

Define and elaborate on the terms below (10 points):

2 pts / question

Replication fork

The branch point in replicating DNA at which the two strands of the parental molecule are separated and serve as templates for the synthesis of the daughter strands

Prebiotic era

An era that had no organic molecules and a reducing atmosphere.

Henderson-Hasselbach equation

The mathematical expression of the relationship between the pH of a solution of a weak acid and its pK

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

Endonuclease

an enzyme that catalyzes the hydrolysis of the phosphodiester bonds between two nucleotide residues within a polynucleotide strand

Pyrosequencing

~ front roads

A procedure for determining the sequence of nucleotides in DNA by copying a DNA strand in such a way that a flash of light is generated when the correct nucleotide is incorporated, generated by release of pyrophosphate:  $PP \rightarrow ATP \xrightarrow{\text{luciferase}} \text{light!}$

## True or false questions (15 points):

3 pts/question

1. A nucleotide contains only a nuclear base, a sugar and at least one phosphate molecule

True

False. If false, why?

2. A polymerase chain reaction (PCR) amplifies a particular DNA segment by repeatedly sequencing the non-complementary (or template) strand.

True

False. If false, why?

Repeatedly sequences the template strand to form a complementary daughter strand.

3. In DNA replication, the template (leading) strand is read from 5' to 3' and the complementary (lagging) strand is synthesized in the 3' to 5' direction.

True

False. If false, why?

strands are read  $3' \rightarrow 5'$  and synthesized  $5' \rightarrow 3'$

4. The primary driving force required for the folding of a biomolecule containing non-polar residues is enthalpy, and the secondary driving force is entropy.

True

False. If false, why?

Primary driving force to folding is entropy

5. Chain-terminator DNA sequencing requires the addition of ddNTP to terminate lagging strand growth

True

False. If false, why?

No lagging strand in CTM method

## Multiple choice (20 points)

$\Sigma$  pts / question

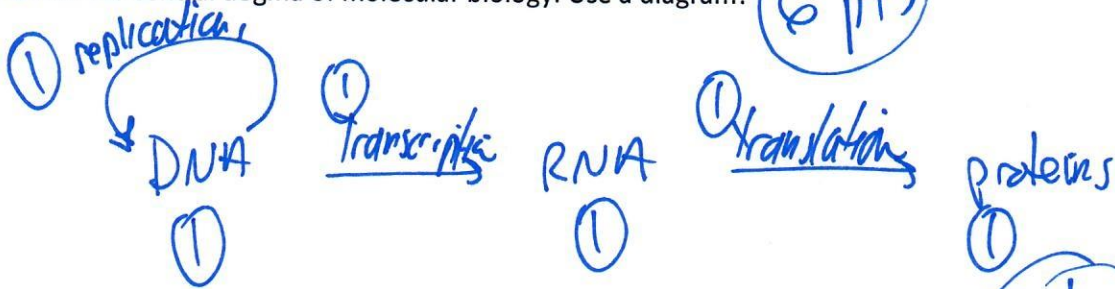
- An endergonic reaction with \_\_\_\_\_  $\Delta H$  and \_\_\_\_\_  $\Delta S$  can be changed to exergonic reaction by decreasing the temperature
  - Positive, positive
  - Negative, positive
  - Negative, negative
  - Positive, negative
- An increase in disorder of a system:
  - Is required for a process to be spontaneous
  - Results in a decrease in entropy
  - Is characteristic of a system increasing enthalpy
  - Results in the factor  $T\Delta S$  being positive
  - Is found in every exergonic reaction
- Carbohydrates, proteins, nucleotides, and nucleic acids are important groups of molecules found in living organisms. Which 6 elements do living organism need to build these molecules?
  - C, H, O, N, S, P
  - C, H, N, Si, S, Na
  - K, C, O, N, H, B
  - C, O, N, H, Li, S
- The insolubility of non-polar molecules is due to the large \_\_\_\_\_, which is the result of water molecules forming an ordered network surrounding non-polar molecules
  - Negative entropy
  - Positive entropy
  - Negative enthalpy
  - Positive enthalpy
- Phosphoric acid is a polyprotic acid, with pKa of 2.14, 6.86, and 12.38. Which ionic forms predominates at pH 9.3?
  - $H_3PO_4$
  - $H_2PO_4^-$
  - $HPO_4^{2-}$
  - $PO_4^{3-}$
  - None of the above
- The weakest non-covalent interaction is:
  - Electrostatic forces
  - London Dispersion Forces
  - Hydrogen bonding
  - Dipole-dipole interactions

