Nucleic Acids Overview

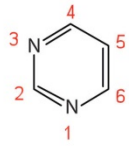
Focus on:

- Structure of DNA/RNA – can I draw it or interpret drawings
- DNA Replication – can I describe the basic process
- RNA Transcription – can I explain role of each type of RNA
- Biosynthesis of Proteins – can I explain the basic process
- Miscellaneous Topics – could I discuss each one
    - Cancer/Chemotherapy
    - Genetic Engineering
    - Human Genome Project
    - Genetic Code (Codons)

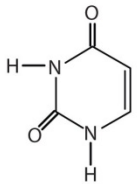
Structure
5 Bases

Focus on:

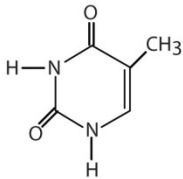
- Molecules given on cheat sheet
- Can I # the molecules and recognize which N-H group reacts
- Purines/Pyrimidine pairs G/C and A/T or A/U



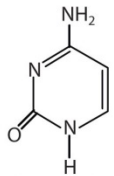
Pyrimidine



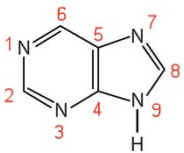
Uracil (U)
RNA only



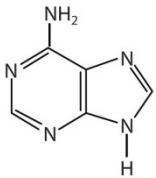
Thymine (T)
DNA only



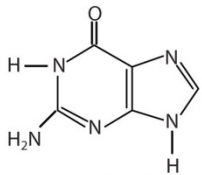
Cytosine (C)
both DNA and RNA



Purine



Adenine (A)

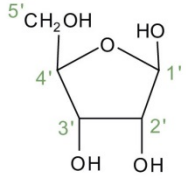


Guanine (G)

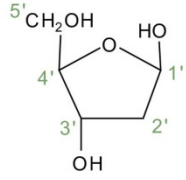
Structure
Sugars

Focus on:

- Molecules given on cheat sheet
- Can I # the molecules and recognize which OH groups react
- Missing 2' OH on deoxyribose



β-Ribose
(found in RNA)

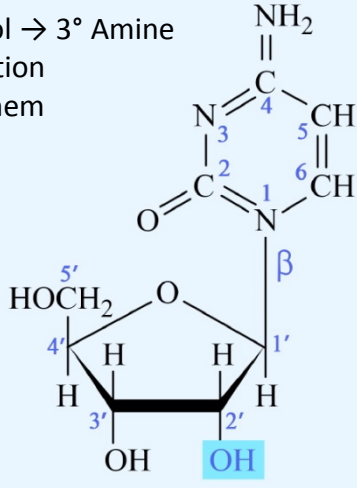


β-2-Deoxyribose
(found in DNA)

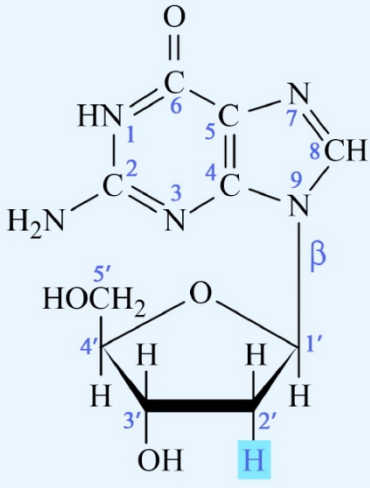
Nucleosides

Focus on:

- Given Table 31.1 on cheat sheet
- Base + Sugar
- 2° Amine + Alcohol → 3° Amine
- Dehydration Reaction
- Be able to draw them



Cytidine
A ribonucleoside

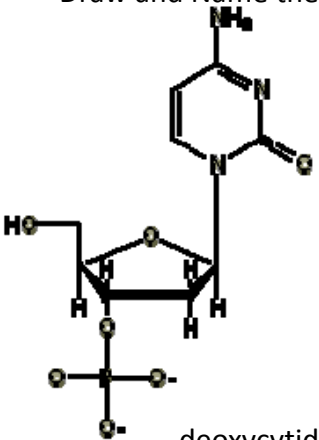


Deoxyguanosine
A deoxyribonucleoside

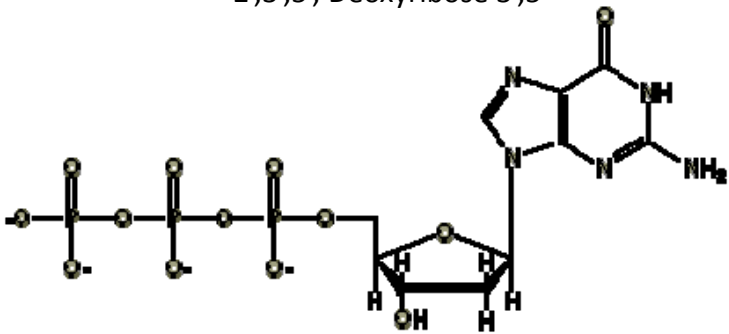
Nucleotides

Focus on:

