DNA and Protein Production

BioSci 105
Lecture 5
Chapter 21 (pages 448 – 457)
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
Discovery of DNA

Watson and Crick
The Players

**Crick:** Ph.D. student at Cambridge in England working on X-ray Crystallography of the protein hemoglobin

**Watson:** Young American scientist visiting the lab to do some work on a protein

Both were interested in unraveling the secret of DNA’s structure – it was not what they were supposed to be working on
Wilkins: Working on DNA structure, had crystallized DNA fibers

Franklin: Working at the same university as Wilkins, just down the hall. Did the X-ray Crystallography on Wilkins DNA fibers

Linus Pauling: discovered the three dimensional structure of proteins know as alpha helixes

Chargaff: Discovered that A=T and G=C Adenine levels always equal thymine levels
Franklin gave a talk describing her work with the X-Ray Crystallography, Watson attended but he was not the crystallographer and did not see the implications of her work.

Watson and Crick met with Wilkins and he shared Franklin’s work with both of them (without her permission or knowledge).
Watson and Crick put all the pieces of information together. They built models to help them come up with the structure. They knew it was a race so they published a one page article in Nature (1953) with their ideas – they performed no experiments but were able to see the big picture. Crick, Watson and Wilkins received the Nobel Prize for their work. Rosalind received no credit until much later. She died before the Nobel Prize.
Nucleotide Structure

Phosphate — Pentose sugar — Nitrogenous base
DNA Structure

Nucleic acids (DNA and RNA) are made of nucleotides.

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

The nucleotides vary in the type of base

DNA has four different bases:
  Adenine (A), Thymine (T), Guanine (G), Cytosine (C)
DNA is a double-stranded molecule that is twisted to form a spiral structure called a double helix.

Following the rules of complementary base pairing, adenine pairs only with thymine, and cytosine pairs only with guanine.

DNA is composed of four nucleotides.
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)
Bases

adenine (A)

thymine (T)

guanine (G)

cytosine
Thymine

Adenine
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
The Structure of DNA

Fosfaat-deoxyribose "ruggegraat"

3' uiteinde

Guanine

Cytosine

5' uiteinde

Adenine

Thymine

3' uiteinde
DNA Replication

Before the structure of DNA was discovered, no one could explain how a cell could divide and replicate the 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

Step 1: The parental molecule unwinds and unzips.

Step 2: Both parental strands serve as templates for new strands.

Step 3: Free nucleotides link to complementary bases on each DNA strand.

Two identical molecules of DNA result, each composed of one parental strand and one new strand.

Figure 21.2
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
Replication of DNA

This is called **semi-conservative replication**

Each new DNA molecule contains one strand of the original DNA and one strand of new DNA.
Notice the three phosphates
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.
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

1. TCAA
2. CGTT
3. AGTT
4. GACC
Mistakes – repair mechanisms

Before a cell can divide, it must make a complete copy of itself

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 one base pair is paired incorrectly
Point Mutations

Starting DNA

Incorrect base-pairing

Mutation

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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, sometime a mutation can produce changes that are better.

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.
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.
A **gene** directs the production of a specific protein
What is the monomer unit of proteins?

1. Glucose
2. Nucleotides
3. Amino acids
4. Fatty acids
What bond connects the monomer units in a protein

1. Hydrogen bond
2. Ionic bond
3. Peptide bond
The amino acid sequence makes up the:

1. Primary structure
2. Secondary structure
3. Tertiary structure
4. Quantinary structure
1. Instructions from DNA are copied onto mRNA.
2. mRNA moves to ribosome.
3. Ribosome moves to endoplasmic reticulum and "reads" mRNA instructions.
4. Amino acid chain growing from ribosome is dropped inside endoplasmic reticulum membrane. Chain folds into protein.
5. Protein moves to Golgi complex for additional processing and for sorting.
6. Protein moves to plasma membrane for export.
## DNA and RNA

