin-based movement of a migrating cell? Be specific. [1 mark]

 myosin

13. In which direction along an F-actin filament does the motor protein in question 12 move? [1 mark]

 + direction

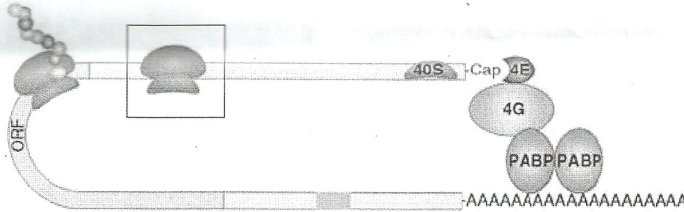
Section C

Record your answers to the questions below in the spaces provided. Show calculations or diagrams used to derive your answer. Section C contains 10 questions for a total of 24 marks.

1. When Avery, MacLeod & McCarty mixed the DNA of "smooth" *Streptococcus* with live cells of the "rough" type, they saw transformation of the rough strain into smooth. The progeny of these transformed smooth cells were also smooth. This transformation could be prevented in the presence of an enzyme that degrades DNA. Why was this an important experiment in the history of molecular biology? [1 mark]

**DNase was used and the strain was degraded
RNA and proteases had no effect**

2. (A) What cellular process is being diagrammed below? [1 mark] transcription
(B) Name the cellular component outlined in the box. [1 mark] ribosome



3. List three structural features of the nuclear envelope. [3 marks]

**membrane
nuclear pores
lamina**

4. Mendel crossed pea plants that produced smooth seeds with those that produced wrinkled seeds and self-fertilized the progeny. In the F₂, he observed 5474 smooth seeds and 1850 wrinkled seeds. Using the letters W and w for the smooth and wrinkled seed texture alleles respectively, diagram Mendel's crosses, showing the genotypes of the plants in each generation. Are the results consistent with the Principle of Segregation? [3 marks]

Principle of segregation - alleles act by themselves

5. Two parents who are not affected by cystic fibrosis have a child who is affected. Assuming that cystic fibrosis is controlled by one gene, what is the probability that exactly three of their next four children will also be affected by cystic fibrosis? [2 marks]

6. Refer back to the pedigree in multiple choice question 18. What assumption did you make about individual III-1 and why? [2 marks]

III-1 has to be homozygous dominant if parents are heterozygous

7. Fruit colour in squash is controlled by the following pathway:



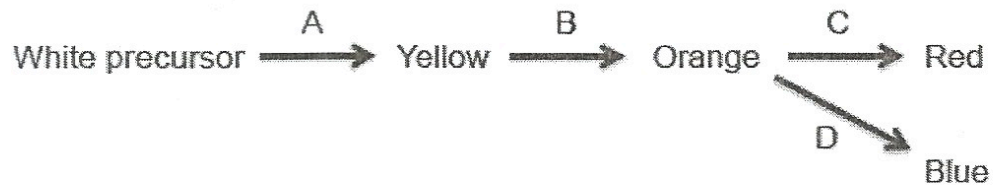
Predict the fruit colour on plants of the following genotypes. [2 marks]

cc gg	<u>green</u>
Cc Gg	<u>white</u>
cc GG	<u>yellow</u>
Cc gg	<u>white</u>

8. What did the experiment that led to the birth of the sheep named Dolly tell us about the nuclear genome of differentiated cells? [1 mark]

Differentiated cells can still reproduce/recreate life - birth of Dolly happened after the nucleus of mammary cells were grown invitro and inputted into a lamb's reproductive system

9. Flower colour in a species of plant is determined by four independently assorting genes (A, B, C, D) that encode enzymes in a biosynthetic pathway for flower pigment. The recessive alleles of each of these genes (a, b, c, d) produce non-functional enzymes. The pathway is diagrammed as follows:



When both blue and red pigments are present, the seeds are purple. Plants with the genotypes $Aa Bb Cc Dd$ and $Aa Bb Cc dd$ were crossed.

- (a) What colour are the seeds in these two parental genotypes? [1 mark]

$A B C D$ - PURPLE
 $A B C d$ - RED

- (b) What proportion of the offspring from the cross will have white seeds? [1 mark]

	A	a	$1/4 aa$
A	AA	Aa	
a	Aa	aa	

- (c) Determine the relative proportions of red, white, and blue offspring from the cross. [1 mark]

	White - $1/4 = 32/128$				Blue		
					D	d	
Red				d	Dd	dd	1/2 homozygous
	C	c		d	Dd	dd	phenotype
C	CC	Cc	3/4 homozygous				
c	Cc	cc	phenotype				
A	B	dd	C	A	B	cc	D
3/4	3/4	1/2	3/4	3/4	3/4	1/4	1/2
= $27/128$				= $9/128$			

Therefore, 27:32:9

10. A researcher studied five independently assorting genes in a plant. Each gene has a dominant and a recessive allele: R black stem, r red stem; D tall plant, d dwarf plant; C full pods, c constricted pods; O round fruit, o oval fruit; H hairless leaves, h hairy leaves. The five questions below refer to the cross (P1) RR Dd cc Oo Hh x (P2) Rr DD cc oo Hh [Each answer is worth 1 mark]

(a) How many kinds of gametes can be formed by P1?

RR DD Oo HH
Rr Dd oo hh

8 gametes

(b) How many different genotypes are possible among the progeny of this cross?

10 genotypes

RR, Rr HH, Hh, hh
DD, Dd Oo, oo
cc

(c) How many different phenotypes are possible among the progeny?

7 phenotypes

black stem round fruit, oval fruit
tall plant Hairless leaves, hairy leaves
constricted pods

(d) What is the probability of obtaining the Rr Dd cc Oo hh genotype in the progeny?

Rr Dd cc Oo hh
(1/2) x (1/2) x (4/4) x (1/2) x (1/4)

1/32

(e) What proportion of the progeny will be black, tall, constricted, oval, and hairy?

RR DD cc oo hh
RR Dd cc oo hh
Rr DD cc oo hh
Rr Dd cc oo hh

The genetic code

Second position

First

	U	C	A	G	
U	Phe Phe Leu Leu	Ser Ser Ser Ser	Tyr Tyr <i>Stop</i> <i>Stop</i>	Cys Cys <i>Stop</i> Trp	U C A G
C	Leu Leu Leu Leu	Pro Pro Pro Pro	His His Gln Gln	Arg Arg Arg Arg	U C A G
A	Ile Ile Ile Met	Thr Thr Thr Thr	Asn Asn Lys Lys	Ser Ser Arg Arg	U C A G
G	Val Val Val Val	Ala Ala Ala Ala	Asp Asp Glu Glu	Gly Gly Gly Gly	U C A G

Third