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Molecular Genetics

Quiz 2

DNA Structure & Organization

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I

PART ONE

Multiple Choice

Choose the one best answer for each question

QUESTIONS 1 – 50

01 Miescher's precipitate 'nuclein' was notable for containing carbon, hydrogen, oxygen, nitrogen and a high percentage of:

A Magnesium
B Manganese
C Potassium
D Phosphorus

02 The flow of information from RNA back to DNA is called:

A Translation of mRNA
B Semiconservative replication
C Reverse transcription
D Protein denaturation

03 Structurally, a purine consists of:

A A single six-membered pyrimidine ring only
B A pyrimidine ring fused to an imidazole ring
C A furanose sugar ring fused to a pyrimidine
D Two fused five-membered imidazole rings only

04 Which ribonucleoside–ribonucleotide pairing is correct?

A Cytidine — CMP (cytidylate)
B Uridine — dTMP (thymidylate)
C Guanosine — dGMP (deoxyguanylate)
D Adenosine — dAMP (deoxyadenylate)

05 Which bases are found in BOTH DNA and RNA?

A Adenine, thymine and uracil only
B Guanine, uracil and thymine
C Cytosine, thymine and uracil
D Adenine, guanine and cytosine

06 Stacking interactions stabilise DNA because stacked base pairs form:

A Covalent bonds between the bases
B Ionic bonds with the phosphate groups
C van der Waals contacts that add up
D Glycosidic bonds with the sugars

07 The number of base pairs per helical turn in B-DNA is about:

A 3.4–3.57
B 10.4–10.5
C 2.0–2.37
D 0.33–0.34

08 **In 1869, Friedrich Miescher obtained nuclei for study by treating:**

- A Red blood cells from plasma with NaOH
- B White blood cells from pus with HCl
- C Bacterial cultures with acetone
- D Liver tissue with phenol and salt

09 **In naturally occurring nucleotides, the phosphoryl group is usually attached to the:**

- A Nitrogen of the base through a β-N-glycosidic bond
- B Oxygen of the 2′-hydroxyl by a peptide linkage
- C Oxygen of the 5′-hydroxyl by a phosphoester bond
- D Carbon 1′ of the sugar by a hydrogen bond only

10 **A nucleotide is composed of:**

- A Hexose sugar, a sulphate group and a base
- B Pentose sugar, phosphate(s) and a base
- C Pentose sugar, an amino acid and a base
- D Ribose sugar, glycerol and a phosphate

11 **Which base is found mainly in deoxyribonucleotides and is described as 5-methyl-uracil?**

- A Cytosine
- B Thymine
- C Uracil
- D Guanine

12 **The deoxyribonucleoside containing adenine is called:**

- A Deoxyadenosine
- B Adenosine
- C Deoxyadenylate
- D Deoxyguanosine

13 **Which interaction is a potential source of INSTABILITY in DNA?**

- A Stacking of hydrophobic base pairs together
- B Hydrogen bonding between the paired bases
- C Repulsion between negative phosphate groups
- D Burying the bases inside the helix interior

14 **DNA is about 2 m long per cell yet fits in a nucleus a few micrometres wide. Which is NOT listed as a reason for packaging DNA tightly?**

- A To save space in the tiny nucleus
- B To protect the DNA from damage
- C To distribute DNA evenly at division
- D To increase the rate of translation

15 How many hydrogen bonds hold together a G–C pair and an A–T pair, respectively?

A 2 and 3
B 3 and 2
C 3 and 3
D 2 and 2

16 The furanose ring found in nucleotide sugars is a five-membered ring made of:

A Five carbon atoms and no oxygen atom
B Three carbon atoms and two oxygen atoms
C Four carbon atoms and one nitrogen
D Four carbon atoms and one oxygen atom

17 The genome is defined as:

A The full set of proteins made by a single cell
B The entire genetic information of an organism
C The DNA found inside the mitochondria alone
D All of the RNA molecules present in the nucleus