- Given Table 31.1 on cheat sheet
- Base + Sugar + Phosphate
- Phosphate Anhydride Bonds
- Draw and Name them
- Dehydration Reaction
- Naming/Abbreviations
- Phosphates can connect to Ribose 2',3',5', Deoxyribose 3',5'

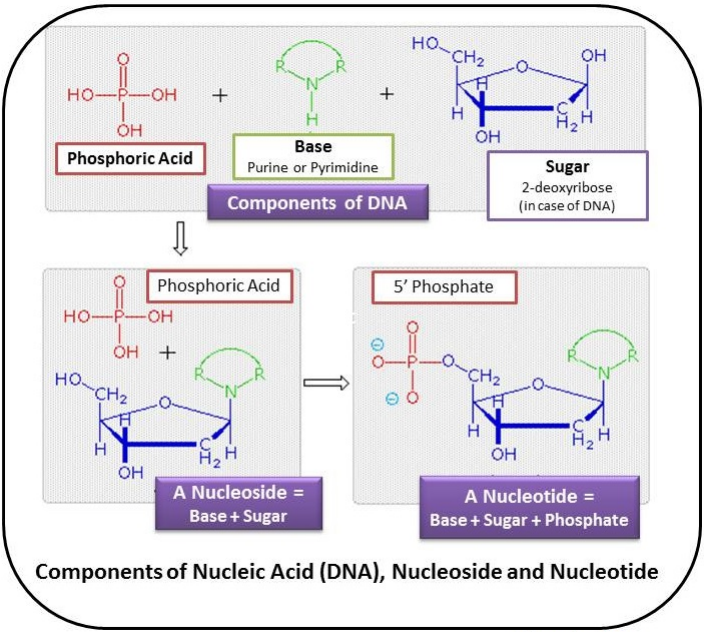


deoxycytidine – 3'-diphosphate



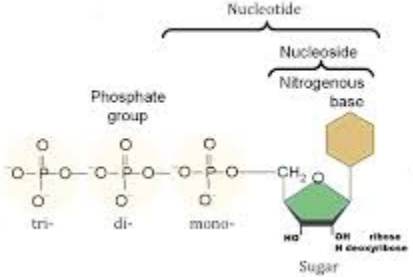
guanosine-5'-triphosphate

Parts of Nucleotide



Components of Nucleic Acid (DNA), Nucleoside and Nucleotide

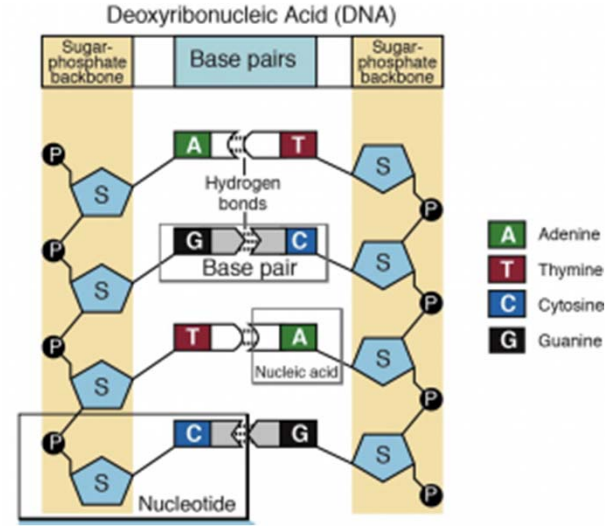
Namrata Heda

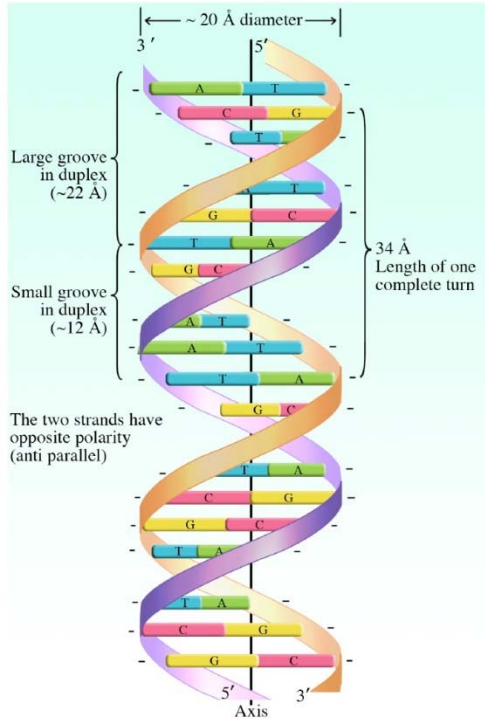


DNA

Focus on:

