The Central Dogma
Transcription and Translation
The Central Dogma

• Genetic information is stored in DNA.

• **DNA Replication** is the genetic information that is replicated directly to create an identical strand of DNA.
  - Main enzyme- DNA polymerase

• **Transcription** is the process of copying a sequence of DNA to produce a complementary strand of RNA.
  - Main enzyme- RNA polymerase

• **Translation** is the process that converts, or translates, an mRNA message into a polypeptide (chain of amino acids).
Where do they occur?

- Replication- Nucleus
- Transcription- Nucleus
- Translation- Cytoplasm

Where do you think all three occur in a prokaryotic cell?
How is RNA different from DNA?

• 1. Sugar- ribose
• 2. Has uracil instead of thymine
• 3. Single stranded, not double stranded
Transcription

- DNA → RNA
- A gene is transferred, not a chromosome, into an RNA message.
- Catalyzed by RNA polymerase, which bonds nucleotides together.
- Three types of RNA
  - **Messenger RNA (mRNA)**: carries DNA message to ribosome for translation to protein
  - **Ribosomal RNA (rRNA)**: forms ribosomes (protein factories)
  - **Transfer RNA (tRNA)**: brings amino acids from the cytoplasm to a ribosome to help make more proteins.
Three Steps - Transcription

1. RNA polymerase and other proteins recognize the start of the gene and begin to unwind the segment of DNA so that the bases are exposed, and the free nucleotides can pair with them.
   - Transcription starts at promoter sequence in DNA
     - TATAAAA (TATA box)

2. RNA nucleotides form complementary base pairs with the DNA template. G-C and A-U.
3. The **completed** RNA strand separates from the DNA template, and the transcription complex falls apart. The **RNA transcript** then leaves the nucleus.
RNA Processing

- A cap and a tail are added to mRNA
  - Cap helps mRNA bind to ribosomes
  - Tail is a string of A’s that helps mRNA exit the nucleus
- Eukaryotic mRNA contains segments called introns and exons
  - Introns – “junk” RNA between exons, may regulate gene expression or protect against mutations
  - Exons – RNA segments that code for protein
- Introns must be removed before translation
- Exons are spliced together
Putting it all together
Translation- converting the message

- mRNA $\rightarrow$ protein
- Occurs in the cytoplasm on a ribosome
- mRNA contains 3 nucleotide codons (3 letters that code for a specific amino acid- language).
- There are 20 amino acids
  - Since there are $4^3$ or 64 codons, some amino acids have multiple codons
  - Example- Leucine: has six different codons: CUU, CUC, CUA, CUG, UUA, & UUG
- Start codon = signals the start of translation and is represented by AUG (codes for amino acid methionine- ALWAYS STARTS WITH THIS)
- Stop codons = the end of the amino acid sequence and are represented by- UAA, UAG, and UGA
How does a cell translate a codon into an amino acid?

- Two tools - ribosomes and tRNA
- Ribosomes are the site of protein synthesis
- Ribosomes are made up of rRNA and proteins
- Ribosomes have large and small subunits. The small subunit holds onto the mRNA strand, and the large subunit holds onto the growing protein.
- The tRNA acts as an adaptor between mRNA and amino acids - acts like a connector to make sure that the free floating amino acids in the cytoplasm make it to the ribosome.
ribosome

large subunit binds to tRNA

binding sites

small subunit binds to mRNA
• Anticodon- set of three nucleotides that is complementary to an mRNA codon.
• Example- Codon= GGG, the anticodon would be_____
Steps of Translation

1. mRNA binds with small ribosomal subunit in the cytoplasm
2. tRNA with methionine binds to the start codon (AUG)
3. This binding causes a large ribosomal subunit to join (has three tRNA binding sites)
4. mRNA is pulled through the ribosome one codon at a time
5. tRNAs pair correct amino acids with each codon
6. Ribosome helps form peptide bonds between the amino acids
7. tRNA leaves to pick up another amino acid
8. Translation stops when a stop codon is reached, and a protein is released
9. Process can be repeated many times on each mRNA
**DNA:** DNA base sequence (triplets) of the gene codes for synthesis of a particular polypeptide chain.

