Chromosomes

The genome is organized into discrete elements known as **chromosomes.** The set of genes within a given chromosome is arranged in a linear fashion, but the number of genes per chromosome is variable. Similarly, although the number of chromosomes per cell is consistent for a given species, this number varies considerably among species. For example, human cells contain 23 pairs (i.e., diploid) of chromosomes whereas bacteria contain a single, unpaired (i.e., haploid) chromosome. The bacterial chromosome contains all genes essential for viability and exists as a double-stranded, closed circular, naked (i.e., not enclosed within a membrane) . The molecule is extensively folded and twisted (i.e., supercoiled) so that it may be accommodated within the confines of the bacterial cell. The fact that the linearized, unsupercoiled chromosome of the bacterium *Escherichia coli* is about 1300 μm in length but fits within a 1 μm × 3 μm cell attests to the extreme compactness that the bacterial chromosome must achieve. For genes within the compacted chromosome to be expressed and replicated, unwinding or relaxation of the molecule is essential.

In contrast to the bacterial chromosome, the chromosomes of parasites and fungi number greater than one per cell, are linear, and are housed within a membrane structure known as the **nucleus.** This difference is a major criterion for classifying bacteria as prokaryotic organisms, while classifying fungi and parasites as eukaryotes. The genome of viruses may be referred to as a chromosome, but the DNA (or RNA) is contained within a protein coat rather than within a cell.

Nonchromosomal Elements of the Genome

Although the bacterial chromosome represents the majority of the genome, not all genes within a given cell are confined to the chromosome. Many genes are also located on plasmids and transposable elements. Both of these are able to replicate and encode information for the production of various cellular products. Although considered part of the bacterial genome, they are not as stable as the chromosome and may be lost during cellular replication, often without severe detrimental effects on the cell.

Plasmids exist as “miniature” chromosomes in being double-stranded, closed, circular structures with size ranges from 1 to 2 kilobases up to 1 megabase or more. The number of plasmids per bacterial cell varies extensively, and each plasmid is composed of several genes. Some genes encode products that mediate plasmid replication and transfer between bacterial cells, whereas others encode products that provide a survival edge such as determinants of antimicrobial resistance. Unlike most chromosomal genes, plasmid genes do not usually encode for products essential for viability. Plasmids, in whole or in part, may also become incorporated in the chromosome. **Transposable elements** are pieces of DNA that move from one genetic element to another, from plasmid to chromosome or vice versa. Unlike plasmids, they do not exist as separate entities within the bacterial cell because they must either be incorporated into a plasmid or the chromosome. The two types of transposable elements are the **insertion sequence (IS)** and the **transposon.** Insertion sequences contain genes that simply encode for information required for movement among plasmids and chromosomes. Transposons contain genes for movement as well as genes that encode for other features such as drug

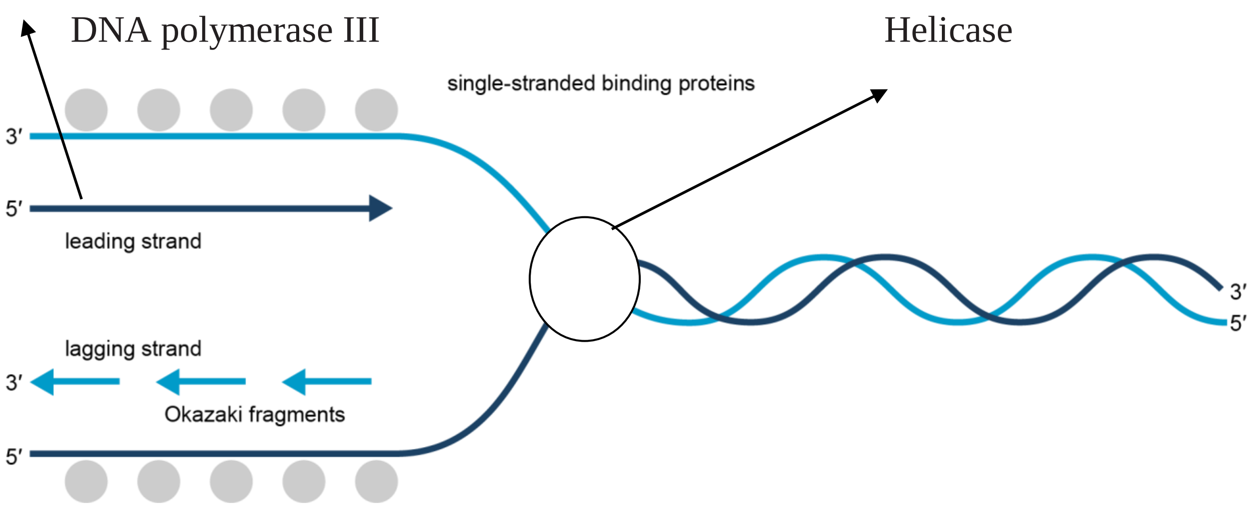
resistance. Plasmids and transposable elements coexist with chromosomes in the cells of many bacterial species. These extrachromosomal elements play a key role in the exchange of genetic material throughout the bacterial, including genetic exchange among clinically relevant bacteria.

