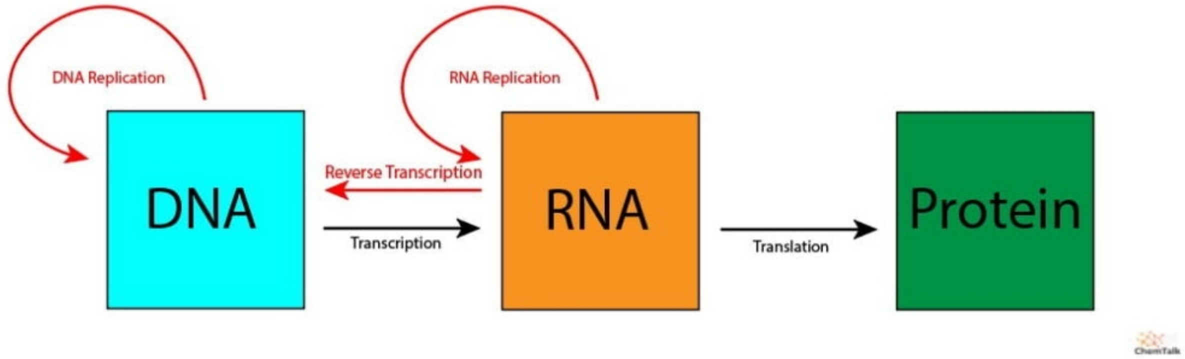
Central Dogma of Biology



Core Concepts

In this biochemistry article, we learn about the Central Dogma of Biology, including its different definitions, the cellular processes that generally cover the Dogma, as well as a few special cases.

Topics Covered in Other Articles

- DNA Tautomerization
- Polymerase Chain Reaction
- Molecular Cloning
- Citric Acid Cycle
- Glycolysis
- Viral Life Cycle

What is the Central Dogma of Biology?

The Central Dogma of Biology states that organisms function based on the flow of biological information from DNA to RNA and RNA to proteins.

Organisms are complex. To construct a living creature, its biochemical components must be synthesized and used according to very specific guidelines. These guidelines come in the form of DNA. However, DNA cannot, itself, run the biological functions of an organism. Instead, proteins carry out all these functions, according to the biochemical characteristics of their structures. Importantly, the biological information of DNA specifies these protein structures. RNA serves as the messenger which transfers DNA's genetic information into the structure of proteins. This flow of information, from DNA to RNA to Protein, provides a crucial basis upon which almost all of our understanding of molecular biology depends. As a result, scientists call it the Central Dogma of Biology.