- Draw a small segment
- Double Helix with Bases = rungs
- Held together by Hydrogen Bonds
- Complementary

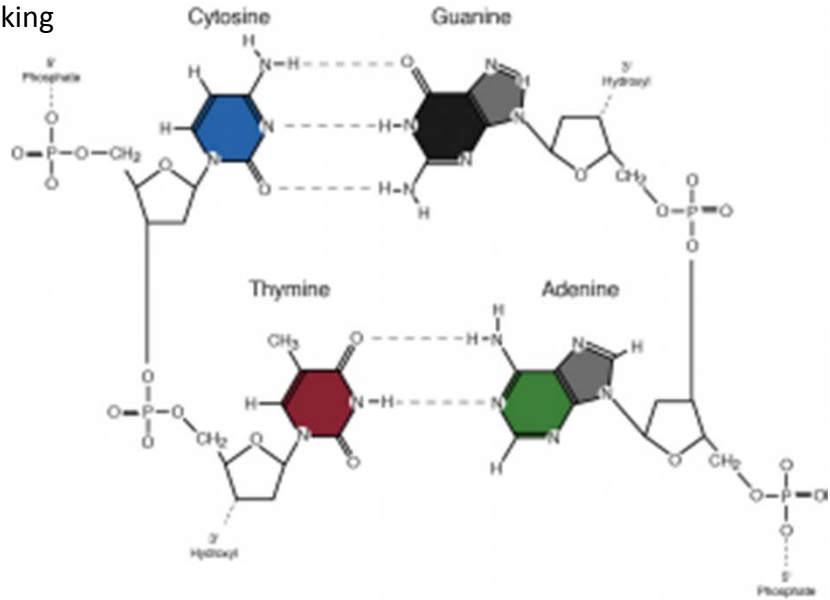




Complimentary Base Pairs

Focus on:

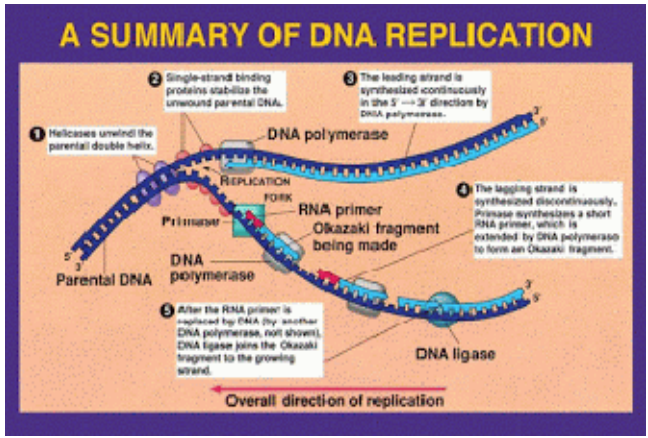
- Hydrogen Bonds
- G/C and T/A
- Built in Error Checking



Replication

Definition: process by which DNA is duplicated

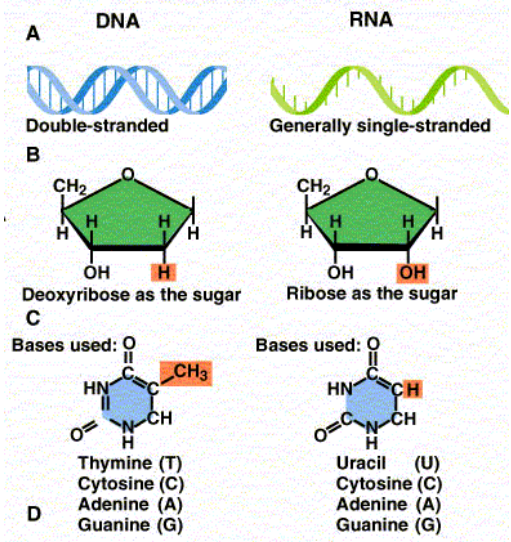
- Complementary nature is key to duplication
- Each new strand is 1 template + 1 new complementary strand
- Strands copied differently
    - Towards the point of unwinding → continuous synthesis
    - Away from the point of unwinding → fragmented synthesis
- Rigorous error checking: 1/Billion error rate



DNA vs RNA

Differences between DNA and RNA

DNA	RNA
1. Double Strand	1. Single Strand
2. Dexoyribose	2. Ribose
3. T	3. U
4. Store Information	4. mRNA/rRNA/tRNA Blueprint/Machinery/Dump Truck
5. Unmodified	5. Heavily Modified



