

NATIONAL UNIVERSITY OF SINGAPORE

DEPARTMENT OF BIOLOGICAL SCIENCES

ADVANCED PLACEMENT TEST
(SAMPLE)

LSM1102 MOLECULAR GENETICS

MMM-YYYY---Time Allowed : 2 hours

INSTRUCTIONS TO CANDIDATES

1. This paper contains a total of **THIRTY (30)** multiple choice questions in Section I and **FOUR (4)** structured questions in Section II; and comprises **ELEVEN (11)** printed pages including this cover page.
2. This is a **CLOSED BOOK** test.
3. Answer **ALL SECTIONS** and carefully follow the instructions given under each section.
4. Use the answer sheet (**Form CC1**) for **Section I** multiple-choice questions and fill in completely the appropriate circles using a **2B** pencil. Write and shade in your matriculation number on the answer sheet. For **Section II**, write all your answers in the answer booklet(s) provided. You are **NOT** required to use separate answer booklets for questions in **Section II**. Do not answer directly on this paper.
5. **Both programmable and non-programmable calculators** without remote communication function are allowed to be used.
6. No Helpsheet(s) or Formula Sheet(s) will be provided.
7. **DO NOT REMOVE THIS QUESTION PAPER FROM THE TEST VENUE.**

SECTION I – MULTIPLE CHOICE QUESTIONS (CHOOSE ONLY ONE ANSWER EACH)

1. DNA gel electrophoresis is an analytical technique used to separate DNA fragments. The migration speed of DNA molecules within the gel from cathode to anode will be affected by:
 - i. Size of the DNA (number of base pairs)
 - ii. DNA conformation
 - iii. Electrical current in voltage
 - iv. Gel concentration
 - A. i. only
 - B. i. and ii.
 - C. i. ii. and iii.
 - D. i. ii. iii. and iv.
 - E. i. and iii.

2. During the plasmid purification procedure, optimal lysis of *E. coli* cells is important to minimize contamination by genome DNA. One reason for this is:
 - A. Genomic DNA from *E. coli* is contained in a membrane-bounded nucleus.
 - B. Genomic DNA from *E. coli* is attached to cell membrane.
 - C. Genomic DNA from *E. coli* is larger in size. As such, it could be pelleted down by centrifugation, while the plasmid DNA remains in the supernatant.
 - D. Genomic DNA from *E. coli* retains its natural structure but plasmid DNA is denatured.
 - E. Genomic DNA from *E. coli* is denatured but plasmid DNA retains its natural structure.

3. Expression of the beta-galactosidase gene within the pUC18 plasmid in *E. coli* can be induced by:
 - A. X-gal and IPTG
 - B. IPTG and lactose
 - C. Lactose and X-gal
 - D. Peptone and lactose
 - E. IPTG, peptone and lactose

4. You are given following number of F₁ flies.

	Male	Female	Total
wild type	80	60	140
mutant	30	30	60

If the mutation was inherited via a simple autosomal recessive mode, what are the possible parental genotypes?

- A. $w w \times w^+ w^+$
- B. $w^+ w \times w^+ w$
- C. $w^+ w \times w w$
- D. $w^+ w \times w^+ w^+$
- E. None of above

5. If 4% of an isolated large population is born with sickle-cell anemia (ss), what percentage of the population will be heterozygous (Ss) for the sickle-cell gene?

- A. 2%
- B. 8%
- C. 16%
- D. 32%
- E. 64%

6. Which of following statements about **genetic drift** is NOT correct?

- A. The effects of genetic drift are strongest in small populations.
- B. In the longer term, the main result of genetic drift is loss of genetic variation.
- C. Genetic drift results in different populations becoming genetically different from each other.
- D. Genetic drift and gene flow are two different forms of evolution.
- E. Genetic drift tends to make natural selection more likely, and can enhance the effects of natural selection.