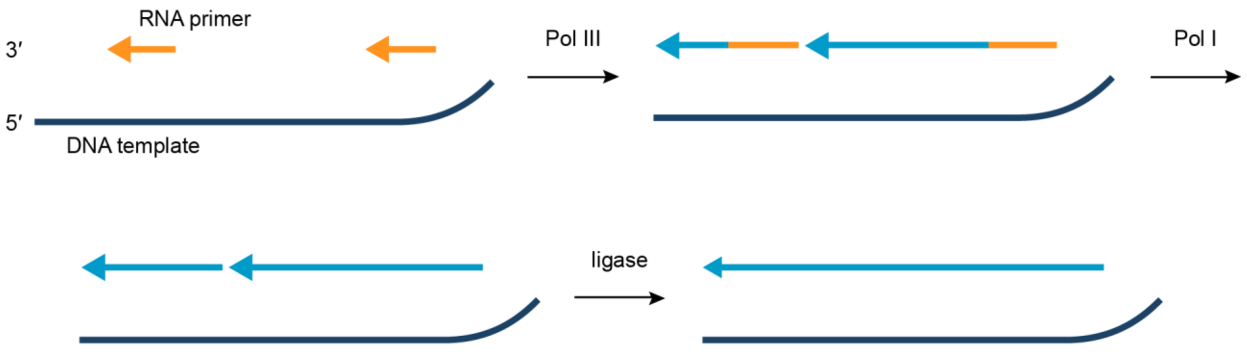
REPLICATION AND EXPRESSION OF GENETIC INFORMATION

Replication

Bacteria multiply by cell division that results in the production of two daughter cells from one parent cell. As part of this process, the genome must be replicated so that each daughter cell receives the same complement of functional DNA. Replication is a complex process that is mediated by various enzymes, such as DNA polymerase and cofactors; replication must occur quickly and accurately. For descriptive purposes, replication may be considered in four stages:

1. Unwinding or relaxation of the chromosome’s supercoiled DNA
2. Unzipping, or disconnecting, the complementary strands of the parental DNA so that each may serve as a template (i.e., pattern) for synthesis of new DNA strands
3. Synthesis of the new DNA strands
4. Termination of replication with release of two identical chromosomes, one for each daughter cell





Replication of DNA in Bacteria

Expression of Genetic Information

Gene expression is the processing of information encoded in genetic elements (i.e., chromosomes, plasmids, and transposons) that results in the production of biochemical products. **The overall process is composed of two complex steps, transcription and translation, and requires various components, including a DNA template representing a single gene or cluster of genes, various enzymes and cofactors, and RNA molecules of specific structure and function.**

Transcription: Gene expression begins with transcription, which converts the DNA base sequence of the gene (i.e., the genetic code) into an mRNA (messenger RNA) molecule that is complementary to the gene's DNA sequence (Figure 2-5).
Usually only one of the two DNA strands (the sense strand) encodes for a functional gene product, and this same strand is the template for mRNA synthesis.
RNA polymerase is the enzyme central to the transcription process.

The genetic code that is originally transcribed from DNA to mRNA and then translated from mRNA to protein. The code consists of triplets of nucleotide bases, referred to as **codons;** each codon encodes for a specific amino acid.
Because there are 64 different codons for 20 amino acids, an amino acid can be encoded by more than one codon. However, each codon specifies only one amino acid.
Therefore, through translation the codon sequences in mRNA direct which amino acids are added and in what order. Translation ensures that proteins with proper structure and function are produced. **Errors in the process can result in aberrant**

proteins that are nonfunctional, underscoring the need for translation to be well controlled and accurate.