RNA - General

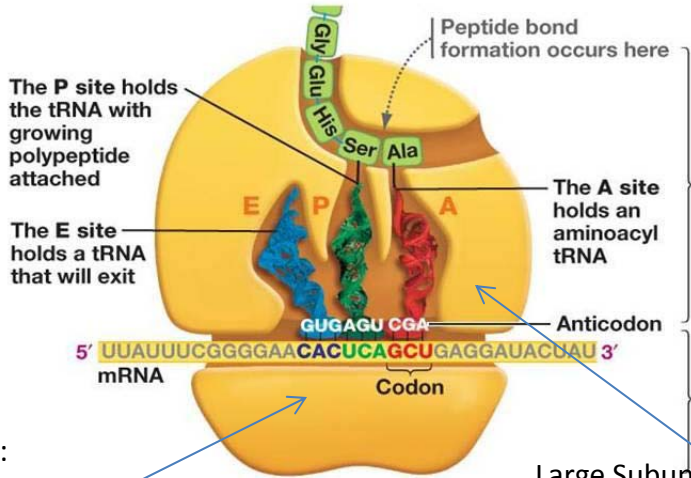
RNA – Summary

- 3 main types
    - rRNA = ribosomal → machinery (80%)
    - mRNA = messenger → blueprint
    - tRNA = transfer → dump truck
- Single Strand
- U instead of T
- Complimentary to DNA (HB)
- Heavily Modified
    - Methylation (add CH_3)
    - Saturation of C=C
    - Isomerization of ribose

rRNA

Ribosomal RNA

- 80% of RNA
- Combines with proteins to make ribosomes
- Machinery to synthesis proteins (30-35% rRNA, 60-65% protein)
- Complicated structure (skip)



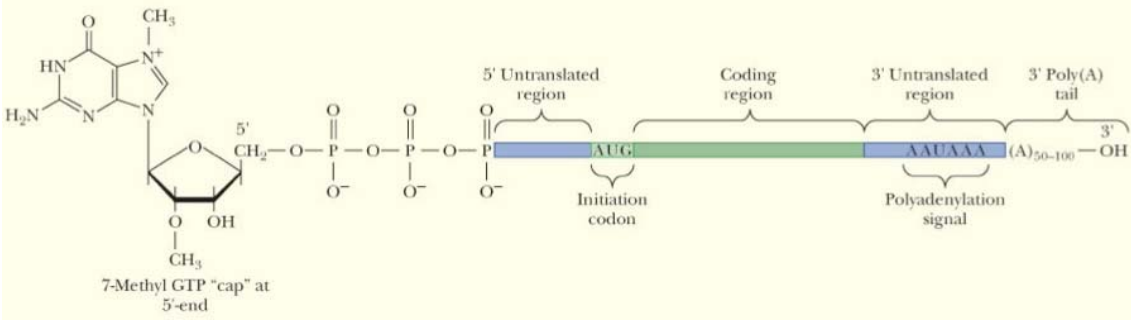
Small Subunit:
21 different proteins
+ rRNA

Large Subunit:
34 different proteins + rRNA

mRNA

Messenger RNA

- Carries information from DNA to Ribosome
- Blueprint
- Undergoes some modification
- More than just Blueprint
    - Includes 5’ cap group
    - Untranslated regions – where ribosome can interact
    - Coding region
    - 3’ tail

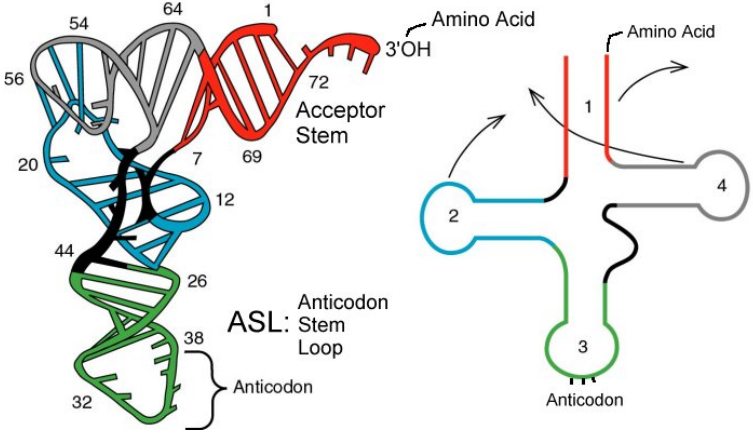


tRNA

Allosteric Regulation:

- Transfer
- Dump truck
- Bring AA to Ribosome – Interacts with ribosome, AA and mRNA
- Unique cloverleaf shape – 3 important regions

1 - Acceptor Region – binds to AA
2,4 – Ribosome handles – interact with ribosome
3 - Anticodon region – binds to mRNA



Other Types of RNA

ncRNA (Noncoding RNA)