18 The rise (distance between consecutive bases) and the helix diameter of B-DNA are, respectively:

A 2.37 nm and 0.33 nm
B 0.33 nm and 2.37 nm
C 3.4 nm and 2.37 nm
D 0.33 nm and 3.57 nm

19 Early experiments showing equal amounts of purines and pyrimidines were explained by the Watson–Crick model, which proposed that DNA is:

A Single-stranded with random pairing of the bases
B Triple-stranded with A–G and T–C base pairs
C Double-stranded with A–C and G–T base pairs
D Double-stranded with specific A–T and G–C pairs

20 Which statement about mRNA is correct?

A It makes up most cellular RNA and is very stable
B It carries activated amino acids to ribosomes
C It is the ribozyme of the large ribosomal subunit
D It makes up only 3% of RNA and is least stable

21 A nucleosome consists of about 200 bp of DNA wrapped around:

A A histone octamer (two each of H2A, H2B, H3, H4)
B A histone tetramer with one each of H1 to H4
C Eight copies of histone H1 joined together in a ring
D Two copies each of H1, H2A, H3 and H4 histones

22 **Which sequence correctly represents the central dogma?**

A DNA → RNA → protein
B RNA → DNA → protein
C Protein → RNA → DNA
D DNA → protein → RNA

23 **Using the B-DNA rise of 0.33 nm per base pair, what is the length of a 1,000 bp DNA segment?**

A 33 nm
B 330 nm
C 3,300 nm
D 3.3 nm

24 **In nucleosides, the β-N-glycosidic bond connects:**

A C-1′ of sugar to N-1 (pyrimidine) or N-9 (purine)
B C-5′ of sugar to N-9 (pyrimidine) or N-1 (purine)
C C-3′ of sugar to N-3 of both purine and pyrimidine
D C-2′ of sugar to N-7 (purine) or N-3 (pyrimidine)

25 **Which pairing of year and milestone is correct?**

A 1953 — Avery, MacLeod and McCarty
B 1869 — Watson and Crick double helix
C 1944 — Avery, MacLeod and McCarty
D 1944 — Watson and Crick double helix

26 **The 11 nm level of DNA packaging corresponds to:**

A The 30 nm solenoid chromatin fibre
B The 300 nm looped chromatin domains
C The 1400 nm condensed chromosome
D Nucleosomes ('beads on a string')

27 **Because DNA strands are complementary, each strand can:**

A Serve as a template for the other
B Code for a different protein
C Replicate without the other strand
D Bind only to RNA molecules

28 **Histones can bind DNA tightly because they are rich in:**

A Acidic residues such as aspartate and glutamate
B Basic residues such as arginine and lysine
C Hydrophobic residues such as leucine and valine
D Sulphur residues such as cysteine and methionine

29 **Which sequence correctly orders DNA packaging levels by size?**

A 11 nm helix → 2 nm → 30 nm → 300 nm → 1400 nm → 700 nm
B 2 nm helix → 30 nm → 11 nm → 700 nm → 300 nm → 1400 nm
C 2 nm helix → 11 nm → 30 nm → 300 nm → 700 nm → 1400 nm
D 2 nm helix → 11 nm → 300 nm → 30 nm → 1400 nm → 700 nm

30 **B-DNA, the form commonly found in living cells, is a:**

- A Left-handed helix with major and minor grooves
- B Right-handed helix with no distinct grooves at all
- C Left-handed helix with a single shallow groove
- D Right-handed helix with major and minor grooves

31 **Two DNA samples are heated while A260 is monitored. Sample X is rich in A–T pairs; sample Y is rich in G–C pairs. Which observation is expected?**

- A Y denatures at a lower temperature than X
- B X denatures at a lower temperature than Y
- C Both denature at exactly the same temperature
- D Neither shows any change in absorbance

32 **The two sugar–phosphate backbones of the DNA double helix are described as:**

