Genetic Code

The genetic code

- is a sequence of amino acids in an mRNA that determine the amino acid order for the protein,
- consists of sets of three bases (triplets) along the mRNA called codons.
- has a different codon for all 20 amino acids needed to build a protein.
- contains codons that signal the “start” and “end” of a polypeptide chain.
## The Genetic Code: mRNA Codons

<table>
<thead>
<tr>
<th>First Base</th>
<th>U</th>
<th>C</th>
<th>A</th>
<th>G</th>
<th>Third Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phe</td>
<td>UUU</td>
<td>UCU</td>
<td>UAU</td>
<td>UGU</td>
<td>U</td>
</tr>
<tr>
<td></td>
<td>UUC</td>
<td>UCC</td>
<td>UAC</td>
<td>UGC</td>
<td>C</td>
</tr>
<tr>
<td>Leu</td>
<td>UUA</td>
<td>UCA</td>
<td>UAA STOP&lt;sup&gt;b&lt;/sup&gt;</td>
<td>UGA STOP&lt;sup&gt;b&lt;/sup&gt;</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>UUG</td>
<td>UCG</td>
<td>UAG STOP&lt;sup&gt;b&lt;/sup&gt;</td>
<td>UGG Trp</td>
<td>G</td>
</tr>
<tr>
<td>Leu</td>
<td>CUU</td>
<td>CCU</td>
<td>CAU</td>
<td>His</td>
<td>CGU</td>
</tr>
<tr>
<td></td>
<td>CUC</td>
<td>CCC</td>
<td>CAC</td>
<td>CGC</td>
<td>Arg</td>
</tr>
<tr>
<td></td>
<td>CUA</td>
<td>CCA</td>
<td>CAA</td>
<td>Gln</td>
<td>CGA</td>
</tr>
<tr>
<td></td>
<td>CUG</td>
<td>CCG</td>
<td>CAG</td>
<td>Arg</td>
<td>CGG</td>
</tr>
<tr>
<td>Ile</td>
<td>AUU</td>
<td>ACU</td>
<td>AAU</td>
<td>Asn</td>
<td>AGU</td>
</tr>
<tr>
<td></td>
<td>AUC</td>
<td>ACC</td>
<td>AAC</td>
<td>Ser</td>
<td>AGC</td>
</tr>
<tr>
<td></td>
<td>AUA</td>
<td>ACA</td>
<td>AAA</td>
<td>Arg</td>
<td>AGA</td>
</tr>
<tr>
<td>START&lt;sup&gt;a&lt;/sup&gt;/Met</td>
<td>AUG</td>
<td>ACG</td>
<td>AAG</td>
<td>Lys</td>
<td>ARG</td>
</tr>
<tr>
<td>Val</td>
<td>GUU</td>
<td>GCU</td>
<td>GAU</td>
<td>Asp</td>
<td>GGU</td>
</tr>
<tr>
<td></td>
<td>GUC</td>
<td>GCC</td>
<td>GAC</td>
<td>Glu</td>
<td>GGC</td>
</tr>
<tr>
<td></td>
<td>GUA</td>
<td>GCA</td>
<td>GAA</td>
<td>Gly</td>
<td>GGA</td>
</tr>
<tr>
<td></td>
<td>GUG</td>
<td>GCG</td>
<td>GAG</td>
<td></td>
<td>GGG</td>
</tr>
</tbody>
</table>

<sup>a</sup>START<sup>a</sup> codon signals the initiation of a peptide chain.

<sup>b</sup>STOP<sup>b</sup> codons signal the end of a peptide chain.