7. A gene's phenotypic expression (expressivity) may be influenced by:

- i. Environment
- ii. The alleles of gene
- iii. Other genes
- iv. Non-coding region of the gene

- A. i., ii, iii. and iv.
- B. ii. iii. and iv.
- C. ii. and iii.
- D. iii. and iv.
- E. i. iii. and iv.

8. Gene transfer in animals and plants can be achieved through sexual reproduction, while in bacteria, it can occur through transformation, conjugation and transduction. Which of the following descriptions is NOT correct?

- A. Transformation can occur in the laboratory and in nature.
- B. Conjugation is the direct transmission of DNA from one bacteria cell to another, but is not a replicative process.
- C. Plasmid DNA transfer from donor to recipient by conjugation is usually initiated at specific site, known as *oriT*.
- D. F plasmid can integrate into *E. coli* chromosome.
- E. Competence of *E. coli* cell generally occurs in late log phase.

9. The genetic information of bacteria is stored in chromosome, plasmids and episomes. Which of following descriptions is true regarding the chromosome, plasmids and episomes?

- A. A single bacterial cell can contain two or more identical copies of the chromosome.
- B. Chromosomes of bacteria go through the mitotic but not meiotic cycles during reproduction.
- C. Gene transfer in bacteria is not unidirectional, two cells can exchange their genetic materials by conjugation.
- D. A single bacterial cell usually contains one copy of a particular plasmid.
- E. Bacterial chromosome DNA does not contain non-transcribed region.

10. Which of following event occurs in metaphase of mitosis?

- A. Disappearance of the nuclear membrane.
- B. Splitting of the centromere.
- C. Decondensation of the chromosome.
- D. Movement of chromosomes to the poles.
- E. Formation of the mitotic spindle.

Questions 11 and 12 will require the following information. Given that A^1A^1 = lethal, A^1A^2 = gray, A^2A^2 = black, B^1B^1 = long hair, B^1B^2 = short hair, B^2B^2 = very short hair (fuzzy), and parents that are $A^1A^2B^1B^2$.

11. The fraction of adult offspring that is expected to be gray and fuzzy is:

- A. 1/4
- B. 1/2
- C. 2/3
- D. 3/4
- E. None of the above.

12. If fuzzy is lethal shortly after birth, the fraction of adult progeny expected to be black and short is:

- A. 1/4
- B. 1/3
- C. 1/2
- D. 2/3
- E. None of the above.

13. When a eukaryotic cell divides, the daughter cells:

- A. manufacture all the organelles from material in the cytoplasm.
- B. receive enough of the organelles to start-up the new cells and produce additional organelles, as needed.
- C. produce individual organelles that attach to the spindle fibers and are distributed just like chromosomes.
- D. produce an equal number of organelles distributed to each cell.
- E. get cellular organelles by an unknown process.

14. Which of the stages below does each chromosome consist of two DNA molecules?

- i. metaphase
- ii. telophase
- iii. prophase
- iv. anaphase

- A. iii and iv
- B. i, iii, and iv
- C. i and iii
- D. i, ii, and iii
- E. i, ii, iii, and iv

15. Crossing over is one of the most important events in meiosis because:

- i. it produces new arrays of alleles on chromosomes.
- ii. homologous chromosomes must be separated into different daughter cells.
- iii. the number of chromosomes allotted to each daughter cell must be halved.
- iv. homologous genes must be separated into different daughter cells.

- A. i only
- B. i, ii, and iii
- C. i and iii
- D. ii, and iii
- E. i, ii, iii, and iv

16. Short hair (*L*) is dominant to long hair (*l*). If a short-haired animal of unknown origin is crossed with a long-haired animal and they produce one long-haired and one short-haired offspring, this would indicate that:

- A. the short-haired animal was a pure-breed.
- B. the short-haired animal was not a pure-breed.
- C. the long-haired animal was not a pure-breed.
- D. the long-haired animal was a pure-breed.
- E. none of these can be determined with two offspring.

