DNA and Protein Production

BioSci 105
Lecture Packet 5
Chapter 21 (pages 442 – 450)

Outline

I. DNA
   A. Structure
   B. Replication

II. RNA

III. Protein Production

DNA

Deoxyribonucleic acid – DNA

The blueprint to making proteins!!!

Chromosomes located inside the nucleus contains long coiled strands of DNA

DNA’s Discovery

Watson and Crick

Nucleotide Structure

Nucleotides have:
- One phosphate (ATP has three)
- One sugar
- One base.

DNA Structure

DNA has four different bases:
- Adenine (A), Thymine (T), Guanine (G), Cytosine (C)

DNA Is a Double Helix

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Double Helix Structure
- The sugars and phosphates link together by covalent bonds to form the rail on the outside.
- The sugars are covalently bound to a base.
- The bases hydrogen bond together to keep the two strands together = double helix.
- Base pairs are two nucleotides, one on each complementary strand of a DNA molecule.

Double Helix
- Two strands bonded together by hydrogen bonds between the bases = weak bonds.
- Each strand has nucleotides bonded together covalently by the phosphate and the sugar.

Base Pairs
- The bases pair up in a specific manner:
  - Adenine (A) pairs with Thymine (T)
  - Guanine (G) pairs with Cytosine (C)

Remember that on one strand:
- The base is covalently bonded to the sugar, which is covalently bonded to the phosphate.
- Between the two strands the bases are bonded together by hydrogen bond:
  - A – T
  - C – G

Base
- adenine (A)
- thymine (T)
- guanine (G)
- cytosine (C)

Thymine

Adenine

Cytosine

The Structure of DNA
- Animation—The Structure of DNA
DNA Replication

- Before the structure of DNA was discovered, no one could explain how a cell could divide and replicate whatever the inheritance molecule was.
- When the structure of DNA was worked out it became apparent how it happens.

DNA Replication

- Before a cell divides, the parent cell needs to make a copy of the DNA.
- Each daughter cell receives a copy of the DNA.

DNA Replication

1. An enzyme, helicase, unwinds the DNA molecule and breaks the hydrogen bonds between the base pairs.
2. Enzymes called DNA polymerases add new nucleotides to pair with the old DNA.

Replication of DNA

- Now there are two double strands of DNA.
- One strand in each is the original parental strand.
- One strand in each is a new strand that was copied off of the parental strand.
- This is called semi-conservative replication.
- Each new DNA molecule contains one strand of the original DNA and one strand of new DNA.

Energy to power binding

- The incoming nucleotides have three phosphates, only one is used to bond to the sugar molecule.
- The energy needed to build the new DNA strand comes from taking the other two phosphates off.
- The energy gained from breaking the bonds is used to build the new bond.

DNA replication Video

- http://www.youtube.com/watch?v=4jtmOZehv50
Pairing

Remember that T pairs with A  
G pairs with C

If the original DNA strand was: TCAT  
then the complimentary strand would be AGTA

If the original DNA strand was TCAA, then the complimentary strand would be

A. TCAA  
B. CGTT  
C. AGTT  
D. GACC

Mistakes – repair mechanisms

- Before a cell can divide, it must make a complete copy of the DNA
- There are millions of bases that need to be added to the DNA strands – many chances for something to go wrong
- Enzymes will take out the wrong nucleotide and replace it with the correct one

Mutations – when replication goes wrong

- The repair mechanisms don’t correct all the mistakes
- There are errors in replications: one example is a point mutation
- A point mutation is when just one base pair is paired incorrectly

Point Mutations

Incorrect Pairing

- A mismatched pairing:
  - GCCT paired with CGTA
- The pair should have been:
  - CGGA

Causes of Mutations

- Random error – sometimes things just go wrong.
- Mutagens – chemicals that damage the DNA and cause mutations in replication  
  - Cigarette smoke  
  - Sunlight  
  - Many chemicals (benzene)

Results of Mutations

- A few things can happen if DNA mutates before the cell replicates:
  1. Enzymes can repair the damage  
  2. Or – The cell may commit suicide (apoptosis)  
  3. Or – The cell may replicate and the mutation becomes permanent

Good mutations - Evolution

- Evolution occurs because there is variation in DNA, sometimes a mutation can produce changes that are good
- If these mutations are better they may allow the organism to survive longer and produce more offspring – the change can spread throughout the population
Paternity test for the father of a baby.

DNA analysis from blood taken from a crime scene. Match the blood to suspects.

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DNA Contains the Code for Proteins

- How does DNA code for proteins?
- Remember that DNA is stored in the nucleus, it is too valuable to leave the nucleus so it makes a copy of itself (RNA) which leaves the nucleus and goes into the cytosol to make the protein.

DNA Codes for RNA, which Codes for Protein

- A gene directs the production of a specific protein
  - DNA → RNA → Protein

What is the monomer unit of proteins?