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**TABLE 21.5** mRNA Codons: The Genetic Code for Amino Acids

- **U**: UUU, UUC, UUA, UUG
- **C**: CUU, CUC, CUA, CUG
- **A**: AUU, AUC, AUA, AUG
- **G**: GUU, GUC, GUA, GUG
Codons and Amino Acids

- Suppose we want to determine the amino acids coded for in the following section of a mRNA:
  
  5′—CCU —AGC—GGA—CUU—3′

- According to the genetic code, the amino acids for these codons are:
  
  CCU = Proline  
  AGC = Serine  
  GGA = Glycine  
  CUU = Leucine

- The mRNA section codes for the amino acid sequence is as follows:
  
  Pro—Ser—Gly—Leu
Learning Check

Write the amino acids coded for by a section of mRNA with the following base sequence.
5’—GCC—GUA—GAC—3’

Some possible codons to use are the following.

GGC = Glycine  GAC = Aspartic acid
CUC = Leucine  GUA = Valine
GCC = Alanine  CGC = Arginine
Solution

Write the amino acids coded for by a section of mRNA with the following base sequence.

5′—GCC—GUA—GAC—3′

5′—GCC—GUA—GAC—3′

↓  ↓  ↓

Ala—Val—Asp
The activation of tRNA

- occurs when a *synthetase* uses energy from ATP hydrolysis to attach an amino acid to a specific tRNA.
- prepares each tRNA to use a triplet called an anticodon to complement a codon on mRNA.
Initiation and Chain Elongation

For the **initiation** of protein synthesis,

- an mRNA binds to a ribosome,
- the start codon (AUG) binds to a tRNA with methionine,
- the second codon attaches to a tRNA with the next amino acid, and
- a peptide bond forms between the adjacent amino acids at the first and second codons.
Translocation

During translocation,

• the first tRNA detaches from the ribosome,
• the ribosome shifts to the adjacent codon on the mRNA,
• a new tRNA/amino acid attaches to the open binding site,
• a peptide bond forms, and the empty tRNA detaches, and
• the ribosome moves down the mRNA to read the next codon.
Chain Termination

The termination of protein synthesis occurs when

- a polypeptide with all the amino acids for a protein is synthesized.
- the ribosome reaches a “stop” codon: UGA, UAA, or UAG.
- there is no tRNA with an anticodon for the “stop” codons.
- the polypeptide releases from the ribosome.
Summary of Protein Synthesis

To summarize protein synthesis:

- An mRNA attaches to a ribosome.
- Molecules of tRNA bonded to specific amino acids attach to the codons on mRNA.
- Peptide bonds form between an amino acid and the peptide chain.
- The ribosome shifts to each codon on the mRNA until it reaches the STOP codon.
- The polypeptide chain detaches to function as an active protein.
Mutations

A mutation

- alters the nucleotide sequence in DNA.
- results from mutagens, such as radiation and chemicals (possibly some viruses).
- produces one or more incorrect codons in the corresponding mRNA.
- produces a protein that incorporates one or more incorrect amino acids.
- causes genetic diseases that produce defective proteins and enzymes.
Normal DNA Sequence

- The normal DNA sequence produces an mRNA that provides instructions for the correct series of amino acids in a protein.
Mutation: Substitution

In a substitution mutation,

- a different base substitutes for the proper base in DNA.
- there is a change of a nucleotide in the codon.
- the wrong amino acid may be placed in the polypeptide.
In a **frame shift mutation**, 
- an extra base adds to or is deleted from the normal DNA sequence.
- the codons in mRNA and the amino acids are incorrect from the base change.
Effects of Mutations

• Some mutations do not cause significant changes in the primary structure of a protein.
• For drastic changes in the amino acid sequence, the structure of the resulting protein may lose its biological activity.
• Proteins that no longer catalyze (i.e., enzymes), certain substances may accumulate in the cells until they are poisonous.
Genetic Diseases

- Genetic diseases result from a defective enzyme caused by mutation in its genetic code.
- Tyrosine is needed for the formation of melanin (skin and hair pigment).
- If the enzyme that converts tyrosine to melanin is defective, no melanin is produced resulting in the genetic disease known as albinism.
Recombinant DNA

In recombinant DNA,

• a DNA fragment from one organism is combined with DNA in another.

• restriction enzymes are used to cleave a gene from a foreign DNA and open DNA plasmids in *Eschericia coli*.

