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ACADEMY
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QUESTION BANK

SEMESTER 1

MOLECULAR GENETICS (CBG)

Lecture 1 - Structure and function of nucleotide & nucleoside

Part 1: MCQs (Choose the correct answer):

1. A 55-year-old man attends the emergency department with a hot, red and extremely painful great toe. His serum uric acid is raised and aspiration of the joint shows urate crystals. Uric acid belongs to which of the following groups of bases?

A. The major purine bases of nucleic acids
B. The minor nitrogenous bases, which are other purine metabolites
C. The pyrimidine bases found in DNA
D. The pentose sugars of the nucleic acids
E. The synthetic nucleotide analogues

2. The same patient is started on allopurinol. This drug is a synthetic analogue of which of the following bases?

A. Adenine
B. Guanine
C. Hypoxanthine
D. Cytosine
E. Uracil

3. In the same patient, by which mechanism does this drug lower the level of uric acid?

A. It raises the urinary excretion of hypoxanthine
B. It blocks the action of xanthine oxidase by substrate competition
C. It changes uric acid back into xanthine and then into hypoxanthine
D. It donates a methyl group to xanthine
E. It lowers the synthesis of thymine

4. A 48-year-old woman with carcinoma of the colon begins chemotherapy with 5-fluorouracil. This drug is an analogue of which of the following?

A. A purine base (hypoxanthine)
B. A pyrimidine base (uracil)
C. The pentose sugar of DNA
D. The phosphate group of a nucleotide
E. A second messenger of hormone action

5. In the same patient, which of the following explains the action of this drug on the tumour cells?

A. It raises the level of uric acid inside the tumour cells
B. It lowers thymine synthesis, so DNA synthesis and the growth of the cancer cells fall
C. It competes with xanthine oxidase for its substrate
D. It removes the ribose from the RNA of the tumour cells
E. It donates sulfate groups for the synthesis of sulfolipids

6. A student is asked in a tutorial to describe the chemistry of nucleic acids. Which of the following is the correct composition of a nucleotide?

A. A nitrogenous base and a pentose sugar only
B. A nitrogenous base and a phosphate group only
C. A nitrogenous base, a pentose sugar and phosphoric acid
D. A pentose sugar and phosphoric acid only
E. Two nitrogenous bases attached to one pentose sugar

7. In the same tutorial, the student is asked how the base is joined to the sugar in a nucleoside. Which of the following is correct?

A. N9 of a purine and N1 of a pyrimidine are joined to carbon 1 of the sugar by an N-glycosidic bond
B. N1 of a purine and N9 of a pyrimidine are joined to carbon 5 of the sugar by an ester bond
C. The base is joined to carbon 3 of the sugar by a phosphodiester bond
D. The base is joined to the phosphate group by an acid anhydride bond
E. The base is joined to carbon 2 of the sugar by a hydrogen bond

8. A researcher compares the pentose sugar present in DNA with the one present in RNA. Which of the following is the difference?

A. The sugar of DNA carries one extra carbon atom
B. The sugar of DNA has lost the oxygen of carbon 2
C. The sugar of DNA has lost the oxygen of carbon 5
D. The sugar of DNA carries an extra phosphate group
E. The sugar of DNA is a hexose, while that of RNA is a pentose

9. Phosphoric acid (H_3PO_4) is one of the three components of a nucleotide. To which carbon of the sugar is it attached, and by which bond?

A. Carbon 1, by an N-glycosidic bond
B. Carbon 2, by a hydrogen bond
C. Carbon 3, by a phosphodiester bond
D. Carbon 5, by an ester bond
E. Carbon 5, by an acid anhydride bond

10. A nitrogenous base built of a single ring is described as 2,4-dioxo pyrimidine, and it is present in RNA. Which base is this?