- A. Glucose
- B. Nucleotides
- C. Amino acids
- D. Fatty acids

What bond connects the monomer units in a protein?

- A. Hydrogen bond
- B. Ionic bond
- C. Peptide bond

The amino acid sequence makes up the:

- A. Primary structure
- B. Secondary structure
- C. Tertiary structure
- D. Quantinary structure

DNA and RNA

### Table 21.1

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarity</td>
<td>Difference</td>
</tr>
<tr>
<td>DNA is a double-stranded molecule</td>
<td>RNA is a single-stranded molecule</td>
</tr>
<tr>
<td>Has four types of bases</td>
<td></td>
</tr>
<tr>
<td>Contains the bases adenine, guanine, cytosine, and thymine</td>
<td>Contains the bases adenine, guanine, cytosine and uracil</td>
</tr>
<tr>
<td>Functions primarily in the nucleus</td>
<td>Functions primarily in the cytoplasm</td>
</tr>
</tbody>
</table>
RNA

- mRNA is only a single strand
- RNA has same “handrail” structure with the phosphates covalently bound to the sugars.
- The sugars are bound covalently to bases

DNA and RNA

1. The sugar is slightly different from DNA’s sugar (has an OH vs H)
   - RNA - ribose
   - DNA - deoxyribose

2. One base is different
   - RNA has four bases: RNA has Cytosine (C), Guanine (G), Adenine (A) and Uracil (U)
   - Uracil is paired to Adenine
   - DNA has CGAT

3. RNA is single stranded, DNA is double stranded

DNA Codes for RNA - Transcription

- Transcription:
  - Synthesis of messenger RNA (mRNA) using DNA as a template
  - The product of transcription is RNA
  - Transcription happens in the nucleus

DNA vs RNA

<table>
<thead>
<tr>
<th>Sugar</th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ribose</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deoxyribose</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bases: AUCG

Number of Strands: Single vs Double

DNA Codes for RNA - Transcription
**Transcription**

- **RNA polymerase** (similar to DNA polymerase) binds to a region on the DNA upstream from the gene called the **promoter region**.
- **RNA polymerase** brings complementary RNA nucleotides together and binds them together into a chain.
- The nucleotide containing uracil is complementary to adenine.

**DNA Codes for RNA - Transcription**

- **RNA polymerase** links together the RNA nucleotides.
- Until it reaches a sequence of bases on the DNA that is the stop signal.
- When the **RNA transcript** is completed, it is released from the DNA.
- The DNA closes again.

**DNA Codes for RNA - Transcription**

- Final processing of the mRNA includes **removal of introns**, leaving the **exons** to direct protein synthesis.

**If the DNA sequence was ATCG then the complementary mRNA sequence would be:**

1. TAGC
2. UAGC
3. UACG
4. ATCG

**RNA to Protein - Translation**

- **Translation** – the process of converting the code in mRNA into a polypeptide chains (proteins).

**RNA to Protein - Translation**

- Remember that mRNA is a chain of nucleotides with four different bases: U, A, G, and C.
- So it could be a chain of: UGCCAGUGC….
- These nucleotides will be read in groups of three = **codons** to code for one amino acid.

**RNA to Protein - Translation**

- **A codon**
  - A three-base sequence that translates into one amino acid.
Translation

Translation:
1. The mRNA leaves the nucleus and enters the cytosol.
2. mRNA docks with ribosomes.
3. tRNA brings amino acids to the ribosome.
4. The amino acids are bound together by a peptide bond by the ribosome.

Codons

• Three mRNA bases code for one amino acid.
• The three mRNA bases together are called a codon.
• So when CGU are next to each other as a codon then that will be read as arginine.
• How does this happen?

RNA Codes for Protein - Translation

• Translation uses transfer RNA (tRNA) to identify and transport amino acids to the ribosome.

Transfer RNA (tRNA)

• The mRNA codes for which amino acids go in what order.
• The ribosome is where the amino acids are bound together.
• tRNA (transfer RNA) brings the amino acids to the ribosomes.

Transfer RNA (tRNA)

• One side of tRNA attaches to an amino acid.
• The other side of tRNA has complementary nucleotides to the codon (called the anticodon).
• Anticodon:
  • A three base sequence on the other end of the tRNA that is complementary to the codon of the mRNA.
Ribosomes

- Ribosomal RNA (rRNA)
  - Ribosomes consist of two rRNA molecules and a protein
  - It is the ribosome that forms the peptide bond
  - rRNA is the enzymatic portion of the ribosome

Types of RNA and their Functions

<table>
<thead>
<tr>
<th>Type of RNA</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>mRNA</td>
<td>Contains the plan to make proteins</td>
</tr>
<tr>
<td>tRNA</td>
<td>Brings the amino acids to the ribosome</td>
</tr>
<tr>
<td>rRNA</td>
<td>Catalytic region of the ribosome, makes the peptide bond between the amino acids</td>
</tr>
</tbody>
</table>

Where are ribosomes produced

A. Rough ER
B. Smooth ER
C. Nucleolus
D. Golgi

Translation

Steps of Translation - Initiation

1. mRNA binds to small subunit of ribosome
2. tRNA with methionine (MET) amino acid attached, binds to the mRNA codon AUG, at the "P" site
3. Large subunit of ribosome attaches
Translation - Elongation

4. tRNA with the next amino acid attached binds to the mRNA codon at the “A site” The bond between the tRNA and MET amino acid is broken.

