Protein biosynthesis (or protein synthesis) is a core biological process, occurring inside cells, balancing the loss of cellular proteins (via degradation or export) through the production of new proteins. Proteins perform a number of critical functions as enzymes, structural proteins or hormones.

Protein biosynthesis is the process by which cells build proteins, involving two main stages: transcription and translation. Each stage consists of multiple steps and requires various cellular machinery.

Overview of Protein Biosynthesis: Transcription:

Initiation: Transcription factors and RNA polymerase bind to the promoter region of a gene. Elongation: RNA polymerase synthesizes a pre-mRNA transcript by reading the DNA template strand. Termination: Transcription ends when RNA polymerase reaches a termination sequence. RNA Processing: The pre-mRNA undergoes splicing to remove introns, addition of a 5' cap, and a poly-A tail to become mature mRNA. Translation:

Initiation: The small ribosomal subunit binds to the mRNA near the start codon (AUG). The initiator tRNA carrying methionine binds to the start codon. The large ribosomal subunit then assembles to form the complete ribosome. Elongation: The ribosome moves along the mRNA, and aminoacyl-tRNAs bring amino acids to the ribosome. The ribosome catalyzes peptide bond formation between amino acids, elongating the polypeptide chain. Termination: When the ribosome encounters a stop codon (UAA, UAG, or UGA), release factors prompt the release of the newly synthesized polypeptide and disassembly of the ribosome. Detailed Steps in Protein Biosynthesis: Transcription: Initiation:

Promoter Recognition: Transcription factors and RNA polymerase bind to the promoter region of the gene. DNA Unwinding: The DNA double helix unwinds to expose the template strand. Elongation:

RNA Synthesis: RNA polymerase moves along the DNA template strand, adding ribonucleotides to the growing RNA chain in a 5' to 3' direction. Termination:

Transcription Termination: RNA polymerase reaches a termination sequence and releases the newly synthesized RNA transcript. RNA Processing:

Splicing: Introns are removed from the pre-mRNA, and exons are joined together. 5' Capping: A 7-methylguanosine cap is added to the 5' end of the mRNA. Polyadenylation: A poly-A tail is added to the 3' end of the mRNA. Translation: Initiation:

Ribosome Assembly: The small ribosomal subunit binds to the mRNA's 5' cap and scans for the start codon (AUG). Initiator tRNA Binding: The initiator tRNA, carrying methionine, pairs with the start codon. Large Subunit Assembly: The large ribosomal subunit joins to form the complete ribosome. Elongation:

Codon Recognition: The ribosome reads the next codon and recruits the corresponding aminoacyl-tRNA. Peptide Bond Formation: The ribosome catalyzes the formation of a peptide bond between the amino acid on the initiator tRNA and the new amino acid. Translocation: The ribosome moves to the next codon, shifting the tRNAs and mRNA. Termination:

Stop Codon Recognition: The ribosome reaches a stop codon. Release Factor Binding: Release factors bind to the stop codon, promoting the release of the polypeptide chain. Ribosome Disassembly: The ribosomal subunits dissociate, and the mRNA is released. Post-Translational Modifications: After translation, proteins often undergo several modifications, such as:

Phosphorylation: Addition of phosphate groups. Glycosylation: Addition of carbohydrate groups. Acetylation: Addition of acetyl groups to lysine residues. Methylation: Addition of methyl groups. Ubiquitination: Addition of ubiquitin for protein degradation. Folding and Assembly: Proteins fold into their functional conformations and may assemble into complexes. These modifications are crucial for protein function, stability, and localization.

Understanding protein biosynthesis and its regulation is fundamental to molecular biology, genetics, and biotechnology, as it underpins cellular function and organismal development.