



Role of RNA in Gene Expression and Regulation

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Received date: 28 May, 2024, Manuscript No. JBPY-24-139474;

Editor assigned date: 30 May, 2024, PreQC No. JBPY-24-139474 (PQ);

Reviewed date: 13 June, 2024, QC No. JBPY-24-139474;

Revised date: 21 June, 2024, Manuscript No. JBPY-24-139474 (R);

Published date: 28 June, 2024, DOI: 10.4172/jbpy.1000158.

Description

RNA (Ribonucleic Acid) plays an important role in gene expression and regulation, acting as both a messenger and regulator of genetic information. Unlike DNA, which serves primarily as a stable storage of genetic information, RNA is dynamic, capable of conveying instructions from DNA to synthesize proteins and modulating gene expression. The multifaceted roles of RNA in gene expression and regulation, emphasizing its importance in cellular function and organismal development.

mRNA carries the genetic information transcribed from DNA to the ribosome, where it guides protein synthesis. During transcription, RNA polymerase reads the DNA template and synthesizes a complementary mRNA strand. This mRNA undergoes processing, including splicing to remove introns, the addition of a 5' cap, and a 3' poly-A tail. The mature mRNA then exits the nucleus and is translated into a protein by ribosomes. The sequence of codons in mRNA dictates the amino acid sequence of the resulting protein, directly linking genetic information to protein synthesis.

rRNA is a structural and functional component of ribosomes, the cellular machinery responsible for protein synthesis. Ribosomes consist of two subunits composed of rRNA and proteins. rRNA ensures the correct alignment of mRNA and tRNAs, catalyzes the formation of peptide bonds between amino acids, and provides structural stability to the ribosome. By facilitating the translation process, rRNA plays a central role in decoding mRNA into functional proteins.

tRNA molecules transport amino acids to the ribosome during translation. Each tRNA has an anticodon that is complementary to an mRNA codon and an attached specific amino acid. The ribosome facilitates the matching of tRNA anticodons with mRNA codons,

enabling the sequential addition of amino acids to the growing polypeptide chain. Thus, tRNA acts as an adaptor molecule, translating the genetic code into a specific protein sequence.

Regulatory RNAs in gene expression

In addition to mRNA, rRNA, and tRNA, several types of regulatory RNAs modulate gene expression at various levels, including transcription, RNA processing, and translation. These regulatory RNAs include microRNAs (miRNAs), small interfering RNAs (siRNAs), and long non-coding RNAs (lncRNAs). miRNAs are short, non-coding RNAs that regulate gene expression post-transcriptionally by binding to complementary sequences on target mRNAs, usually in their 3' Untranslated Regions (UTRs). This binding typically results in mRNA degradation or translational repression, thereby reducing protein production. miRNAs are involved in various biological processes, including development, differentiation, and stress responses. Dysregulation of miRNAs is associated with diseases such as cancer, highlighting their critical regulatory functions.

siRNAs are similar in function to miRNAs but are derived from double-stranded RNA precursors. They play a key role in RNA interference (RNAi), a cellular defense mechanism against viral infections and transposable elements. siRNAs guide the RNA-Induced Silencing Complex (RISC) to complementary mRNA targets, leading to their cleavage and degradation. RNAi technology harnesses siRNAs for gene silencing in research and therapeutic applications, illustrating their utility in modulating gene expression.

lncRNAs are a diverse class of non-coding RNAs longer than 200 nucleotides. They regulate gene expression at multiple levels, including chromatin remodeling, transcriptional control, and post-transcriptional processing. lncRNAs can act as scaffolds, guides, or decoys for protein complexes, influencing gene expression by altering chromatin states, modulating transcription factors, or sequestering miRNAs. The functional versatility of lncRNAs underscores their importance in gene regulation.

Conclusion

RNA's roles in gene expression and regulation are fundamental to cellular function and organismal development. mRNA, rRNA, and tRNA are essential for translating genetic information into functional proteins, while regulatory RNAs like miRNAs, siRNAs, and lncRNAs finely tune gene expression through various mechanisms. Understanding RNA's diverse functions not only elucidates the complexity of gene regulation but also opens avenues for therapeutic interventions in diseases linked to RNA dysregulation. As research continues to uncover new facets of RNA biology, its significance in gene expression and regulation will undoubtedly expand, offering deeper insights into the molecular basis of life.

Citation: Fe S (2024) Role of RNA in Gene Expression and Regulation. J Biochem Physiol 7:2.