I. Protein Synthesis (2 stage processing of information from DNA to proteins) = gene expression
REVIEW:

• Proteins are composed of amino acids – there are 20 different amino acids

• Different proteins are made by combining these 20 amino acids in different combinations
• Proteins are manufactured (made) by the ribosomes.

Ribosomes are the cell’s protein factories.
A. chromosomes are divided into segments called genes – **genes are directions for building all the proteins needed by an organism**
B. Not all genes are active (expressed) at the same time.

1. Why: Because the cell would produce many molecules it did NOT need – waste of energy and raw materials

different kinds of cells require different kinds of molecules to function

ex: RBC’s need hemoglobin to bind O$_2$, but other cells do not
2. Gene expression (protein synthesis) is when the product of a gene (a specific protein) is being actively produced by a cell.

a. some genes are – rarely expressed -- adrenaline

b. some genes are – constantly expressed – hair growth, blood pressure

c. some genes are expressed for a time, then turned off (cyclical) -- estrogen
C. 2 stages of protein synthesis:

1. DNA is transcribed into mRNA – Transcription
2. mRNA is translated into a protein – Translation
D. TRANSCRIPTION - Process of transferring information from DNA to RNA

Why:
• DNA has code for -- protein that needs to be made
• Proteins are made -- in the ribosomes
• DNA is too large -- to leave the nucleus (double strand)
• RNA can -- leave the nucleus (single strand)
1. The enzyme **RNA polymerase** binds to DNA, unzips it and uses one strand of DNA as a template to build a single stranded mRNA (messenger RNA) – a strand of mRNA with DNA code on it.
2. mRNA is small enough to get through the nuclear envelope pores and leaves the nucleus to go to the -- ribosomes

3. 3 adjacent nucleotides code for -- one amino acid
   this 3-nucleotide code on the mRNA is called a -- codon
E. TRANSLATION - Decoding of mRNA into a protein

1. tRNA (transfer RNA) carries amino acids that are in the cytoplasm to the ribosome

Amino acids originate from -- the food (protein) we eat that is broken down during digestion

tRNA has a triplet of nucleotides that is complementary to the codon in mRNA – anticodon

Each tRNA codes – for a different amino acid
2. mRNA (carrying the DNA instructions) and tRNA (carrying amino acids) meet in the ribosomes where rRNA (ribosomal RNA) helps match them up.
3. Amino acids are joined together to make a **protein/polypeptide**.

**C** The Polypeptide “Assembly Line”
The ribosome joins the two amino acids—methionine and phenylalanine—and breaks the bond between methionine and its tRNA. The tRNA floats away from the ribosome, allowing the ribosome to bind another tRNA. The ribosome moves along the mRNA, binding new tRNA molecules and amino acids.

**D** Completing the Polypeptide
The process continues until the ribosome reaches one of the three stop codons. The result is a complete polypeptide.

**Polypeptide = Protein**
Find the amino acid sequence coded for by the following mRNA strands.

**CAC/CCA/UGG/UGA**

___________/_____________/_____________/_____________

**AUG/AAC/GAC/UAA**

___________/_____________/_____________/_____________
<table>
<thead>
<tr>
<th>1st Base</th>
<th>2nd Base</th>
<th>3rd Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>UUU</td>
<td>UCU</td>
<td>UAU</td>
</tr>
<tr>
<td>UUC</td>
<td>UCC</td>
<td>UAC</td>
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<tr>
<td>C</td>
<td>CUU</td>
<td>CAU</td>
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<tr>
<td>CUC</td>
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<td>GAA</td>
</tr>
<tr>
<td>GUG</td>
<td>GCG</td>
<td>GAG</td>
</tr>
</tbody>
</table>

- **Histidine**: 1st Base U, 2nd Base U, 3rd Base U
- **Proline**: 1st Base C, 2nd Base C, 3rd Base G
- **Tryptophan**: 1st Base A, 2nd Base A, 3rd Base G
- **Stop**

**Additional Notes**:
- Methionine (Start) is indicated at AUG.
AUG/AAC/GAC/UAA

Methionine / Asparagine / Aspartic Acid / Stop
Movie about translation at bottom of webpage. Click on hyperlink in picture above.
F. Gene structure:

1. Gene is composed of – **exons** and **introns**
   a. code for protein – **exons** – “expressed” in making proteins
   b. do not code for protein – **introns**

2. Both introns and exons are transcribed by mRNA – but introns are non-coding for proteins and -- **do not leave nucleus** (may be old DNA no longer used, or may regulate gene expression)

3. Before mRNA leaves the nucleus, introns are cut out so just the code for protein production leaves. **exons are spliced together to form final mRNA that leaves nucleus**
II. Gene mutations (errors made when cells copy DNA) – produce changes in a single gene

Rare occurrence: 1 in every 100,000,000 bases

A. Change one base – point mutation (occurs at a single point)

1. Substitution – one base (one nucleotide) is changed for another

   a. code is UGU for amino acid cysteine
      error is UGC -- still cysteine – mutation has no effect on protein being made

   b. UGU – cysteine
      error is UGA – stop codon -- mutation has large effect on protein being made
ORIGNAL SEQUENCE

- UGUAC AUG UAU ACG UCU CAA UGA UCCA
  Met Tyr Ser Thr Gln STOP

POINT MUTATIONS

- UGUAC AUG UAU ACG UCU CAG UGA UCCA
  Met Tyr Ser Thr Gln STOP

- UGUAC AUG UAU ACG CCU CAA UGA UCCA
  Met Tyr Ser Pro Gln STOP

- UGUAC AUG UAA ACG UCU CAA UGA UCCA
  Met STOP
2. Deletion or insertion – **base (nucleotide)** removed or inserted from DNA sequence

**example:**

![Diagram of nucleotide insertion and deletion](Image)

Figure 2. Schematic representation of nucleotide insertion and deletion
3. Frame shift mutation – *shift reading frame of genetic message*

a. frame shift mutation may change every amino acid that follows the point of mutation making protein unable to function \(\textit{change in sequence will change the protein}\)
B. Causes:

1. Occurs spontaneously in the cell

2. Environmental agents – *mutagenic agent* (mutation inducing agent)
   
   *examples: UV light, radiation (x-ray)*
3. Cancer causing agents – carcinogens

*examples:* chemicals (cigarette smoke) viruses (HPV, Hepatitis B)
III. How do proteins determine traits?

DNA → RNA → protein → trait

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**Hair and Nails**
A protein called alpha-keratin forms your hair and fingernails, and also is the major component of feathers, wool, claws, scales, horns, and hooves.

**Muscles**
Muscle proteins called actin and myosin enable all muscular movement—from blinking to breathing to rollerblading.

**Cellular Messengers**
Receptor proteins stud the outside of your cells and transmit signals to partner proteins on the inside of the cells.

**Antibodies**
Antibodies are proteins that help defend your body against foreign invaders, such as bacteria and viruses.

**Blood**
The hemoglobin protein carries oxygen in your blood to every part of your body.

**Brain and Nerves**
Ion channel proteins control brain signaling by allowing small molecules into and out of nerve cells.

**Enzymes**
Enzymes in your saliva, stomach, and small intestine are proteins that help you digest food.

**Cellular Construction Workers**
Huge clusters of proteins form molecular machines that do your cells’ heavy work, such as copying genes during cell division and making new proteins.