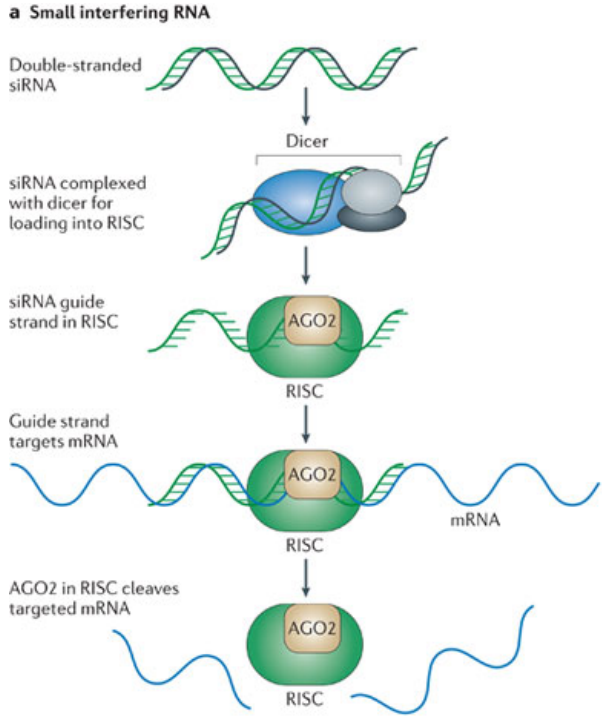
- Control flow of genetic information
- Know 1 example
- Hot new area to research for curing genetic diseases

Type	Size	Location	Purpose
Micro (miRNA)	20-25	Cytoplasm	Stop translation by blocking ribosomes
Small Nuclear (snRNA)	60-200	Nucleus	Control post transcription modification
Small Nucleolar (snoRNA)	70-100	Nucleolus	Control modification of rRNA
Small Interfering (siRNA)	20-25	Cytoplasm	Stop translation by triggering mRNA destruction

siRNA

siRNA

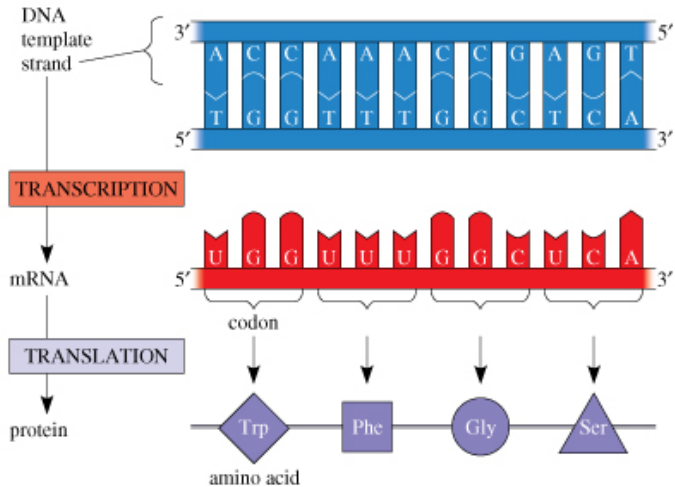
- Stops translation by signaling the destruction of mRNA before it is translated into a protein



Genetic Code

Genetic Code:

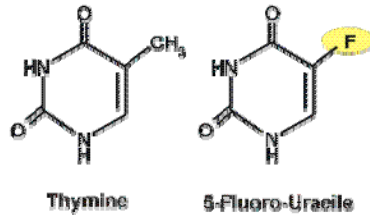
- Given on cheat sheet, just know how to use it
- Understand complementary relationships
    - G/C and A/T/U
- Convert sequences
    - DNA ↔ mRNA
    - mRNA ↔ tRNA
    - DNA ↔ AA Sequence



Cancer

Cancer:

- **Oncogenes:** proteins that code for cell growth
- **Cancer:** uncontrolled/unregulated cell growth/reproduction caused by loss of oncogene regulation
- **Tumor-Suppressor Genes:** block/reduce cancer by causing apoptosis if cell is damaged
    - 20+discovered for rare cancers
    - Example p53 is inactive in about 50% of cancers
    - Suppression of gene allows cancer to develop
- **Apoptosis:** cause cell destruction
    - release of cytochrome C from mitochondria activates caspases (digestive enzyme) → breaks apart cell machinery
- **Treatments:**
    - Radiation → kills fast growing cells
    - Chemotherapy → kills fast growing cells
    - Genetics → activate tumor-suppressing genes
    - Example: 5-fluoro-uracile inhibits production of thymine



Human Genome Project

Human Genome Project:

- Heredity is controlled by DNA
- Genetic Diseases effect 8% humans
- Started 1998 → Map 3 billion base pairs
- Finished 2001!