7. What functional group is attached to the pyrimidine ring in thymine and is not present in uracil & at what position is this group attached?
- Ribose, position 1
  - CH<sub>3</sub>, position 6
  - NH<sub>2</sub>, position 5
  - Deoxyribose, position 2
  - CH<sub>3</sub>, position 5
8. DNA fragments are usually inserted into a plasmid vector and cloned before they are analyzed by chain-terminator sequencing because:
- DNA fragments need to be pure in order to obtain unambiguous sequence
  - A large number of identical fragments is needed in a sequencing reaction in order to generate detectable amounts of products
  - Plasmid vectors have known sequences that can be used for design and annealing of the primer oligonucleotides, which are used to initiate the sequencing reaction
  - All of the above
  - None of the above
9. In molecular cloning, transformed organisms must be identified. One common method for accomplishing this involves the inclusion of \_\_\_\_\_ in the plasmid.
- A restriction site
  - A deletion
  - An origin of replication
  - An antibiotic resistance gene
  - A nuclease gene
10. Which of the following statements about PCR is (are) true? Select all that apply.
- Large amounts of DNA can be easily amplified
  - PCR is often used in forensic laboratories
  - PCR reaction products can be used in molecular cloning
  - PCR is used in clinical laboratories
  - All of the above

Short answer (20 points)

Describe the central dogma of molecular biology. Use a diagram!

(6 pts)



Describe the hydrophobic effect, using the Gibbs free energy equation. Be succinct!

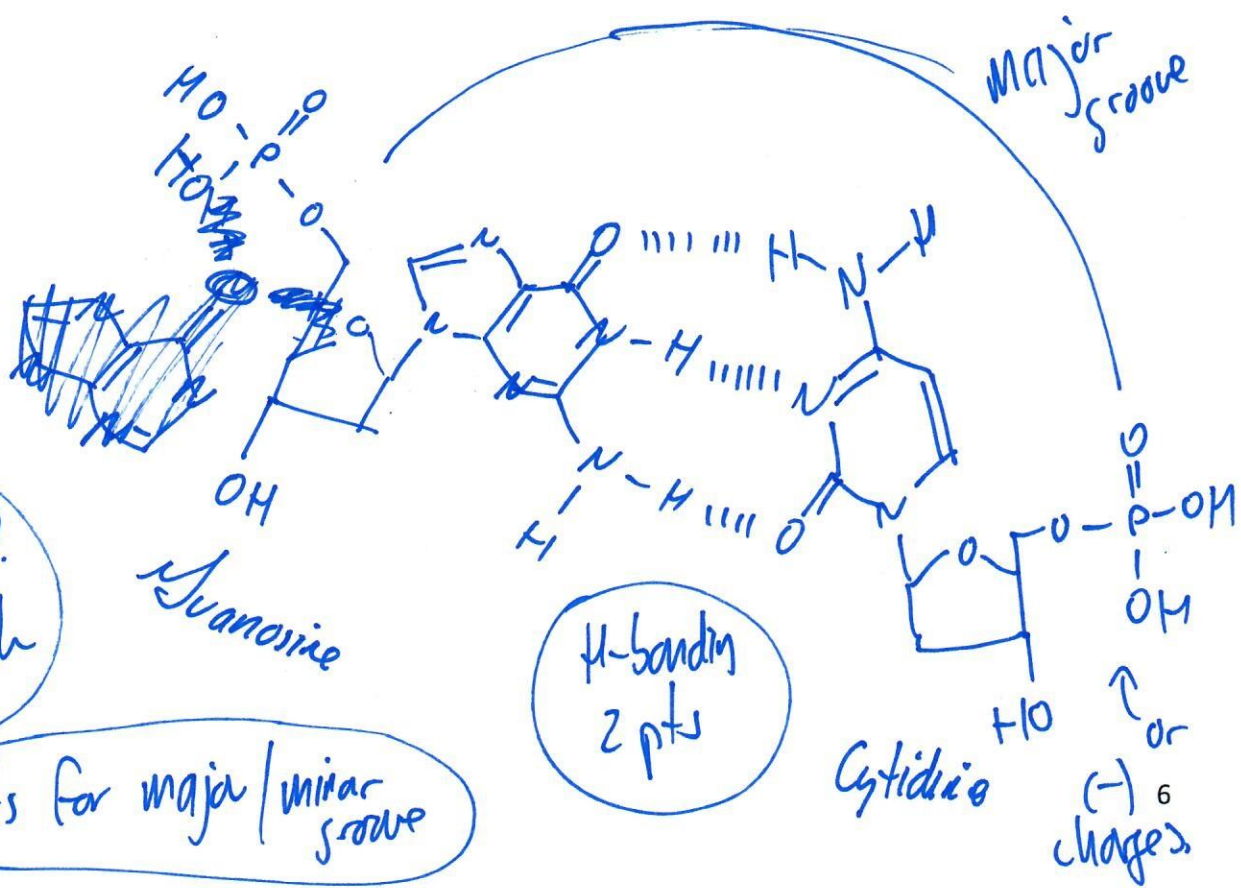
(6 pts)