- A Parallel — both strands running 5′→3′
- B Parallel — both strands running 3′→5′
- C Antiparallel — one 5′→3′, the other 3′→5′
- D Perpendicular to the long axis of the helix

33 **Deoxythymidine 5′-monophosphate is also called:**

- A UMP, uridylate
- B dCMP, deoxycytidylate
- C TTP, triphosphate
- D dTMP, thymidylate

34 **The melting point (Tm) of DNA is the temperature at which:**

- A All of the DNA has become single-stranded
- B Half the DNA has become single-stranded
- C The DNA begins to absorb light at 280 nm
- D Histones dissociate from the nucleosomes

35 **The 5′-monophosphate ester of adenosine is known as:**

- A AMP (adenylate)
- B dAMP (deoxyadenylate)
- C ADP (diphosphate)
- D Adenine (free base)

36 **Which statement about the genomes of individuals is correct according to the notes?**

- A All members of a species share one sequence
- B With rare exceptions, no two are identical
- C Only identical bacteria differ in sequence
- D Genome sequence never varies within humans

37 **Enzymatic copying of DNA information during the synthesis of RNA is called:**

A Transcription
B Translation
C Replication
D Denaturation

38 **Which statement about genomes is correct?**

A All genomes are composed only of DNA
B Bacterial genomes are always multiple RNAs
C Eukaryotic genomes lie in the cytoplasm
D Some viral genomes are composed of RNA

39 **A nucleoside consists of:**

A A sugar and a heterocyclic base
B A sugar, a base and a phosphate
C A base and one phosphate group
D A sugar and one phosphate group

40 **Primes (1′, 2′, 3′ …) are used in nucleoside numbering to:**

A Distinguish purine rings from pyrimidines
B Mark the atoms that carry phosphate groups
C Distinguish sugar atoms from base atoms
D Show the atoms joined by hydrogen bonds

41 **The human genome is stated to contain 3,200,000 kb of DNA. Expressed in base pairs, this equals:**

A 3.2×10^{6} bp
B 3.2×10^{12} bp
C 3.2×10^{3} bp
D 3.2×10^{9} bp

42 **Electrostatic repulsion in DNA is minimised by:**

A Cl^- and anionic proteins such as serum albumin
B Water molecules entering the helix core
C Mg^{2+} and cationic proteins such as histones
D Extra phosphate groups on the backbone

43 **A DNA sample is analysed and found to contain 30% adenine. Using the base-pairing rules, the percentages of thymine, guanine and cytosine are:**

A T 20%, G 30%, C 20%
B T 30%, G 30%, C 10%
C T 30%, G 20%, C 20%
D T 70%, G 15%, C 15%

44 **Why was the name 'nuclein' later changed to 'nucleic acid'?**

A It was found to be strongly acidic
B It was found inside the cytoplasm
C It was found to contain much protein
D It was found to be strongly basic

45 DNA is a linear polymer of deoxyribonucleotide residues linked by:

A β-N-glycosidic bonds
B Hydrogen bonds between bases
C 3′–5′ phosphodiester bonds
D 1′–4′ glycosidic linkages

46 Ribose and deoxyribose differ at which position of the sugar?

A 3′ — ribose has –H, deoxyribose has –OH
B 5′ — ribose has phosphate, deoxyribose none
C 2′ — ribose has –OH, deoxyribose has –H
D 1′ — ribose binds base, deoxyribose does not

47 Using 10.5 base pairs per turn, how many complete helical turns does a 210 bp segment of B-DNA make?

A 20 turns
B 10 turns
C 21 turns
D 2 turns

48 The '5′-end' of a linear polynucleotide is so called because:

A No residue is attached to its 3′-carbon
B It always carries a free 5′ base
C It carries the 5′ hydrogen bond pair
D No residue is attached to its 5′-carbon

49 A short double-stranded DNA segment contains 6 A–T base pairs and 4 G–C base pairs. How many hydrogen bonds hold the two strands together?