**Table 21.1** Comparisons of DNA and RNA

<table>
<thead>
<tr>
<th>Differences</th>
<th>DNA</th>
<th>RNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Similarities</td>
<td>Are nucleic acids</td>
<td>Are composed of linked nucleotides</td>
</tr>
<tr>
<td></td>
<td>Are composed of linked nucleotides</td>
<td>Have a sugar-phosphate backbone</td>
</tr>
<tr>
<td></td>
<td>Have a sugar-phosphate backbone</td>
<td>Have four types of bases</td>
</tr>
<tr>
<td>Differences</td>
<td>Is a double-stranded molecule</td>
<td>Is a single-stranded molecule</td>
</tr>
<tr>
<td></td>
<td>Has a sugar deoxyribose</td>
<td>Has a sugar ribose</td>
</tr>
<tr>
<td></td>
<td>Contains the bases adenine, guanine,</td>
<td>Contains the bases adenine, guanine,</td>
</tr>
<tr>
<td></td>
<td>cytosine, and thymine</td>
<td>cytosine, and uracil (instead of thymine)</td>
</tr>
<tr>
<td></td>
<td>Functions primarily in the nucleus</td>
<td>Functions primarily in the cytoplasm</td>
</tr>
</tbody>
</table>
(a) Comparison of RNA and DNA nucleotides

RNA nucleotide:
- Base: uracil (U)
- Sugar: ribose
- Phosphate group

DNA nucleotide:
- Base: thymine (T)
- Sugar: deoxyribose
- Phosphate group

(b) Comparison of RNA and DNA three-dimensional structure

RNA strand:
- Sugar-phosphate handrails
- Bases: cytosine (C), guanine (G), adenine (A), uracil (U)

DNA strand:
- Sugar-phosphate handrails
- Bases: cytosine (C), guanine (G), adenine (A), thymine (T)
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

(a) Comparison of RNA and DNA nucleotides
DNA and RNA

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
DNA and RNA

3. RNA is single stranded, DNA is double stranded
<table>
<thead>
<tr>
<th></th>
<th>RNA</th>
<th>DNA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar</td>
<td>Ribose</td>
<td>Deoxyribose</td>
</tr>
<tr>
<td>Bases</td>
<td>AUCG</td>
<td>ATCG</td>
</tr>
<tr>
<td># of Strands</td>
<td>Single</td>
<td>Double</td>
</tr>
</tbody>
</table>
1. **Transcription**: DNA is copied to produce mRNA

2. mRNA leaves nucleus

3. **Translation**: At the ribosome, the amino acids are chained together to form a polypeptide chain.
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 Codes for RNA - Transcription

Step 1: The segment of DNA to be transcribed unwinds.

Step 2: RNA nucleotides pair with the complementary DNA bases and are linked together to form an RNA transcript.

Step 3: The RNA transcript is released from the DNA.

Figure 21.3
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.
DNA Codes for RNA - Transcription

Figure 21.4
http://www.youtube.com/watch?v=WsofH466lqk
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:

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.
The Triplet Code

DNA

G C A A G T A C C T G A

transcription

mRNA

C G U U C A U G G A C U

codon
codon
codon
codon

translation

protein

arg ser trp thr

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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?
<table>
<thead>
<tr>
<th>first base</th>
<th>second base</th>
<th>third base</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>UU</td>
<td>UU</td>
</tr>
<tr>
<td></td>
<td>UUC</td>
<td>UCC</td>
</tr>
<tr>
<td></td>
<td>UUA</td>
<td>UCA</td>
</tr>
<tr>
<td></td>
<td>UUG</td>
<td>UCG</td>
</tr>
<tr>
<td></td>
<td>phe</td>
<td>ser</td>
</tr>
<tr>
<td></td>
<td>UUU</td>
<td>UCU</td>
</tr>
<tr>
<td></td>
<td>UUC</td>
<td>UCC</td>
</tr>
<tr>
<td></td>
<td>UUA</td>
<td>UCA</td>
</tr>
<tr>
<td></td>
<td>UUG</td>
<td>UCG</td>
</tr>
<tr>
<td></td>
<td>leu</td>
<td>pro</td>
</tr>
<tr>
<td></td>
<td>CUU</td>
<td>CCU</td>
</tr>
<tr>
<td></td>
<td>CUC</td>
<td>CCC</td>
</tr>
<tr>
<td></td>
<td>CUA</td>
<td>CCA</td>
</tr>
<tr>
<td></td>
<td>CUG</td>
<td>CCG</td>
</tr>
<tr>
<td></td>
<td>leu</td>
<td>thr</td>
</tr>
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<td>AAU</td>
<td>ACU</td>
</tr>
<tr>
<td></td>
<td>AUC</td>
<td>ACC</td>
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<tr>
<td></td>
<td>AUA</td>
<td>ACA</td>
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<td></td>
<td>AUG</td>
<td>ACG</td>
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<td>ile</td>
<td>thr</td>
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<tr>
<td></td>
<td>AAU</td>
<td>ACU</td>
</tr>
<tr>
<td></td>
<td>AUC</td>
<td>ACC</td>
</tr>
<tr>
<td></td>
<td>AUA</td>
<td>ACA</td>
</tr>
<tr>
<td></td>
<td>AUG</td>
<td>ACG</td>
</tr>
<tr>
<td></td>
<td>met (start)</td>
<td>lys</td>
</tr>
<tr>
<td></td>
<td>GUU</td>
<td>GCU</td>
</tr>
<tr>
<td></td>
<td>GUC</td>
<td>GCC</td>
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<td></td>
<td>GUA</td>
<td>GCA</td>
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<td>GCG</td>
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<td>GAU</td>
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</tr>
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<td>GAG</td>
<td>GAG</td>
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<tr>
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<td>GGU</td>
<td>GGC</td>
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<td></td>
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<td>GCC</td>
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<tr>
<td></td>
<td>GUA</td>
<td>GCA</td>
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<tr>
<td></td>
<td>GUG</td>
<td>GCG</td>
</tr>
<tr>
<td></td>
<td>asp</td>
<td>glu</td>
</tr>
<tr>
<td></td>
<td>U</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>G</td>
<td></td>
</tr>
</tbody>
</table>
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 complementarity nucleotides to the codon

**Anticodon**

A three base sequence on the other end of the tRNA that is complementary to the codon of the mRNA
Transfer RNA

Amino acid attachment site:
Binds to a specific amino acid.

Anticodon:
Binds to codon on mRNA, following complementary base-pairing rules.

Amino acid (phenylalanine)

Figure 21.6
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>Molecule</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Messenger RNA (mRNA)</td>
<td>Carries DNA’s information in the sequence of its bases (codons) from the nucleus to the cytoplasm</td>
</tr>
<tr>
<td>Transfer RNA (tRNA)</td>
<td>Binds to a specific amino acid and transports it to be added, as appropriate, to a growing polypeptide chain</td>
</tr>
<tr>
<td>Ribosomal RNA (rRNA)</td>
<td>Combines with protein to form ribosomes (structures on which polypeptides are synthesized)</td>
</tr>
<tr>
<td>Type of RNA</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>----------</td>
</tr>
<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

1. Rough ER
2. Smooth ER
3. Nucleolus
4. Golgi
Translation
Ribosomes

Note: there are three tRNA binding sites: E, P, A
(a) Large and small ribosomal units

large subunit

small subunit

mRNA

protein

(b) Binding sites in the ribosome

large subunit

small subunit

mRNA

E P A

site site site

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**Step 1:** The small ribosomal subunit joins to mRNA at the start codon, AUG.

**Step 2:** A tRNA with complementary anticodon pairs with the start codon. Ribosomal subunits join to form a functional ribosome.
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

**Step 1:**
- A tRNA with the appropriate anticodon pairs with the next codon on mRNA.
- Enzymes link the amino acids.

**Step 2:**
- Enzymes link the amino acids.

**Step 3:**
- The tRNA in the first binding site leaves the ribosome.
- The ribosome moves along the mRNA, exposing the next codon.
- Enzymes link the amino acids.
- The process is repeated many times.