Hydrophobic effect promotes the folding of proteins (or the aggregation of non-polar molecules) in  $H_2O$  due to the increase in ~~entropy~~ the  $\Delta S$  of bulk water that results, which

means  $\Delta G = \Delta H - T\Delta S < 0$  for the system and surroundings

Draw the structure of <sup>cytosine</sup> monophosphate and <sup>guanine</sup> monophosphate and show the hydrogen bonding between the two nucleotides. Be sure to identify the major and minor groove.

(8 pts)



Correct structures? 2 pts/each

H-bonding 2 pts

2 pts for major/minor groove

or (-) 6 charges

## Long answer (35 points).

10 pts

1. A buffer contains 0.01 mol of lactic acid ( $pK_a$  3.86; 90.08 g/mol; ) and 0.050 mol sodium lactate (112.06 g/mol) per liter of aqueous solution.

- a. Calculate the pH of this buffer

$$pH = 3.86 + \log \frac{[50 \text{ mM}]}{[10 \text{ mM}]} = 3.86 + 0.70 = \boxed{4.56}$$

4 pts

- b. Calculate the pH after 5.0 mL of 0.50 M HCl is added to 1 liter of the buffer (assume the total volume will be 1005 mL)

$$\text{add } 5.0 \times 10^{-3} \text{ L} \times \frac{0.50 \text{ mol}}{\text{L}} \text{ HCl} = 2.5 \times 10^{-3} \text{ mol or } 2.5 \text{ mmol HCl added}$$

3 pts

$$\left[ \begin{array}{l} 50 \text{ mmol lactate} + 2.5 \text{ mmol } H^+ = 47.5 \text{ mmol Lactate} \\ 10 \text{ mmol lactic acid} + 2.5 \text{ mmol} = 12.5 \text{ mmol acid} \end{array} \right.$$

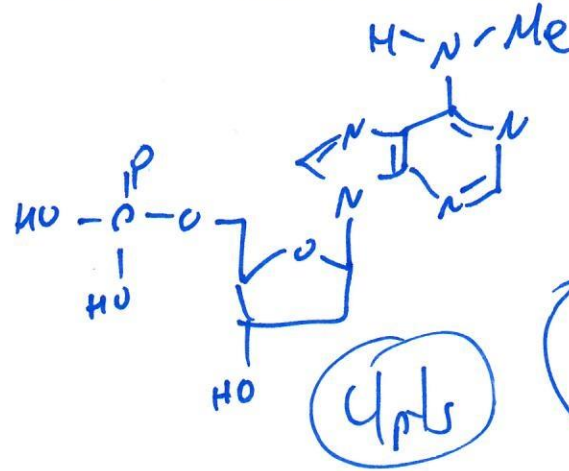
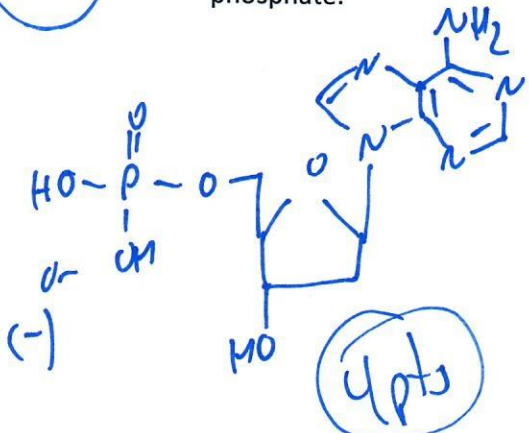
3 pts

$$pH = pK_a + \log \frac{\left( \frac{47.5 \text{ mol}}{1005} \right)}{\left( \frac{12.5}{1005} \right)} = pH = 3.86 + \log \frac{47.5}{12.5} = \boxed{4.44}$$

2. Methylation of nucleotides is important in controlling gene expression in organisms. For example, adenosine mono-phosphate can be methylated at the N6 position.