17. Mendel's dihybrid crosses provided indirect evidence for the following?

- i. independent assortment
- ii. dominance
- iii. linkage
- iv. segregation of factors
- v. presence of two factors in parents and offspring

- A. i only.
- B. i and ii.
- C. i, ii and iii.
- D. i, ii and iv.
- E. i, ii, iv and v.

18. Nondisjunction involving the X chromosomes may occur during oogenesis and produce two kinds of eggs. If normal sperms fertilize these two types, which of the following pairs of genotypes are possible?

- A. XX and XY
- B. XXY and XO
- C. XYY and XO
- D. XYY and YO
- E. none of these

19. The conversion of proinsulin (inactive form) into insulin (active form) by the removal of a portion of the polypeptide chain is an example of:

- A. transcriptional control.
- B. transcript processing control.
- C. transport control.
- D. translational control.
- E. post-translational control.

20. Only identical twins have the same:

- i. genotype.
- ii. phenotype.
- iii. traits.
- iv. behavior.

- A. i only.
- B. i and ii.
- C. i, ii and iii.
- D. i, ii, iii and iv.
- E. none of the above combinations.

21. A tRNA has an anticodon sequence 5'-UGG-3'. What is (i) the codon sequence recognized and (ii) amino acid carried by this tRNA?

- A. 5'-ACC-3', Threonine
- B. 5'-AUC-3', Isoleucine
- C. 3'-ACC-5', Threonine
- D. 3'-CCG-5', Proline
- E. 5'-CCA-3', Proline

22. Which statement(s) below is/are correct regarding RNA transcription?

- i. In eukaryotes, RNA splicing occurs after the mRNA is transported into the cytoplasm.
- ii. Only prokaryotic mRNAs are polyadenylated at the 3' end.
- iii. In prokaryotes, transcription is coupled to translation.
- iv. RNA splicing requires the formation of a spliceosome.
- v. Both prokaryotic and eukaryotic mRNAs are synthesized by RNA polymerase.

- A. ii, iii and iv.
- B. i, iv and v.
- C. ii, iii and iv.
- D. i, iii and v.
- E. iii, iv, and v.

23. What is the sequence of an RNA molecule produced from transcription of the following DNA strand: 5' GCCACGTGCCACGT 3'.

- A. 5' CGGUGCACGGUGCA 3'
- B. 5' UCGTGGCUCGTGGC 3'
- C. 5' ACGTGGCACGTGGC 3'
- D. 5' ACGUGGCACGUGGC 3'
- E. 5' CGGTGCUCGGTGCU 3'

24. Which statement(s) below is/are correct regarding the structures of prokaryotic and eukaryotic mRNAs?

- i. Prokaryotic mRNAs are not processed; the transcript is the actual molecule that is translated.
- ii. Prokaryotic mRNA is colinear with the gene that encoded it.
- iii. Prokaryotic mRNAs do not have 5' caps or 3' poly(A) tails.
- iv. Eukaryotic mRNAs have 5' caps and a 3' poly(A) tail.
- v. Eukaryotic mRNAs have introns removed by RNA splicing before they are transported to the cytoplasm.

- A. iii and iv.
- B. ii, iii and v.
- C. ii, iii and iv.
- D. i, iii, iv and v.
- E. All of the above.

25. Which statement(s) below is/are correct regarding the structural features of A-, B- and Z-DNA.

- i. A- and B-DNA are right-handed helices and the backbones are relatively helical.
- ii. Z-DNA is left-handed and the backbone is rather zigzagged.
- iii. A- and B-DNA have the bases tilted relative to the central axis.
- iv. Z-DNA has bases that are perpendicular to the central axis.
- v. A-DNA occurs under condition of high salt concentration; while Z-DNA occurs under condition of low humidity.

- A. i and ii.
- B. i, ii and iii.
- C. i, iii and v.
- D. ii, iii and iv.
- E. All of the above, except v.