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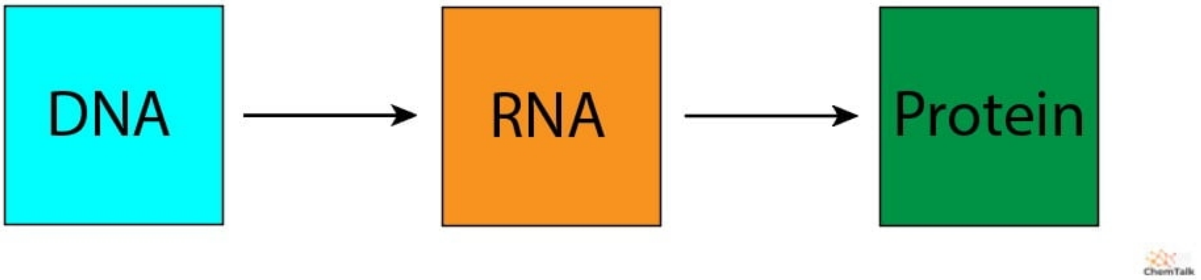
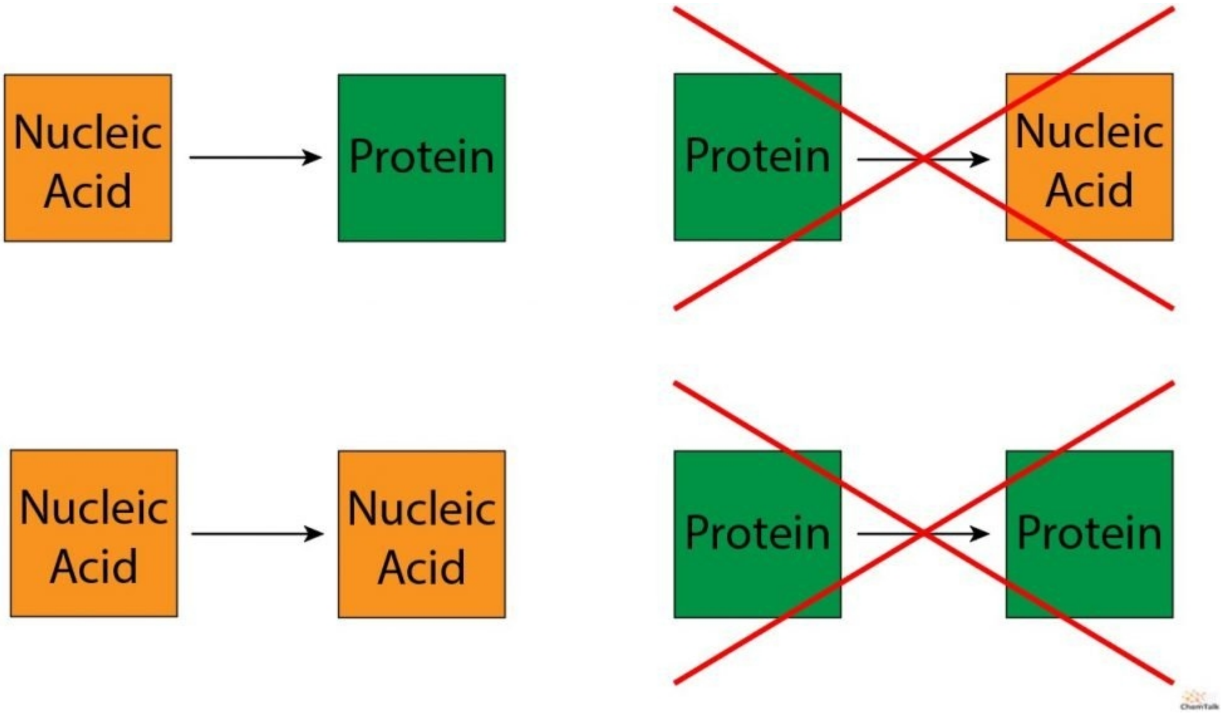


Is the Central Dogma of Biology Unidirectional?

In many contexts, the Central Dogma is described as the “unidirectional” flow of biological information from DNA to RNA through transcription and RNA to Protein through translation. While this interpretation covers the most important flows of biological information, many information transfers, such as DNA replication, are left out.

A more accurate version of the Central Dogma can be found in its original meaning. Francis Crick, one of the co-discoverers of DNA’s helical structure, first articulated the Central Dogma in 1957. He stated that information only transfers from nucleic acid (DNA and RNA) to nucleic acid or nucleic acid to protein. Information does not flow, however, from protein to protein or protein to nucleic acid.



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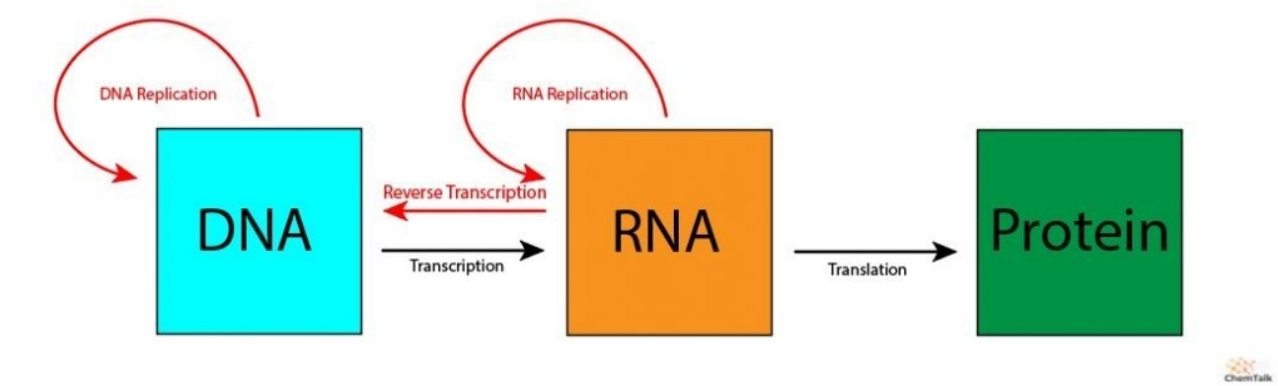
Crick's version incorporates the conventional transfers of biological information, such as transcription, translation, and DNA replication. Additionally, it includes a few "special transfers" that are proven to exist but go against the "unidirectional" flow, such as reverse transcription and RNA replication.