Translation: diagrammatically shown in Figure 2-6, **involves three steps: initiation, elongation, and termination**. **Following termination, bacterial proteins often undergo posttranslational modifications as a final step in protein synthesis.**

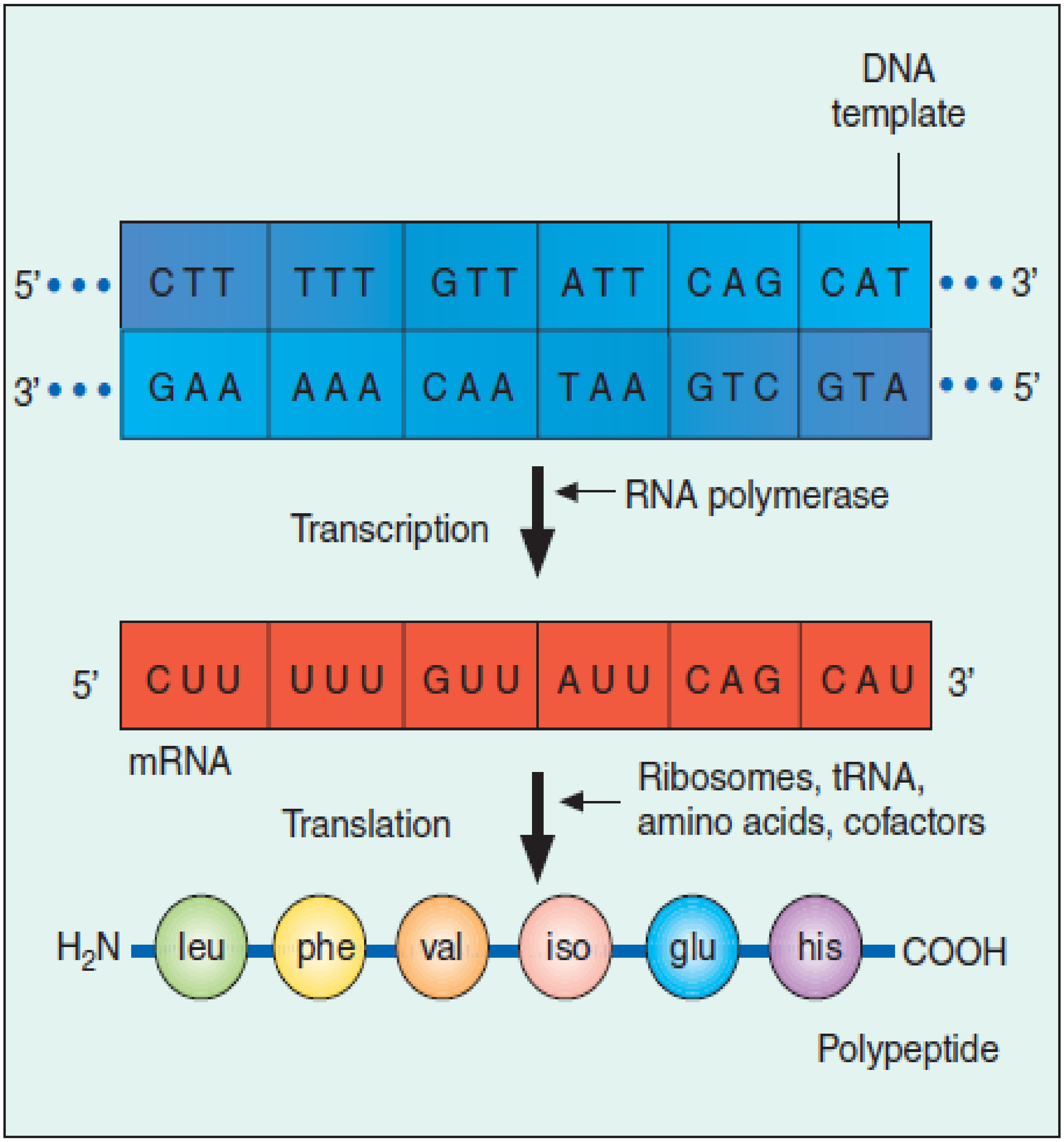


Figure 2-5 Overview of gene expression components; transcription for production of mRNA and translation for production of polypeptide (protein).