Results:

- Codes for 23,000 enzymes but potentially could code for 100,000+ (junk DNA)
- 98% of Genome ≠ code proteins
    - Unknown or no function
    - Junk DNA
    - Regulation
    - Unused/Abandoned genes
- 1000 of genetic tests developed

Goal:

- Cure Genetic Diseases – easier said than done, but some successes

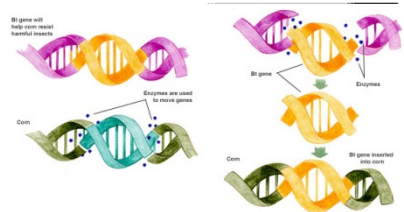
Genetic Engineering

Genetic Engineering

- Laboratory technique for controlling/causing genetic change
- DNA polymerase chain reaction: copies specific genes over and over
- Restriction Endonucleases: split DNA at very specific points
- Insertion: Ability to insert genetic material
- Ligases: covalently bond DNA back together
- Recombinant DNA: DNA whose base pairs have been rearranged to contain new information

Examples:

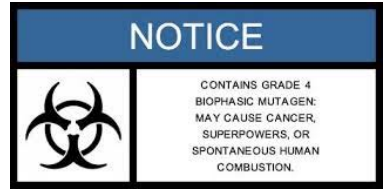
- Yeast/Bacteria → Insulin, Anemia drugs, Interferon
- Agriculture → GMO crops, pesticide resistance

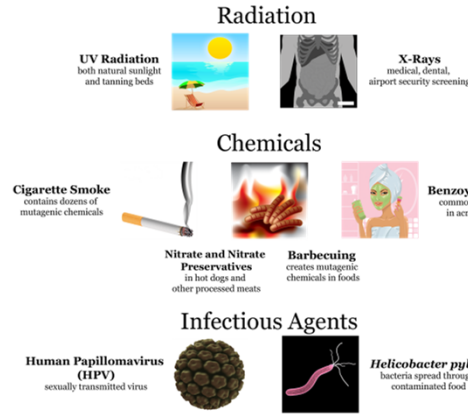


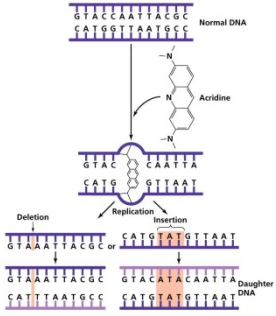
Mutation

Mutation

- Mutation: alteration to DNA that changes genome in child but not parent
  - Good (Superpowers) or Bad (Cancer, diseases)
  - Evolution
- Mutagens: cause genetic damage
  - Ionizing Radiation – UV, x-rays, cosmic rays
  - Chemicals
  - Radioactive decay
  - Heavy Metals
  - Viruses
- Anti-oxidants







Examples:

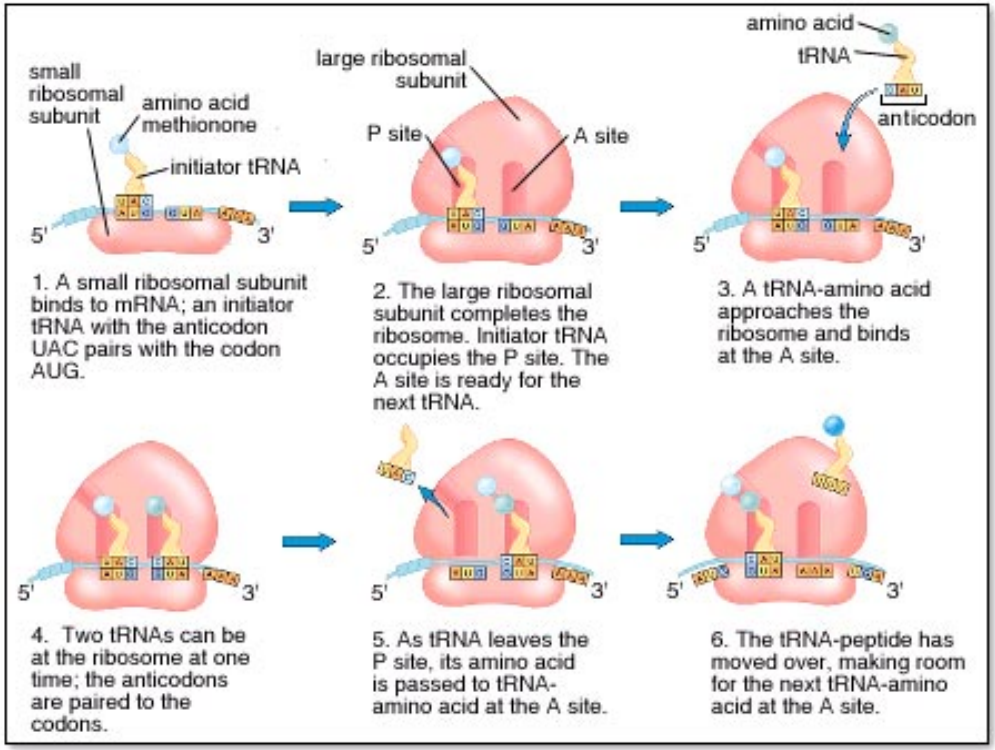
- Cancer
- Superpowers
- Evolution

Translation
General (I)