Figure 21.9
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).
Translation - Elongation

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
Figure 21.5 The genetic code

<table>
<thead>
<tr>
<th>First base</th>
<th>Second base</th>
<th>Third base</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>UUUPhenylalanine</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>UUCPhenylalanine</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>UUALeucine</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>UUGLeucine</td>
<td>G</td>
</tr>
<tr>
<td>C</td>
<td>CUULeucine</td>
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</tr>
<tr>
<td></td>
<td>CUCLeucine</td>
<td>C</td>
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<td></td>
<td>CUALeucine</td>
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</tr>
<tr>
<td></td>
<td>CUGLeucine</td>
<td>G</td>
</tr>
<tr>
<td>A</td>
<td>AUULysine</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>AUCIsoleucine</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>AUAIsoleucine</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>AUG(M)Methionine</td>
<td>G</td>
</tr>
<tr>
<td>G</td>
<td>GUULysine</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>GUCIsoleucine</td>
<td>C</td>
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<tr>
<td></td>
<td>GUAIsoleucine</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>GUGIsoleucine</td>
<td>G</td>
</tr>
</tbody>
</table>

The genetic code is represented in a table format, showing the corresponding amino acids for each codon. The table includes the first base (U, C, A, G), the second base, the third base, and the resulting amino acid. The table also highlights stop codons (UAA, UAG, UGA).
## Figure 21.5 (1 of 2) The genetic code

<table>
<thead>
<tr>
<th>First base</th>
<th>Second base</th>
<th>Third base</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>U</strong></td>
<td><strong>U</strong></td>
<td><strong>U</strong></td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>UUU</td>
<td>Phenylalanine</td>
</tr>
<tr>
<td>Serine</td>
<td>UCU</td>
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</tr>
<tr>
<td>Tyrosine</td>
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<td>UUG</td>
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<tr>
<td>Cysteine</td>
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<td>UCC</td>
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<td>Leucine</td>
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</tr>
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<td>UAG</td>
</tr>
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<td>Tryptophan</td>
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<td>Leucine</td>
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<td>UGA</td>
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<td>Tryptophan</td>
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<td></td>
</tr>
<tr>
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<td>CCC</td>
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<td>Histidine</td>
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<td>CAA</td>
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<tr>
<td>Arginine</td>
<td>CGU</td>
<td>CGA</td>
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<tr>
<td>Leucine</td>
<td>CUA</td>
<td>CCG</td>
</tr>
<tr>
<td>Proline</td>
<td>CCA</td>
<td>CCG</td>
</tr>
<tr>
<td>Glutamine</td>
<td>CAG</td>
<td>CCG</td>
</tr>
<tr>
<td>Arginine</td>
<td>CGA</td>
<td>CCG</td>
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<tr>
<td>Leucine</td>
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<td>Arginine</td>
<td>CGA</td>
<td>CCG</td>
</tr>
</tbody>
</table>

The table above illustrates the genetic code, where each combination of the first three bases (U, C, A, G) corresponds to a specific amino acid or a stop codon (UAA, UAG, UGA).
<table>
<thead>
<tr>
<th>AUG (start)</th>
<th>AUU</th>
<th>ACU</th>
<th>AAU</th>
<th>AGU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methionine</td>
<td>Isoleucine</td>
<td>Threonine</td>
<td>Asparagine</td>
<td>Serine</td>
</tr>
<tr>
<td>AUG (start)</td>
<td>AUC</td>
<td>ACC</td>
<td>AAC</td>
<td>AGC</td>
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<tr>
<td>Methionine</td>
<td>Isoleucine</td>
<td>Threonine</td>
<td>Asparagine</td>
<td>Serine</td>
</tr>
<tr>
<td>AUG (start)</td>
<td>AUA</td>
<td>ACA</td>
<td>AAA</td>
<td>AGA</td>
</tr>
<tr>
<td>Methionine</td>
<td>Isoleucine</td>
<td>Threonine</td>
<td>Lysine</td>
<td>Arginine</td>
</tr>
<tr>
<td>AUG (start)</td>
<td>AUG</td>
<td>ACG</td>
<td>AAG</td>
<td>AGG</td>
</tr>
<tr>
<td>Methionine</td>
<td>Threonine</td>
<td>Lysine</td>
<td>Arginine</td>
<td>Arginine</td>
</tr>
<tr>
<td>GUU</td>
<td>GCU</td>
<td>GAU</td>
<td>GGU</td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>Alanine</td>
<td>Asparagine</td>
<td>Glycine</td>
<td></td>
</tr>
<tr>
<td>GUC</td>
<td>GCC</td>
<td>GAC</td>
<td>GGC</td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>Alanine</td>
<td>Asparagine</td>
<td>Glycine</td>
<td></td>
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<tr>
<td>GUA</td>
<td>GCA</td>
<td>GAA</td>
<td>GGA</td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>Alanine</td>
<td>Glutamic acid</td>
<td>Glycine</td>
<td></td>
</tr>
<tr>
<td>GUG</td>
<td>GCG</td>
<td>GAG</td>
<td>GGG</td>
<td></td>
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<td>Valine</td>
<td>Alanine</td>
<td>Glutamic acid</td>
<td>Glycine</td>
<td></td>
</tr>
</tbody>
</table>
If the mRNA sequence is: AUGCCCAAGUAA then the amino acid sequence would be: (Do at home)