5. A peptide bond is formed between the MET amino acid and the second amino acid.

6. The transfer RNAs all move over one space on the ribosome (translocation).

7. Now the “free tRNA”, which used to hold the MET amino acid, is now in the “E site”

8. The tRNA with two amino acids is in the “P site” and the “A site” is open

9. The next tRNA with the 3rd amino acid is brought into the “A site”

10. The “free tRNA” is released from the “E site”

Translation - Termination

11. When translation reaches a stop codon, no tRNA binds to the stop codon

12. Instead the polypeptide chain is released and the ribosome breaks apart, releasing the mRNA

If the mRNA sequence is: AUGCCCAAGUAA then the amino acid sequence would be:

A. Start-Pro-Lys
B. Met-Pro-Lys
C. Met-Pro-Lys-Stop
D. Start-Pro-Lys-Stop

If the mRNA sequence is: AUGCCCAAGUAA then the amino acid sequence would be:

A. Start-Pro-Lys
B. Met-Pro-Lys
C. Met-Pro-Lys-Stop
D. Start-Pro-Lys-Stop

25% 25% 25% 25%

What molecules are produced in transcription?

A. Nucleotides
B. DNA
C. Polypeptide chains (Proteins)
D. Amino acids
E. RNA
What molecules are produced in translation?

A. Nucleotides
B. DNA
C. Polypeptide chains (Proteins)
D. Amino acids
E. RNA

Which process(es) occur in the nucleus?

A. DNA replication and transcription
B. DNA replication only
C. Transcription only
D. Transcription and translation

Protein production – cytosolic proteins

- All polypeptide chains are produced in the ribosomes
- Polypeptides/proteins that will be cytosolic are produced on free floating ribosomes

Protein production – membrane and export proteins

- If the polypeptides/proteins are going to become membrane proteins or are exported out of the cell
- Then the polypeptide chain will be produced in a ribosome that is brought to the rough ER

Where in the cell is the polypeptide chain/protein produced?

A. in the nucleus
B. at the ribosomes
C. on the chromosomes
D. Endoplasmic reticulum
E. Nucleus

Important Concepts

- What is the structure of DNA – and their nucleotides
- What molecules are bonded together – order
- What type of bonds holds the subunits together
- What are the four bases
- Which bases are paired together

Protein Production

<table>
<thead>
<tr>
<th>Organelle</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nucleus</td>
<td>DNA copied to mRNA</td>
</tr>
<tr>
<td>Ribosomes</td>
<td>&quot;reads&quot; mRNA to assemble amino acids into a polypeptide chain</td>
</tr>
<tr>
<td>Rough ER</td>
<td>Polypeptide chain folded and tagged with a carbohydrate chain</td>
</tr>
<tr>
<td>Golgi complex</td>
<td>Processes, sorts and repackages proteins</td>
</tr>
<tr>
<td>Vesicles</td>
<td>Transports proteins</td>
</tr>
</tbody>
</table>

Animation – Protein Synthesis youtube video
Important Concepts

- Be able to draw DNA. Use one letter abbreviations for the bases, phosphates, and sugars (you don’t need to draw the structure of the base, sugar and phosphate)
- What are the steps of DNA replication
- When does DNA replication take place
- What is helicase’s and DNA polymerase’s roll

Important Concepts

- What supplies the energy to be used to build the new strand
- What are mutations, what are point mutations
- Be able to recognize an incorrectly paired sequence
- What are the possible outcomes of mutations
- What is a positive aspect of mutations

Important concepts

- What is the structure of proteins
- What are the structural differences between DNA and RNA, what are the structural similarities?
- Determine the complementary mRNA sequence from a DNA sequence.
- Know the parts of the cell and their role in protein synthesis of an exported protein. Include protein modification (including the golgi, ER, etc)

Important concepts

- What is transcription and translation
- Where does RNA polymerase bind to the DNA
- What is the function of RNA polymerase
- What are the steps of transcription
- What are the steps of translation

Important concepts

- Be able to “read” the mRNA to make a protein, given the table of codons to amino acids.
- Know the types of RNA, their functions, and where in the cell do they complete their function

Definitions

- DNA polymerase, RNA polymerase, helicase, semiconservative replication, complimentary strand, point mutation, mutagens, base pairs, gene, tRNA, mRNA, rRNA, promotor region, polypeptide chain, peptide bond, transcription, translation, codon, anticodon

YouTube video link for protein synthesis

- http://www.youtube.com/watch?v=41_Ne5mS2is