A 24
B 20
C 26
D 30

50 Purines and pyrimidines can absorb ultraviolet light because they are:

A Unsaturated with conjugated double bonds
B Saturated with only single C–C bonds
C Joined by 3′–5′ phosphodiester linkages
D Positively charged at every possible pH value

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II

PART TWO

True or False

Tick one box for each statement

STATEMENTS 1 – 15

NO.	STATEMENT	T	F
01	The pitch of one complete B-DNA helical turn is 0.33 nm.	☐	☐
02	Hydrogen bonding between base pairs is a significant stabilising force in DNA.	☐	☐
03	Uracil is found mainly in ribonucleotides.	☐	☐
04	Humans have 46 chromosomes.	☐	☐
05	RNAs are single-stranded but often form complex secondary structures.	☐	☐
06	The sugars in nucleic acids are in the α-conformation of the furanose ring.	☐	☐
07	A nucleoside contains a sugar, a base and one or more phosphate groups.	☐	☐
08	All nucleotide residues within a polynucleotide chain have the same orientation.	☐	☐
09	Double-stranded DNA absorbs more light at 260 nm than single-stranded DNA.	☐	☐
10	Miescher knew at the time that he had discovered DNA.	☐	☐
11	Eukaryotes have three types of histones.	☐	☐
12	A genome may consist of a single DNA molecule, as in many species of bacteria.	☐	☐
13	The genome of eukaryotes is one complete set of DNA molecules found in the nucleus.	☐	☐
14	Watson and Crick proposed the DNA double helix model in 1953.	☐	☐
15	tRNA molecules are typically 730 to 950 nucleotides long.	☐	☐

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PART THREE

III Matching

Match each term (Column A) with its description (Column B). Two options in Column B are not used.

ITEMS 1 – 8

COLUMN A		COLUMN B	
1	Nuclein	A	Nucleoside plus phosphoryl group(s)
2	Nucleoside	B	A 30 nm fibre forming loops of 700 nm
3	Nucleotide	C	Carries activated amino acids to ribosomes
4	Denaturation	D	DNA plus proteins packaged in eukaryotic cells
5	Chromatin	E	Miescher's phosphorus-rich precipitate from nuclei
6	Ribosomal RNA	F	Binds to the exterior of the nucleosome
7	Transfer RNA	G	Ribozyme forming the main part of ribosomes
8	Histone H1	H	Sugar plus a heterocyclic base
		I	Copies the DNA sequence to encode amino acids
		J	Complete unwinding into two single strands

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IV

PART FOUR

Short Answer

Answer each question in the space provided

QUESTIONS 1 – 5

S1 Discovery of DNA — 4 MARKS

(a) Describe Miescher's experiment and how nuclein got its names.

(b) State the 1944 and 1953 milestones.

S2 Nucleosides and nucleotides — 5 MARKS

(a) Define a nucleoside and describe the glycosidic bond and numbering system.

(b) Define a nucleotide, state where phosphate attaches, and name the 5′-monophosphates of adenosine and deoxythymidine.

S3 The double helix — 6 MARKS

(a) Describe the Watson–Crick double helix: strands, orientation, base pairing and hydrogen bonds.

(b) A 21 bp B-DNA segment contains 9 G–C pairs. Calculate its hydrogen bonds, length and number of turns.

S4 Forces stabilising DNA — 5 MARKS

(a) Describe the four types of interactions affecting DNA conformation.

(b) Explain how repulsion is minimised.

S5 DNA packaging and melting — 6 MARKS

(a) List the levels of DNA packaging with their sizes, and describe a nucleosome.

(b) Define denaturation and Tm, and explain why G–C-rich DNA melts at a higher temperature.