12 pts

a. Draw the structure of adenosine monophosphate and the structure of N6-methyladenosine mono-phosphate.



2 pts for work  
6 pts for structure

b. Would the modified base be able to participate in Watson-Crick base pairing?

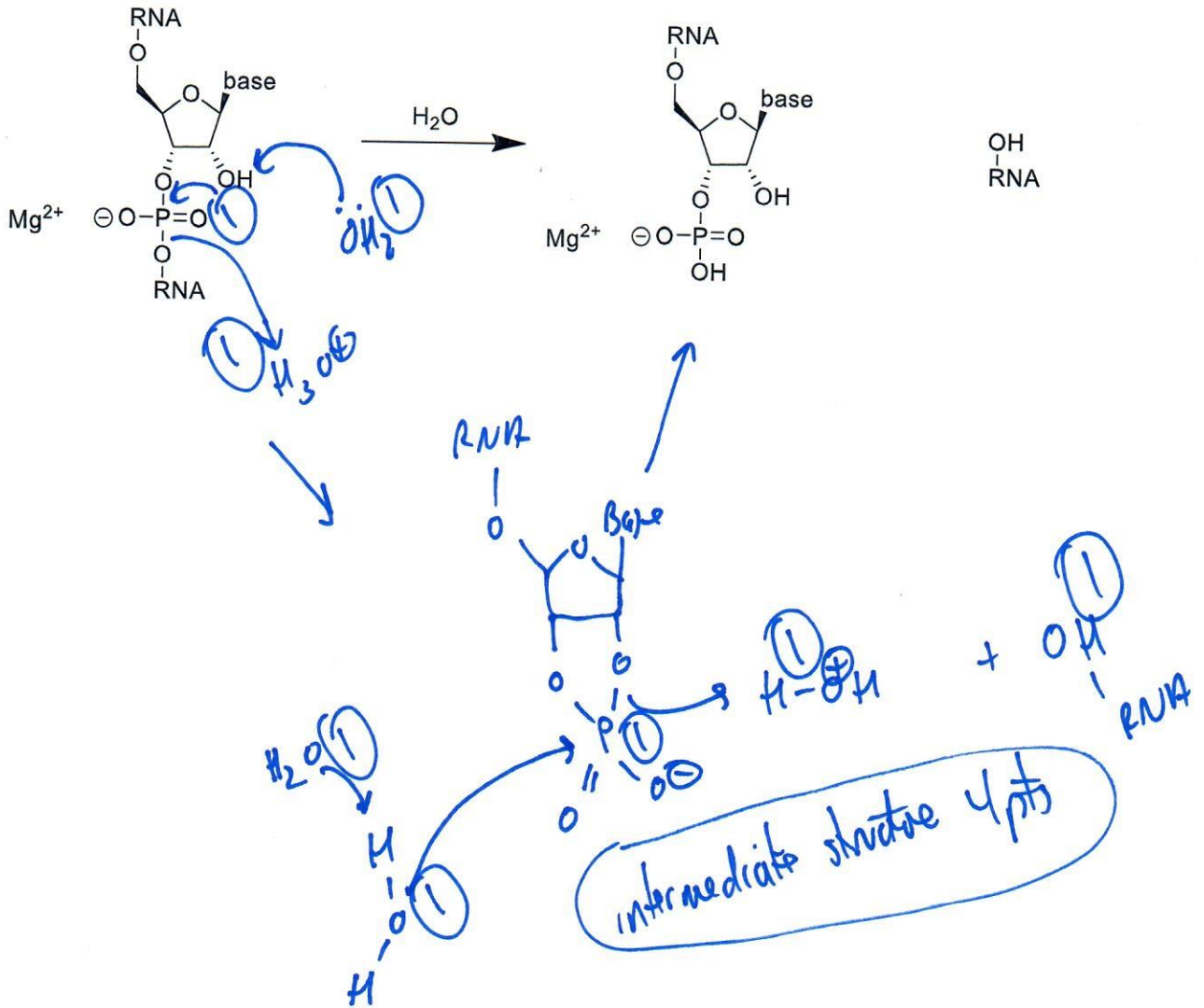
2 pts ~~No~~ Yes, b/c no impact on hydrogen bonds with complementary base.

2 pts for explanation

4 pts

3. RNA polymer has a higher turnover (rate of degradation) than DNA due alkaline hydrolysis. Propose a two-step mechanism where water is used both as the acid and base.

13 pts



Half-marks for the whole question if OH<sub>2</sub> not used as acid/base