Translation – General

- Dfn: Biosynthesis of Proteins (DNA → RNA → Protein)
    - Step 0: Preparation
    - Step 1: Initialization
    - Step 2: Elongation
    - Step 3: Termination
- Know the roles of:
    - DNA
    - mRNA, tRNA, rRNA
    - Ribosomes – 2 subunits, 3 binding sites (1 mRNA, 2-tRNA)
    - AA
    - ATP

Translation
General (II)

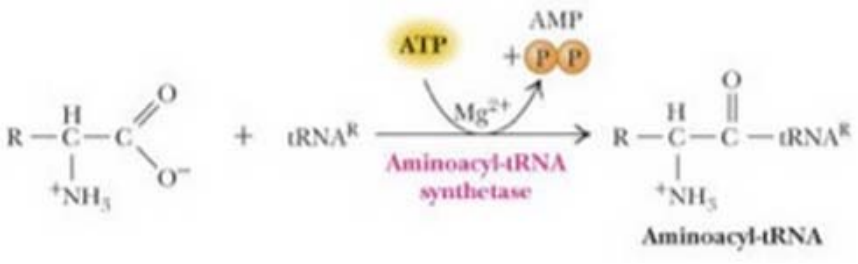

small ribosomal subunit
amino acid methionone
initiator tRNA
5'
3'
1. A small ribosomal subunit binds to mRNA; an initiator tRNA with the anticodon UAC pairs with the codon AUG.
large ribosomal subunit
P site
A site
5'
3'
2. The large ribosomal subunit completes the ribosome. Initiator tRNA occupies the P site. The A site is ready for the next tRNA.
amino acid
tRNA
anticodon
5'
3'
3. A tRNA-amino acid approaches the ribosome and binds at the A site.
5'
3'
4. Two tRNAs can be at the ribosome at one time; the anticodons are paired to the codons.
5'
3'
5. As tRNA leaves the P site, its amino acid is passed to tRNA-amino acid at the A site.
5'
3'
6. The tRNA-peptide has moved over, making room for the next tRNA-amino acid at the A site.

Translation
Step 0 - Preparation

Translation – Step 0 – Preparation

- DNA transcribed to mRNA
- mRNA moves from nucleous to cytoplasm
- mRNA binds to 5+ ribosomes
- tRNA binds to AA (requires an enzyme)

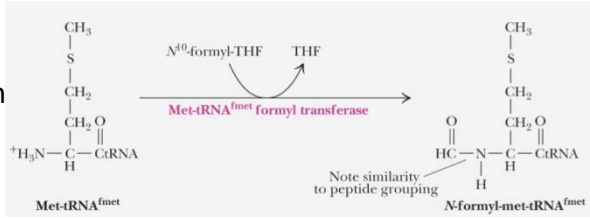
$$AA + tRNA + ATP \rightarrow AA\text{-}tRNA + AMP + 2\ P_i$$

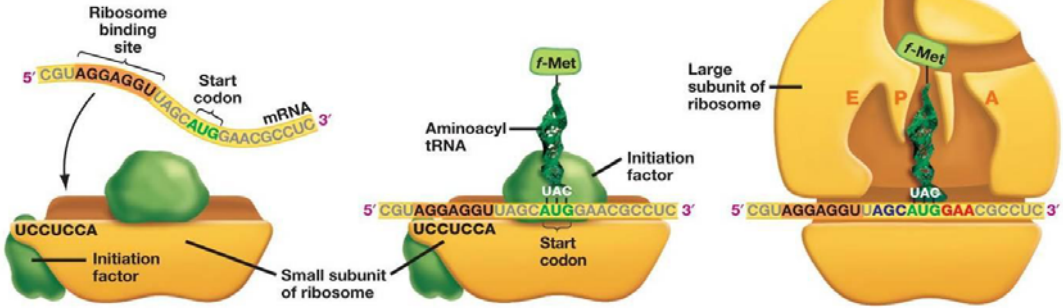


Translation
Step 1 - Initiation

Translation – Step 1 – Initiation

- AUG (Met) = start codon
  - Capped to prevent reaction on amine end
- Ribosome binds to mRNA at/near the initiator/start codon