**mRNA:** Base sequence (codons) of the transcribed mRNA.

**tRNA:** Consecutive base sequences of tRNA anticodons recognize the mRNA codons calling for the amino acids they transport.

**Polypeptide:** Amino acid sequence of the polypeptide chain.

Start translation.
How to translate mRNA

To decode the codon, move from the center circle towards the periphery.
Practice!

DNA:    T A C G G A C G T A T G C C T T T A A T T

mRNA:   

Protein: 

DNA:    T A C T C A C T G A G G G C G A C T A A T C

mRNA:   

Protein: 

What would happen if the sixth DNA base was changed from an A to a T? Why?
Gene Regulation: Prokaryotes

- Because prokaryotes have no nucleus, transcription and translation occur simultaneously
- Genes organized in operons
  - Promoter: helps RNA polymerase find the beginning of the gene
  - Operator: turns genes on or off
  - Gene: codes for protein
**lac operon**

- Genes code for enzymes that break down lactose.
- When lactose is absent, gene is turned off.
  - Repressor protein binds to operator which prevents transcription.

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Operon turned off (lactose absent)
When lactose is present, gene is turned on

- lactose binds to repressor protein making it fall off the operator, allows transcription
Gene Regulation: Eukaryotes

- Gene regulation is more complex in eukaryotes because transcription and translation are more complex.
- Transcription factors bind to gene promoters to help RNA polymerase find the start of the gene.
  - Ex: Glucose triggers the production of a transcription factor (HNF1α) which promotes the transcription of insulin genes.
- Gene regulation also occurs during RNA processing.
  - One mRNA transcript can yield different proteins based on how exons are spliced together.
Gene Mutations

• Point mutation
  • One nucleotide is substituted for another (ex. A → G)
  • This may change the amino acid coded for by the affected codon
  • Ex: sickle cell anemia
  • SAM MET BAT MAN → SAM MET CAT MAN

![Gene Mutations Diagram](image-url)
Gene Mutations

• Frameshift mutation
  • One nucleotide is inserted or deleted
  • This shifts the entire codon reading frame
  • Can have a disastrous effect on protein product
  • Ex: cystic fibrosis
  • Deletion: SAM MET BAT MAN \(\rightarrow\) SAM ETB ATM AN
  • Insertion: SAM MET BAT MAN \(\rightarrow\) SAM NME TBA TMA N
Effects of Mutations

- **Silent**: no change in amino acid sequence
- **Missense**: one amino acid is changed (sickle cell anemia)
- **Nonsense**: mutation creates a stop codon

http://evolution.berkeley.edu/evolibrary/article/mutations_05
<table>
<thead>
<tr>
<th>Mutation</th>
<th>Type of Mutation</th>
<th>Effect on Protein Sequence</th>
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</thead>
<tbody>
<tr>
<td>ATA → ATG</td>
<td></td>
<td></td>
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<tr>
<td>ACG → ACT</td>
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Chromosomal Mutations

- Create large scale changes in DNA, can occur mid-gene

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<th>Inversion</th>
<th>Deletion</th>
<th>Insertion</th>
<th>Translocation</th>
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<tr>
<td>Segment of a chromosome is duplicated</td>
<td>Segment of a chromosome is inverted (flipped)</td>
<td>Segment of a chromosome is deleted</td>
<td>Segment of one chromosome is removed and inserted into a different chromosome</td>
<td>Two different chromosomes exchange segments</td>
</tr>
</tbody>
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Williams Syndrome

- Caused by a deletion on chromosome 7
- Causes low birth weight, distinctive facial features, learning disabilities, overly friendly personalities

http://www.genetics4medics.com/williams-syndrome.html
Are all mutations inherited?

- Mutations in germ-line cells (cells that become sex cells) are inherited.
- Mutations in somatic cells (body cells) are not inherited.

What causes mutations?

• Errors in DNA replication
  - Build up over time → aging

• Mutagens: chemicals or environmental factors that can damage DNA
  - Ex: UV rays, tobacco, asbestos, X rays

https://socratic.org/questions/what-can-cause-mutations