• DNA fragments are mixed with the plasmids in *E. coli* and the ends are joined by *ligase*.

• the new gene in the altered DNA produces protein.
Recombinant DNA (Continued)
DNA Fingerprinting

In DNA fingerprinting (Southern transfer),

• restriction enzymes cut a DNA sample into smaller fragments (RFLPs).
• the fragments are sorted by size.
• a radioactive isotope that adheres to certain base sequences in the fragments produces a pattern on X-ray film, which is the “fingerprint.”
• the “fingerprint” is unique to each individual DNA.
Polymerase Chain Reaction

A polymerase chain reaction (PCR),
• produces multiple copies of a DNA in a short time.
• separates the sample DNA strands by heating.
• mixes the separated strands with enzymes and nucleotides to form complementary strands.
• is repeated many times to produce a large sample of the DNA.
Polymerase Chain Reaction (Continued)
DNA Fingerprinting

- Also known as DNA profiling
- Small sample of DNA obtained from blood, skin, saliva, or semen
- DNA amount is amplified using the polymerase chain reaction.
- Restriction enzymes cut DNA sample into smaller fragments, which are placed on a gel.
- DNA fragments are separated by size using electrophoresis.
- Used in forensic science to connect a suspect with a crime
DNA Fingerprinting
Human Genome Project (1990–2003)

- The goals were to identify ~25,000 genes in human DNA, determine the base pair sequences in human DNA, and to store this information in databases accessible on the Internet.
- Scientists determined that most of the human genome is not functional.
- The coding portion of the genes is about 1% of the total genome.
- Results of the project will aid in the identification of defective genes that lead to genetic disease.
Viruses

- Small particles of DNA or RNA that require a host cell to replicate
- Cause a viral infection when the DNA or RNA enters a host cell
- Synthesized in the host cell from the viral RNA produced by viral DNA
- Vaccines are inactive forms of viruses that boost the immune response (help promote production of antibodies).
Viruses (Continued)
# Diseases Caused by Viruses

<table>
<thead>
<tr>
<th>Disease</th>
<th>Virus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common cold</td>
<td>Coronavirus (over 100 types), rhinovirus (over 110 types)</td>
</tr>
<tr>
<td>Influenza</td>
<td>Orthomyxovirus</td>
</tr>
<tr>
<td>Warts</td>
<td>Papovavirus</td>
</tr>
<tr>
<td>Herpes</td>
<td>Herpesvirus</td>
</tr>
<tr>
<td>HPV</td>
<td>Human papilloma virus</td>
</tr>
<tr>
<td>Leukemia, cancers, AIDS</td>
<td>Retrovirus</td>
</tr>
<tr>
<td>Hepatitis</td>
<td>Hepatitis A virus (HAV), hepatitis B virus (HBV), hepatitis C virus (HCV)</td>
</tr>
<tr>
<td>Mumps</td>
<td>Paramyxovirus</td>
</tr>
<tr>
<td>Mononucleosis</td>
<td>Epstein–Barr virus (EBV)</td>
</tr>
<tr>
<td>Chicken pox (shingles)</td>
<td>Varicella zoster virus (VZV)</td>
</tr>
</tbody>
</table>
Reverse Transcription

In reverse transcription,
• a retrovirus, which contains viral RNA, but no viral DNA, enters a cell.
• the viral RNA uses reverse transcriptase to produce a viral DNA strand.
• the viral DNA strand forms a complementary DNA strand.
• the new DNA uses the nucleotides and enzymes in the host cell to synthesize new virus particles.
HIV Virus and AIDS

The HIV-1 virus

- is a retrovirus that infects T4 lymphocyte cells.
- decreases the T4 level, making the immune system unable to destroy harmful organisms.
- is associated with an increased chance of developing pneumonia and skin cancer associated with AIDS.
Next Week

- Thursday 29th: Final Lab
- Monday 3rd: Exam #3 Review and Final Exam Review
- Thursday: Exam #3
- Monday 10th: Final 7-10pm