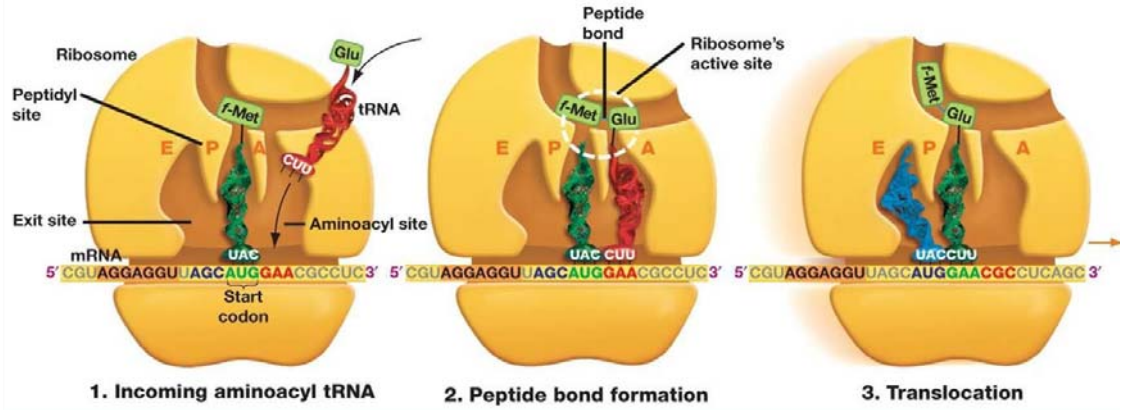




Translation
Step 2 - Elongation

Translation – Step 2 – Elongation

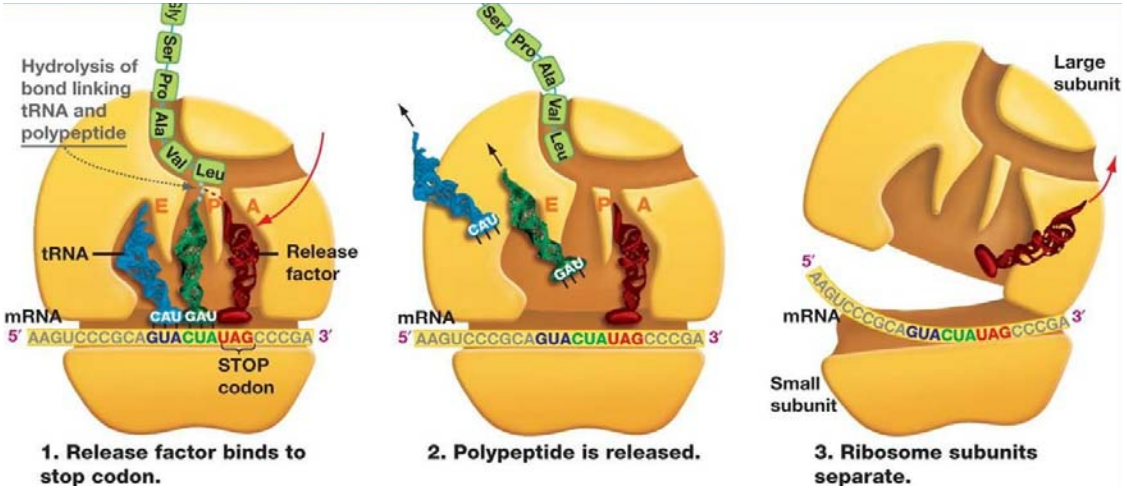
- tRNA HB to mRNA anticodon
- Ribosome makes peptide bond between AA
- tRNA breaks off (to be reused)
- Process repeats….



Translation
Step 3 - Termination

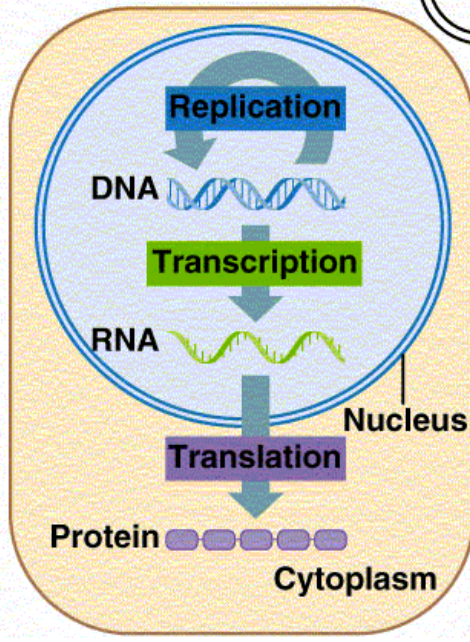
Translation – Step 3 – Termination

- Elongation stops when a TC/nonsense codon is reached
- Last tRNA is hydrolyzed
- Ribosomes separate and release mRNA and finished protein



Big Picture: Central Dogma of Biology

Central Dogma of biology



Hydrogen Bonding

Hydrogen Bonding:

- Complementary - Between Base Pairs in DNA or DNA/RNA
- Structure → specific shapes of proteins and RNA