1. Start-Pro-Lys
2. Met-Pro-Lys
3. Met-Pro-Lys-Stop
4. Start-Pro-Lys-Stop
What molecules are produced in transcription?

1. Nucleotides
2. DNA
3. Polypeptide chains (Proteins)
4. Amino acids
5. RNA
What molecules are produced in translation?

1. Nucleotides
2. DNA
3. Polypeptide chains (Proteins)
4. Amino acids
5. RNA
Which process(es) occur in the nucleus?

1. DNA replication and transcription
2. DNA replication only
3. Transcription only
4. 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
Protein Production – export proteins

1. **DNA** is in the **nucleus**. It is the instructions for making protein.

2. During transcription, a copy of the **DNA** is made = **mRNA**

3. **mRNA** leaves the nucleus and enters the cytosol.

4. Ribosomes are made in the **nucleolus** and also go to the cytosol.

5. **mRNA** docks with a **ribosome**
   - The mRNA has the plan of which amino acids go where.
   - The ribosome is the place where the amino acids are linked together.
Protein Production

6. tRNA brings the amino acids to the ribosome
7. At the ribosome, the amino acids are bound together with a peptide bond to make a polypeptide chain (translation)
8. The ribosome with the polypeptide chain docks with the Rough Endoplasmic Reticulum (RER)
9. Only the polypeptide chain enters the lumen of the RER
Protein Production

10. In the RER, the polypeptide chain/protein is folded by the chaparones into its final shape and the protein is given a carbohydrate tag.

11. A transport vesicle containing the new protein pinches off from the RER.

12. The transport vesicle carries the protein from the RER to the Golgi Complex.

13. In the Golgi the protein is further processed, sorted and repackaged into a new transport vesicle.
Protein Production

13. The protein is transported from the Golgi Complex to the plasma membrane in a new transport vesicle.

14. The protein is exported out of the cell using exocytosis.
Endoplasmic reticulum
(a) Diagram of the Golgi complex. This organelle serves as the site for protein processing and packaging within the cell.

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1. Instructions from DNA are copied onto mRNA.
2. mRNA moves to ribosome.
3. Ribosome moves to endoplasmic reticulum and “reads” mRNA instructions.
4. Amino acid chain growing from ribosome is dropped inside endoplasmic reticulum membrane. Chain folds into protein.
5. Protein moves to Golgi complex for additional processing and for sorting.
6. Protein moves to plasma membrane for export.
Where in the cell is the polypeptide chain/protein produced?

1. in the nucleus
2. at the ribosomes
3. on the chromosomes
4. Endoplasmic reticulum
5. Nucleus
# 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>“reads” 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>
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
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.

What are the steps of protein synthesis (production) for a cytosolic protein and for a protein that will be exported from the cell – starting in the nucleus, know the parts of the cell and their role in protein synthesis and 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
http://www.youtube.com/watch?v=41_Ne5mS2ls