A. Thymine
B. Cytosine
C. Uracil
D. Adenine
E. Guanine

11. In the ribonucleotide series, hypoxanthine gives rise to which nucleoside and which nucleotide?

A. Adenosine and AMP
B. Xanthosine and XMP
C. Inosine and IMP
D. Uridine and UMP
E. Cytidine and CMP

12. A molecule is built of thymine, deoxyribose and a single phosphate group. What is the name of this molecule?

A. Deoxythymidine monophosphate (dTMP)
B. Deoxythymidine triphosphate (dTTP)
C. Deoxythymidine, a nucleoside
D. Deoxycytidylic acid (dCMP)
E. Uridine monophosphate (UMP)

13. Adenosine triphosphate (ATP) is described as a high-energy compound. Which of the following is the reason?

A. The N-glycosidic bond between adenine and ribose
B. The hydrolytic energy associated with its acid anhydride bonds
C. The ester bond between the first phosphate and carbon 5
D. The hydrogen bonds holding its two strands together
E. The presence of two rings in its nitrogenous base

14. A physician explains that one nucleotide supplies the methyl groups needed for the transmethylation reactions of the body. Which nucleotide is this?

A. Cyclic AMP
B. Phosphoadenosine-phospho-sulfate (PAPS)
C. S-adenosyl methionine (SAM)
D. UDP-glucose
E. CDP-ethanolamine

15. Which of the following nucleotides supplies the sulfate group needed for the synthesis of sulfolipids?

A. SAM
B. Phosphoadenosine-phospho-sulfate (PAPS)
C. CDP-choline
D. Cyclic GMP
E. NAD

16. A hormone binds to a receptor on the surface of its target cell, and cyclic AMP then rises inside that cell. Which function of nucleotides is served by cyclic AMP here?

A. A building block of DNA and RNA
B. A source of energy for the cell
C. A second messenger that mediates the action of the hormone
D. A chemical group donor
E. A co-enzyme of the surface receptor

17. NAD, FAD and coenzyme A are all built from nucleotides. Which function of nucleotides is represented by these three compounds?

A. Building blocks of the nucleic acids
B. Co-enzymes
C. Second messengers
D. Sulfate donors
E. Synthetic analogues

18. Which of the following activated compounds is used by the cell for the synthesis of glycogen?

A. CDP-choline
B. CDP-ethanolamine
C. UDP-glucose
D. PAPS
E. SAM

19. In a polynucleotide chain, which bond joins one nucleotide to the next, and between which two groups is it formed?

A. A hydrogen bond, between the bases of the two nucleotides
B. An N-glycosidic bond, between the base and the sugar
C. A 3',5' phosphodiester bond, between the 3'-OH of one nucleotide and the 5'-phosphate of the next
D. An ester bond, between the phosphate groups of the two strands
E. An acid anhydride bond, between two neighbouring sugars

20. A student writes a DNA sequence as 5' GCA 3'. Which of the following is true of the two ends of this strand?

A. The 5' end carries a free phosphate group and the 3' end carries a free hydroxyl group
B. The 5' end carries a free hydroxyl group and the 3' end carries a free phosphate group
C. Both ends carry free phosphate groups
D. Both ends carry free hydroxyl groups
E. The two ends are alike, so the sequence may be written in either direction

21. Which of the following describes the secondary structure of most of the DNA occurring in nature?

A. A right-handed double helix, the sugar-phosphate backbone outside and the base pairs stacked in the centre
B. A left-handed double helix, with the bases lying outside the molecule
C. A right-handed single-stranded helix carrying its bases in the centre
D. A double helix in which the two strands run in the same direction
E. A triple-stranded molecule held together by ester bonds

22. A sample of double-stranded DNA is analysed and guanine is found to form 15% of the total bases. What is the percentage of adenine in this sample?

A. 15%
B. 30%
C. 35%
D. 70%
E. 85%

23. A left-handed double-helical form of DNA is met with in sequences that are rich in G and C, and it may have a role in gene regulation. What is this form called?

A. A-DNA
B. B-DNA
C. Z-DNA
D. Watson and Crick DNA
E. Single-stranded DNA

24. The total RNA of a eukaryotic cell is extracted. One type forms about 80% of it and is attached to several proteins. Which type is this, and what does it build?

A. Messenger RNA; it builds the codons of the protein
B. Transfer RNA; it builds the anticodons
C. Ribosomal RNA; it joins with proteins to build the ribosome
D. Small nuclear RNA; it builds the nuclear membrane
E. Heterogeneous nuclear RNA; it builds the poly-A tail

25. Another type of RNA in the same extract forms 15% of the total and shows a clover-leaf appearance. What holds this shape stable?