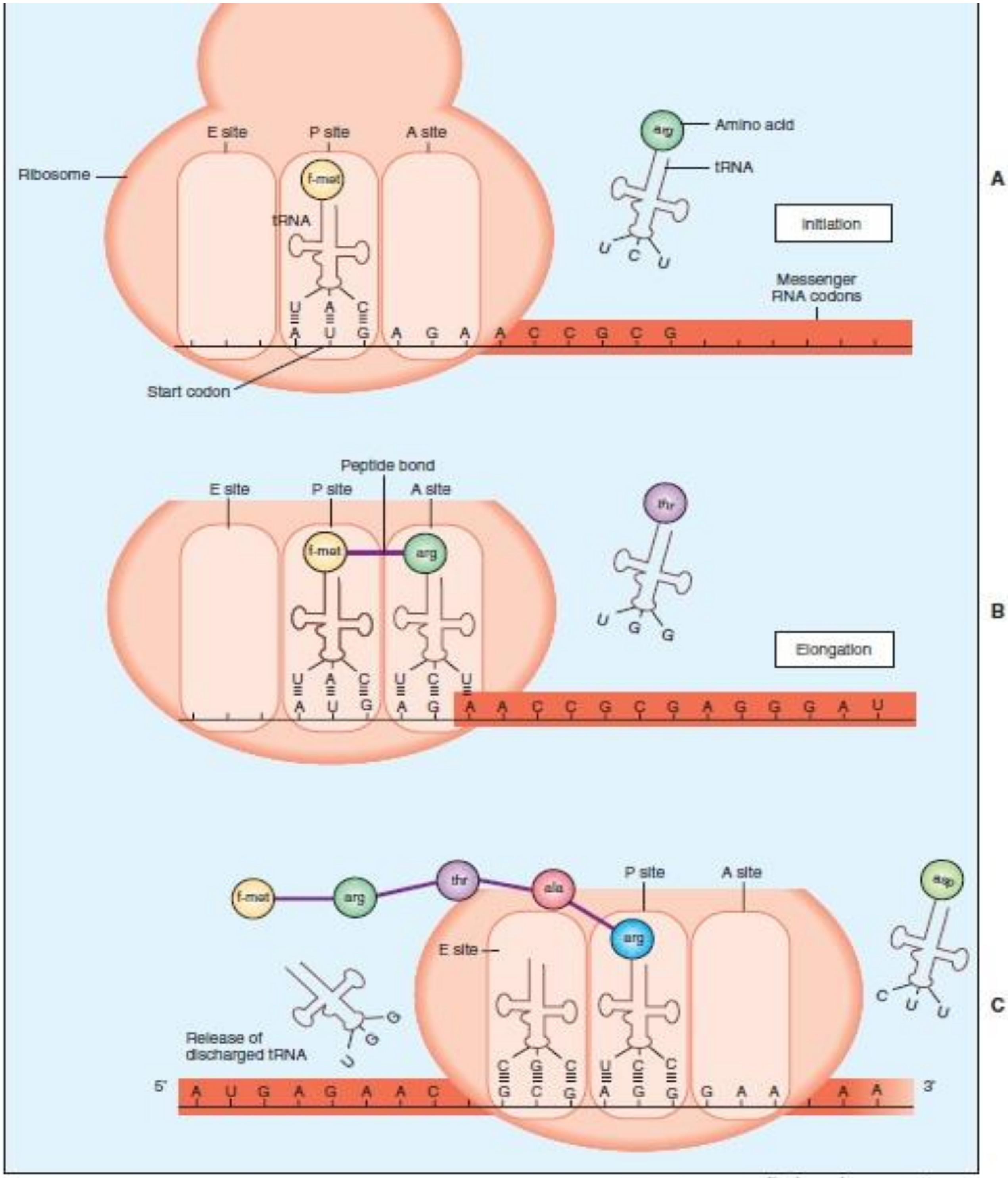


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Figure 2-6 Overview of translation in which mRNA serves as the template for the assembly of amino acids into polypeptides. The three steps include initiation **(A)**, elongation (**B** and **C**), and termination (not shown).