26. The single-stranded RNA molecule below is able to form a stable secondary structure (hairpin). What is the sequence of the loop region (6 nucleotides) of this structure?

5'- AUGCCAUGGCCGAGAUGGGCCAUGGCUA -3'

- A. 5'-AUGCCA-3'
- B. 5'-UGGCCG-3'
- C. 5'-GAGAUG-3'
- D. 5'-GGGCCA-3'
- E. 5'-GGUAGA-3'

27. During DNA replication, which of the following is required by DNA polymerase?

- i. dNTPs
 - ii. RNA primers
 - iii. Tus protein
 - iv. template DNA strand
 - v. phosphodiester bonds
 - vi. telomerase
 - vii. NusA
 - viii. promoter
- A. i, ii and iv.
 B. i, ii, iii, iv and v.
 C. i, ii, iv, v and vi.
 D. ii, iv, v, vi, vii and viii.
 E. i, ii, iv, v, vi and viii.

28. What is the sequence of the polypeptide produced from transcription/translation of the following DNA template (use AUG as the start codon)?

5'- CGGTACTTCCCCGAGCCCCAAGTGCATGGGCC-3'

		Second letter				
		U	C	A	G	
First letter	U	UUU } Phe UUC } UUA } Leu UUG }	UCU } UCC } Ser UCA } UCG }	UAU } Tyr UAC } UAA Stop UAG Stop	UGU } Cys UGC } UGA Stop UGG Trp	U C A G
	C	CUU } CUC } Leu CUA } CUG }	CCU } CCC } Pro CCA } CCG }	CAU } His CAC } CAA } Gln CAG }	CGU } CGC } Arg CGA } CGG }	U C A G
	A	AUU } AUC } Ile AUA } AUG Met	ACU } ACC } Thr ACA } ACG }	AAU } Asn AAC } AAA } Lys AAG }	AGU } Ser AGC } AGA } Arg AGG }	U C A G
	G	GUU } GUC } Val GUA } GUG }	GCU } GCC } Ala GCA } GCG }	GAU } Asp GAC } GAA } Glu GAG }	GGU } GGC } Gly GGA } GGG }	U C A G

- A. Arg-Try-Phe-Pro-Glu-Pro-Gln-Val-His-Gly-Pro
 B. Ala-Met-Lys-Gly-Leu-Gly-Val-His-Val-Pro-Gly
 C. Met-Lys-Gly-Leu-Gly-Val-His-Val-Pro-Gly
 D. Met-His-Leu-Gly-Leu-Gly-Glu-Val-Pro
 E. Gly-Pro-Met-His-Leu-Gly-Leu-Gly-Glu-Val-Pro

29. Which statement(s) below is/are correct?

- i. Chargaff's results would probably not be very convincing if done on a single species.
- ii. The purpose of chromatography is to separate DNA of different length.
- iii. The Avery, MacLeod, and McCarty experiment would have failed if RNA was the genetic material.
- iv. Using isotope (³⁵S and ³²P) labeled T2 phages, Hershey and Chase provided evidence that genetic material injected into bacterial is DNA, and not protein.
- v. Based on Griffith's and their own experiments, Avery *et al.* proposed the term "transformation".

- A. i, ii, and iv
- B. i, iii, and iv
- C. i and iv
- D. i, iv and v
- E. ii, iii, and iv

30. Which statement(s) below is/are correct regarding DNA replication?

- i. In the lagging strand, many short pieces of DNA are made and this requires many RNA primers and DNA polIII.
- ii. RNA primers are removed by PolI, which then fills in the gaps with DNA.
- iii. DNA ligase covalently connects the Okazaki fragments together.
- iv. The 3' overhang binds to the complementary RNA in telomerase. For this reason, a 3' overhang is necessary for telomerase to replicate the telomere.
- v. Telomerase is different from DNA polymerase in that it uses a short RNA sequence, which is part of its structure, as a template for DNA synthesis.