A. Phosphodiester bonds between the loops
B. Hydrogen bonds between the complementary bases (A=U and G to C)
C. Ester bonds between the sugar and the phosphate
D. N-glycosidic bonds between the bases and the sugars
E. Acid anhydride bonds at the acceptor stem

Part 2: Essay / Short-Answer Questions:

1. A 55-year-old man is admitted with a hot, swollen and acutely painful great toe. His serum uric acid is raised and urate crystals are seen in the joint fluid. He is started on allopurinol. Explain, on a biochemical basis, the group of bases from which the crystallised substance is derived and how this drug lowers it.

2. A 48-year-old woman with carcinoma of the colon is receiving 5-fluorouracil as part of her chemotherapy.

a. How are the synthetic nucleotide analogues prepared?

b. To which family of bases does this drug belong, and name the analogue used in the treatment of gout.

c. Explain the mechanism by which this drug lowers the growth of the cancer cells.

3. Define the following terms:

A. Nucleoside:

B. Nucleotide:

C. Z-DNA:

4. As regards RNA, answer the following:

a) Mention the structure of RNA and the types of nucleotides it contains.

b) Name the only type of RNA that is translated, and mention the three regions into which it is divided.

c) Describe the appearance of transfer RNA and mention what stabilises it.

d) Enumerate the four types of RNA with the percentage of each:

1.
2.
3.
4.

5. A sample of double-stranded DNA is analysed and thymine is found to represent 12% of the total bases. What is the percentage of guanine in this sample, and on which rule is your calculation based?

6. Mention the name of each of the following:

#	Description	Answer
1	The bond that links the nitrogenous base to carbon 1 of the pentose sugar	
2	The nucleotide that acts as the methyl donor in the transmethylation reactions	
3	The activated compound used for the synthesis of glycogen	
4	The rare left-handed double-helical form of DNA found in G-C rich sequences	
5	The type of RNA that forms about 80% of the total cellular RNA	

Part 1: MCQ Answer Key (with slide references)

1. B – The minor nitrogenous bases, which are other purine metabolites Slide 13 (xanthine, hypoxanthine and uric acid are not usually found in nucleic acids)
2. C – Hypoxanthine Slide 24 (allopurinol is a hypoxanthine analogue used for the treatment of gout)
3. B – It blocks the action of xanthine oxidase by substrate competition Slide 24 (hypoxanthine is therefore not changed into xanthine and then into uric acid)
4. B – A pyrimidine base (uracil) Slide 24 (5-fluorouracil is a pyrimidine analogue used as an anti-cancer drug)
5. B – It lowers thymine synthesis, so DNA synthesis and the growth of the cancer cells fall Slide 24 (analogues are prepared by altering the base ring or the sugar part)
6. C – A nitrogenous base, a pentose sugar and phosphoric acid Slides 7 & 15 (ribose in RNA and 2-deoxyribose in DNA)
7. A – N9 of a purine and N1 of a pyrimidine are joined to carbon 1 of the sugar by an N-glycosidic bond Slide 14 (this is how a nucleoside is formed)
8. B – The sugar of DNA has lost the oxygen of carbon 2 Slide 8 (deoxyribose is present in DNA and ribose in RNA)
9. D – Carbon 5, by an ester bond Slide 9 (phosphoric acid is attached to C5 of the sugar)
10. C – Uracil Slide 12 (thymine is 2,4-dioxo, 5-methyl pyrimidine and is found in DNA instead)
11. C – Inosine and IMP Slide 16 (xanthine gives the nucleoside xanthosine and the nucleotide XMP)
12. A – Deoxythymidine monophosphate (dTMP) Slide 17 (also called deoxythymidylic acid)
13. B – The hydrolytic energy associated with its acid anhydride bonds Slide 15 (nucleoside di- and triphosphates are high-energy compounds)
14. C – S-adenosyl methionine (SAM) Slides 18 & 23 (SAM is the methyl donor of the transmethylation reactions)
15. B – Phosphoadenosine-phospho-sulfate (PAPS) Slides 19 & 23 (PAPS is the sulfate donor for the synthesis of sulfolipids)
16. C – A second messenger that mediates the action of the hormone Slides 20 & 22 (cyclic AMP and cyclic GMP are the second messengers)
17. B – Co-enzymes Slide 22 (other functions are building blocks, source of energy and mediation of hormone action)
18. C – UDP-glucose Slide 23 (CDP-choline and CDP-ethanolamine are used for phospholipid synthesis)
19. C – A 3',5' phosphodiester bond, between the 3'-OH of one nucleotide and the 5'-phosphate of the next Slides 27 & 42 (a phosphate links the 3' carbon of one sugar to the 5' carbon of the next)
20. A – The 5' end carries a free phosphate group and the 3' end carries a free hydroxyl group Slide 28 (this is the polarity of the strand; sequences are written 5' to 3')
21. A – A right-handed double helix, the sugar-phosphate backbone outside and the base pairs stacked in the centre Slide 29 (this is the Watson and Crick DNA, the B-form)
22. C – 35% Slide 33 (15% G = 15% C, a total of 30%; A + T = 70%, so A = 35% and T = 35%)
23. C – Z-DNA Slide 32 (its biologic function is unknown but may be related to gene regulation)
24. C – Ribosomal RNA; it joins with proteins to build the ribosome Slides 36 & 37 (80S = 60S + 40S subunits in eukaryotes)
25. B – Hydrogen bonds between the complementary bases (A=U and G to C) Slides 36 & 38 (tRNA also shows an acceptor stem ending in CCA, a D loop, a T loop and an anticodon loop)