SOLUTIONS

Answer Key

Check your work, then review the model answers

TOTAL MARKS 99

PART I · MULTIPLE CHOICE

01	02	03	04	05	06	07	08	09	10
D	C	B	A	D	C	B	B	C	B
11	12	13	14	15	16	17	18	19	20
B	A	C	D	B	D	B	B	D	D
21	22	23	24	25	26	27	28	29	30
A	A	B	A	C	D	A	B	C	D
31	32	33	34	35	36	37	38	39	40
B	C	D	B	A	B	A	D	A	C
41	42	43	44	45	46	47	48	49	50
D	C	C	A	C	C	A	D	A	A

PART II · TRUE OR FALSE

01	02	03	04	05	06	07	08	09	10
FALSE	TRUE	TRUE	TRUE	TRUE	FALSE	FALSE	TRUE	FALSE	FALSE
11	12	13	14	15					
FALSE	TRUE	TRUE	TRUE	FALSE					

PART III · MATCHING

1 → E	2 → H	3 → A	4 → J	5 → D	6 → G	7 → C	8 → F

PART IV · MODEL ANSWERS

S1 Discovery of DNA

(a) In 1869 Friedrich Miescher treated white blood cells (from pus on surgical bandages) with hydrochloric acid to obtain nuclei; a precipitate containing C, H, O, N and a high percentage of phosphorus formed. He called it 'nuclein' because it came from nuclei; when found to be strongly acidic it was renamed nucleic acid — he had unknowingly discovered DNA. (b) 1944: Avery, MacLeod and McCarty showed DNA carries genetic information. 1953: Watson and Crick proposed the double helix model.

S2 Nucleosides and nucleotides

(a) Nucleoside = sugar (ribose or deoxyribose) + heterocyclic base; a β-N-glycosidic bond links C-1′ of the sugar to N-1 of a pyrimidine or N-9 of a purine. Base atoms are numbered 1, 2, 3…; sugar atoms carry primes (1′, 2′, 3′…). (b) Nucleotide = nucleoside + phosphoryl group(s); usually attached to the oxygen of the 5′-hydroxyl by a phosphoester bond (1, 2 or 3 phosphates at 3′ or 5′). AMP (adenylate); dTMP (deoxythymidylate or thymidylate).

S3 The double helix

(a) Two polynucleotide strands wrap around each other; their sugar–phosphate backbones are antiparallel (5′→3′ and 3′→5′); bases pair specifically A with T (2 H-bonds) and G with C (3 H-bonds); strands are complementary, each a template for the other; B-DNA is right-handed with major and minor grooves. (b) 9 G–C × 3 = 27 and 12 A–T × 2 = 24 → 51 hydrogen bonds. Length = 21 × 0.33 nm ≈ 6.9 nm. Turns = 21 ÷ 10.5 = 2 turns.

S4 Forces stabilising DNA

(a) Stacking interactions — stacked base pairs form weak van der Waals contacts that add up to stabilise large DNA; hydrogen bonds between base pairs — a significant stabilising force; hydrophobic effects — burying hydrophobic purine and pyrimidine rings inside the helix increases stability; charge–charge interactions — electrostatic repulsion of negatively charged phosphates is a potential source of instability. (b) Repulsion is minimised by cations such as Mg^{2+} and cationic proteins such as histones (rich in arginine and lysine).

S5 DNA packaging and melting

(a) 2 nm double helix → 11 nm nucleosomes (beads on a string) → 30 nm chromatin fibre → 300 nm chromatin loops → 700 nm condensed chromatin → 1400 nm condensed chromosome. A nucleosome is ~200 bp of DNA wrapped around a histone octamer (two each of H2A, H2B, H3, H4), with H1 bound to the exterior. (b) Denaturation: complete unwinding and separation into two single strands by heat or chemicals. Tm: temperature at which half the DNA is single-stranded. G–C pairs have three hydrogen bonds vs two for A–T, so G–C-rich DNA needs a higher temperature (A–T-rich DNA denatures at a lower temperature).

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