- A. i, iii and iv.
- B. iii, iv and v.
- C. i, iv and v.
- D. ii, iii, and v.
- E. All of the above.

Chi-square values

Df	P=.99	.95	.80	.50	.20	.05	.01
1	.000157	.00393	.0642	.4550	1.642	3.841	6.639
2	.0201	.103	.446	1.386	3.219	5.991	9.210
3	.115	.352	1.005	2.366	4.642	7.815	11.345
4	.297	.711	1.649	3.357	5.989	9.488	13.277
5	.554	1.145	2.343	4.351	7.289	11.070	15.086
6	.872	1.635	3.070	5.348	8.558	12.592	16.812
7	1.239	2.167	3.822	6.346	9.803	14.067	18.475
8	1.646	2.733	4.594	7.344	11.030	15.507	20.090
9	2.088	3.325	5.380	8.343	12.242	16.919	21.666
10	2.558	3.940	6.179	9.342	13.442	18.307	23.209
15	5.229	7.261	10.307	14.339	19.311	24.996	30.578
20	8.260	10.851	14.578	19.337	25.038	31.410	37.566
25	11.524	14.611	18.940	24.337	30.675	37.652	44.314

SECTION II – STRUCTURED QUESTIONS
ANSWER ALL QUESTIONS.

1. You are provided an *E. coli* DH5 α strain and the pUC18 plasmid with other essential laboratory materials. Please design an experiment to demonstrate how the plasmid DNA can affect the phenotype of the DH5 α strain.
 - a). List the experimental protocols with proper negative control, but do eliminate unnecessary steps.
 - b). What kind of phenotypes will you be able to observe/measure?
 - c). Explain the underlying mechanism of what has been observed above.(10 marks)

2.
 - a). Explain briefly why telomeric sequences are needed? (3 marks).
 - b). Why do the overhang sequences occur only in the 3' end of the template strand? (3 marks).
 - c). Why would the chromosome become progressively shorter with each round of DNA replication without the presence of telomerase. (4 marks).

3.
 - a). In garden pea, homozygosity for a recessive allele at the *A* locus causes white flowers, transparent seed coats, and absence of a purple ring at the leaf axils. Homozygosity at the *B* locus causes white flowers but does not prevent colouration of the seed coats and leaf axils. Explain briefly (in one paragraph and you may use diagrams) using a plausible biochemical model why one gene may show pleiotropy while another that affects the same trait does not. (3 marks).
 - b). In sweet pea, crosses between certain varieties of true-breeding white-flowered plants yield F₁ progeny that are all purple-flowered, a dominant phenotype. If the F₁ plants are self-pollinated, the progeny segregate in a 9 purple-flowered:7 white-flowered ratio. What is this type of epistatic interaction called? (1 mark).
 - c). In the sweet pea example, briefly (in not more than one paragraph each and you may use diagrams to illustrate your point) give TWO different but plausible biochemical models explaining how this type of epistatic interaction could be explained. (3 marks each).

4. A group of native subsistence farmers in eastern Africa, where malaria is common, were evaluated. They are the most ancient population in the area, and there is little intermarriage outside the population. A total of 875 adults from that population (representing approximately 60% of the entire population) were evaluated. Among these, 626 were homozygous for the *A* allele of the beta-globin gene (*HBB***A*/**A*), 249 were heterozygous *HBB***A*/**S*, and none were homozygous *HBB***S*/**S* (the sickle-cell allele).
 - a). Determine the frequency of *HBB***S* and *HBB***A* alleles in this sample, and determine whether or not the population is in Hardy-Weinberg equilibrium. (5 marks).
 - b). Determine the relative fitness values for the three genotypes under the assumption that the population is in a balanced polymorphism equilibrium. (5 marks).(Note: The chi-square value distribution is given in the previous page).

END OF PAPER