Part 2: Essay Answer Key (with slide references)

1. Gout, the minor bases and allopurinol — Slides 13 & 24

- Uric acid is derived from the purine bases. Xanthine, hypoxanthine and uric acid are the minor nitrogenous bases: other purine metabolites, not usually found in nucleic acids.
- Allopurinol is a hypoxanthine analogue. It blocks the action of xanthine oxidase by substrate competition, so hypoxanthine is not changed into xanthine and then into uric acid.

2. 5-Fluorouracil — Slide 24

- a. Nucleotide analogues are prepared by altering the base ring or the sugar part.
- b. It is a pyrimidine (uracil) analogue, used as an anti-cancer drug; allopurinol (a hypoxanthine analogue) is the anti-gout drug.
- c. It lowers thymine synthesis, which lowers DNA synthesis and so lowers the growth of the cancer cells.

3. Definitions — Slides 14, 15 & 32

- A. Nucleoside = base + sugar, formed by covalently linking the base (N1 of pyrimidine, N9 of purine) to carbon 1 of the sugar by an N-glycosidic bond.
- B. Nucleotide = nucleoside + one or more phosphate groups attached to carbon 5 of the sugar by an ester bond (base + pentose sugar + phosphoric acid).
- C. Z-DNA = a rare left-handed double-helical form of DNA occurring in G-C rich sequences; its biologic function is unknown but may be related to gene regulation.

4. RNA — Slides 35, 36, 38, 40 & 41

- a. A single strand containing 4 types of nucleotides (AMP, GMP, CMP and UMP) connected by phosphodiester bonds; its sugar is ribose and it carries uracil instead of thymine.
- b. Messenger RNA. Its three regions: 5' untranslated leading sequence (ends by a cap); translated coding sequence; 3' untranslated tailing sequence (ends by a poly-A tail).
- c. tRNA has a clover-leaf appearance, stabilized by hydrogen bonds between complementary bases (A=U and G to C).
- d. Ribosomal RNA 80%, transfer RNA 15%, messenger RNA 5%, small nuclear RNA less than 1%.

5. Chargaff calculation — Slide 33

- By Chargaff's rules % A = % T and % G = % C, and total purines = total pyrimidines. 12% T = 12% A, a total of 24%; therefore G + C = 76%, so guanine = 38% (and cytosine = 38%).

6. Mention the name of each — Slides 14, 18, 23, 32 & 37

- 1. N-glycosidic bond. 2. S-adenosyl methionine (SAM). 3. UDP-glucose.
- 4. Z-DNA. 5. Ribosomal RNA (rRNA), which is associated with several proteins to form the ribosome.