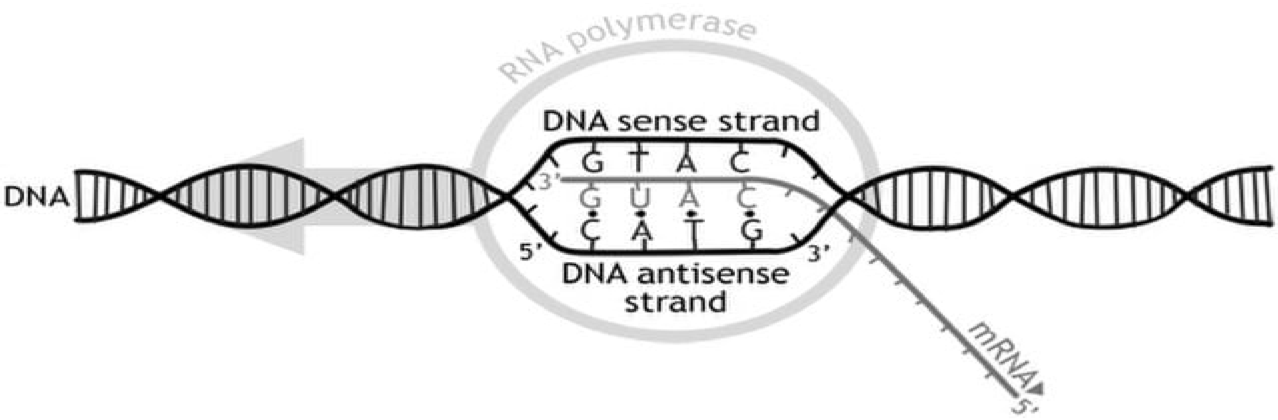


Central Dogma Step 1: DNA to RNA

To end up with a functional biological system, information must first transfer from DNA to RNA. Cells do this through a process called transcription. To get a more in-depth explanation about transcription, check out this article.

The information recorded in DNA that eventually informs protein structure comes in the form of genes. These genes are sequences of nucleotides that have one of four nitrogenous bases: adenine, guanine, cytosine, and thymine (AGCT). Though remarkably simple, sequences of these four nucleotides provide all the necessary information to construct a protein.

Before the DNA can direct the synthesis of a protein, the sequence must first be transcribed into RNA. Using Watson-Crick base pairing rules (A with T, G with C), the enzyme RNA Polymerase builds a strand of RNA along a sequence of DNA. The resulting mRNA strand, or "messenger" RNA, has the complementary sequence to the DNA gene. Thus, through RNA transcription, the biological information of DNA transfers to RNA, which can then leave the nucleus to synthesize protein.



