Nucleic acids and the rna world essay sample

1. 4. 1 – What is a Nucleic Acid?

* Nucleic acids are made up of monomers called nucleotides

* Three components of a nucleotide:

1. Phosphate group—attached to the 5’ carbon

2. Sugar – carbonyl group and several hydroxyl groups

3. Nitrogenous base

* The prime (‘) symbols indicate the carbon being is part of the sugar—not attached to the nitrogenous base. * Four different nucleotides, each of which contains a different nitrogenous base 1. Purines—adenine (A), guanine (G)

2. Pyrimidines—cytosine (C), uracil (U); T for DNA

A. How Do Nucleotides Polymerize to form Nucleic Acids?

i. The polymerization reactions involve the formation of a bond between the phosphate group of one nucleotide and the hydroxyl group of the sugar components phosphodiester linkage ii. When the nucleotides involved contain the sugar ribose, they polymer that is produced is ribonucleic acid (RNA) iii. DNA and RNA strands are directional

iv. The sugar phosphate backbone of a nucleic acid is directional, as in the peptide-bonded backbone of a polypeptide. v. In a strand of RNA or DNA, one end has an unlinked 5’ carbon while the other has an unlinked 3’ carbon—meaning a carbon that is not linked to another nucleotide. 5’ 3’ direction. vi. The sequence of nitrogenous bases forms the primary structure of a molecule, analogous to the sequence of amino acids.

2. 4. 2 – DNA Structure and Function

* The primary structure of nucleic acids is somewhat similar to the primary

structure of proteins; Proteins have a peptide-bonded backbone with a series of R-groups. * DNA and RNA molecules have a sugar phosphate backbone, created by phosphodiester linkages, and a sequence of any 4 nitrogenous bases. * The secondary structure of nucleic acids is formed
by H-bond between nitrogenous bases.

A. What is the Nature of DNA's secondary structure?

i. (1) The # of purines in a given DNA is equal to the # of pyrimidines ii. (2) The # of T's and A's and C's and G's in DNA are equal iii. Rosalind Franklin calculated the distances between groups of atoms in the molecule: X-ray crystallography iv. The pattern of the X-ray scattering suggested that the molecule was helical, or spiral in nature. v. What type of helix would have a sugar-phosphate backbone and explain both Chargaff's rules and Wilkins measurements?

B. DNA strands are antiparallel

i. Watson & Crick arranged two strands of DNA side by side and running in opposite directions—5'3' while the other 3'5'. Strands with this orientation are said to be antiparallel ii. If the antiparallel strands are twisted together to form a double-helix, the coiled sugar phosphate backbone end up on the outside of the spiral and the nitrogenous base on the inside. iii. The pairing allows H-bonds to form between certain purines and pyrimidines. (A forms H bonds with T) iv. The A-T and G-C bases are complementary

v. 2 H-bonds form when A and T are formed, but 3 H-bonds form between G and C pairs. vi. The nitrogenous bases tight packing forms a hydrophobic interior that is difficult to break apart vii. The molecule as a whole is hydrophilic because the sugar-phosphate backbone face the exterior and is negatively charged (PO43-) viii. DNA’s secondary structure consists of two antiparallel strands twisted into a double helix. ix. DNA is stable because DNA lack a reactive 2’ –OH group and because antiparallel DNA strands form a secondary structure called a double helix. x. The molecule is stabilized by hydrophobic interactions in its interior and by hydrogen bonding between the complementary base pairs. xi. DNA’s structural stability and regularity make it ineffective at catalysis.

C. DNA functions as an Information-Containing Molecule

i. DNA carries the information required for an organism’s growth/reproduction

3. RNA Structure and Function

* A self-replicating molecule has to perform two key functions: carry information and perform catalysis * Information storage requires regularity and stability;

* Catalysis requires variation in chemical composition and variation in shape

* How is it possible for a molecule to do both? Structure.

A. Primary Structure

i. Like DNA, RNA has a primary structure consisting of a sugar-phosphate backbone formed by phosphodiester linkages and, extending from the backbone, a sequence of 4 types of nitrogenous bases. ii. The sugar in the sugar-phosphate backbone of RNA is ribose, not deoxyribose as in DNA—critical because the –OH group on the 2’ carbon of ribose is much more reactive than the H atom on the 2’ carbon of deoxyribose. This can participate in reactions that tear the polymers apart. The presence of this –OH group makes RNA much less stable than DNA. iii. The pyrimidine base thymine doesn't exist in RNA, instead it's Uracil.

B. Secondary Structure

i. Adenine forms H bonds with Uracil (A-U, G-C)

ii. Three H bonds form between Guanine and Cytosine, but only two H bonds form between Adenine and Uracil iii. How do secondary structures of RNA and DNA differ? The purine and pyrimidine bases in RNA undergo H bonding with complementary bases on the same strand, rather than forming H bonds with complementary bases on a different strand, as in DNA. iv. If the section where the fold occurs includes a large number of unbounded bases, then the stem-and-loop configuration shown results. (Fig. 4. 10) This type of secondary structure is called a hairpin

C. Tertiary and Quaternary Structures

i. RNA molecules can also have tertiary structure, owing it to interactions that (1) fold secondary structures into complex shapes, or (2), hold different RNA strands together ii. H-bonding allows RNA molecules to fold in precise ways, and thus interact with each other. iii. RNA
molecules are much more diverse in size, shape, and reactivity.

D. RNA as an Information Containing Molecule

i. Because H bonding occurs between A-U pairs and G-C pairs, it is possible for RNA to furnish the information required to make a copy of itself.

E. RNA Can Function as a Catalytic Molecule

i. There are only 4 types of nitrogenous bases in RNA versus the 20 types of amino acids found in proteins ii. Secondary through quaternary structure is more limited as a result, meaning RNA cannot form the wide array of active sites observed among proteins. iii. Because RNA has a degree of structural and chemical complexity, it is capable of stabilizing a few transition states and catalyzing at few chemical reactions. iv. Tertiary structure of Tetrahymena Ribozyme—this ribozyme catalyzes both the hydrolysis and condensation of phosphodiester linkages.