Cell Biology: RNA and Protein synthesis

In all living cells, DNA molecules are the storehouses of information

Outline
1. Key concepts
2. Central Dogma
3. RNA Types
4. RNA (Ribonucleic Acid)
5. Codon and Protein synthesis
6. Mutation
7. Conclusions

Key Concepts:
1. Life cannot exist without enzymes and other proteins
2. The path leading from genes to proteins involves two steps, called transcription and translation
3. Transcription involves assembly of an RNA molecule
4. In translation, a certain type of RNA directs the linkage of amino acids to produce a polypeptide chain
Key Concepts:
5. The genetic “code words” by which DNA’s instructions are translated into proteins are the same in all species of organisms
6. A mutation is a permanent change in a gene’s base sequence
7. Mutations give rise to alterations in protein structure and protein function

Central Dogma

From DNA to Protein
RNA (Ribonucleic Acid)

1. Single-stranded
2. Four nucleotides, one is different from DNA
   - DNA – Thymine
   - RNA – Uracil
   - DNA – A, C, G, T
   - RNA – A, C, G, U.
3. Ribose instead of deoxyribose

RNA Types

1. Messenger RNA (mRNA)
   a. Complementary copies of DNA sequences
   b. Formed from only one strand of the DNA
   c. Carries the code from genes to ribosomes
2. Ribosomal RNA (rRNA)
   - combines with protein to form ribosomes, on which protein synthesis occurs (with two subunits)
3. Transfer RNA (tRNA)
   - carries amino acids to ribosome (with Anticodon)

Structure of an RNA Nucleotide

Uracil instead of Thymine (DNA)
RNA Types

Base Pairing of RNA with DNA

Base pairing
A = U
G = C

Codon and Protein synthesis
Gene expression is the process of making proteins from DNA nucleotide message.

Protein synthesis is a two-step process:
1. Transcription—nucleotide message sent from nucleus to cytoplasm
   a. DNA nucleotide sequence "copied" (using complementary base pairing) as a "messenger" nucleotide sequence of RNA (mRNA)
   b. The synthesis of mRNA; similar to DNA replication
   c. The entire DNA molecule in a chromosome is not transcribed, only a specific gene or family of genes is transcribed
Codon and Protein synthesis

2. Translation—Nucleotide sequence of mRNA used to synthesize a sequence of amino acids
a. Occurs on the endoplasmic reticulum (Rough ER)
b. mRNA codons are used to specify amino acids
c. Ribosomes "read" mRNA codons to synthesize a specific amino acid sequence
d. Each of the 20 amino acids has a specific "carrier" transfer RNA that brings the AAs to the ribosome
e. Complementary base pairing between the mRNA and tRNAs determines the amino acid sequence
f. Ribosomes need to recognize the beginning and end:
   1) Initiation (start) codon: AUG (methionine)
   2) Stop codons: UAA, UAG, UGA

Codon and Protein synthesis

Codon— the genetic code words are a sequence of nucleotides of mRNA that are read in blocks of three (read in triplets).
one gene — one protein
one codon — one amino acid
4 nucleotides, if read 2 at a time, 16 possible combination; if read in triplets, 64 possible combinations. (Only 20 AAAs)
Exons = coding sequences of DNA.
Introns = one type of non-coding sequences of DNA (in eukaryotes, more than 90% of DNA sequences are non-coding sequence)
The genetic code is nearly universal. All living things share the codons:

1. Common ancestors
2. Genetic engineering

A tobacco plant expressing a firefly gene (a gene codes for the firefly enzyme that catalyzes the chemical reaction that releases energy in the form of light.)
Process of Gene Transcription

RNA polymerase binds with promoter

Transcription begins

Assembly or RNA transcript

The transcript is released from the DNA
Finishing Touches on mRNA Transcripts

Modification
- Introns
  - Snipped out
- Exons
  - Get translated

The Genetic Code

Codons
- On mRNA
- Triplets
- 64 kinds of codons
- Only 20 amino acids

Structure of tRNA

anticodon

tRNA MOLECULE

amino acid attachment site
Role of tRNA

tRNA
Attachment site for amino acid
Anticodon

Role of rRNA

rRNA
Components of ribosomes

Translation

THREE STEPS

Initiation
tRNA and mRNA are loaded onto a ribosome

Elongation
Polypeptide chain forms as mRNA passes between ribosome subunits

Termination
Stop codon and detachment of mRNA and polypeptide chain
How is mRNA Translated?

Initiation

mRNA transcript leaves nucleus

In cytoplasm

Elongation begins

Translation begins
How is mRNA Translated?

Peptide bond formation

Additional amino acid forms a peptide bond between amino acids 2 and 3

Termination

Stop codon moves in
How is mRNA Translated?

Termination

Polypeptide chain is released from the ribosome

Protein Synthesis

Small subunit

mRNA

Large subunit

mRNA

Small subunit

Large subunit

Protein Synthesis

The small ribosomal subunit binds to the mRNA and recognition sequence or an mRNA, and the messenger RNA (mRNA) binds the A site and ribosome, engaging the initiation complex.

The large ribosomal subunit then initiates translation, with another mRNA (tRNA) now occupying the P site.
Do Mutations Affect Protein Synthesis?

Gene mutations Sequences can change

Mutations and gene

Point mutation – a mutation limited to about one or a few base pairs in a single gene. (two types: 1. Substitutions 2. Insertions or deletion)

Substitutions:
- a. silent substitution
- b. conservative substitution
- c. significant change in protein (rare occasion → enhance success of its descendants)
- d. missense and nonsense

Insertions and deletions:
- Frameshift mutation produces nonfunctional protein
In Conclusion

1. Cells cannot stay alive without enzymes and other proteins
2. The amino acid sequence of a polypeptide chain corresponds to a gene region in a double-stranded DNA molecule
3. The path from genes to proteins is DNA → RNA → Protein
4. In transcription, double-stranded DNA is unwound at a gene region
5. In translation, the three classes of RNA’s interact in the synthesis of polypeptide chains
6. Translation proceeds through three stages: Initiation, elongation, and termination
7. Gene mutations are heritable small-scale changes in DNA’s base sequence