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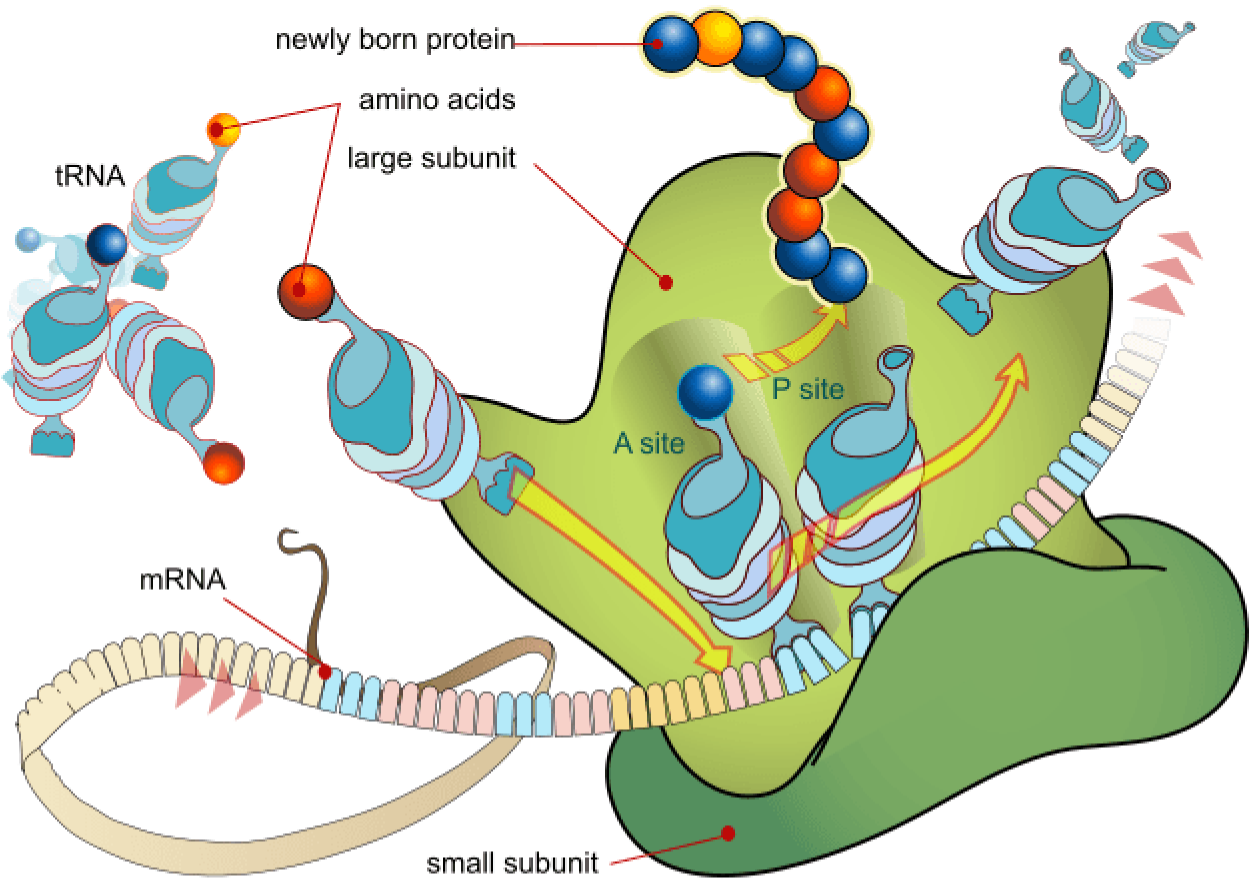
Central Dogma Step 2: RNA to Protein

To complete the utilization of biological information, the transcribed RNA gene must convert to the structure of a protein. This occurs through a process called translation. To get a more in-depth explanation about translation, check out this article.

Specifically, the mRNA strand synthesized in the nucleus informs the protein's sequence of amino acids. To do this, the strand interacts with a ribosome, the cellular organelle tasked with protein synthesis. Using molecules of tRNA as intermediates, the ribosome "reads" groups of three mRNA bases called "codons" which code for one of the twenty common amino acids.

Thus, based on the sequence of mRNA, which itself bases on the DNA sequence, the ribosome strings together a sequence of amino acids. This sequence provides the most fundamental, or "primary", structure of a protein. The exact correspondence between the mRNA sequence and the protein sequence is determined by the genetic code.



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Once synthesized, the amino acid sequence folds into a functional protein in the Golgi apparatus. Importantly, the order of amino acids determines how the protein ultimately folds, as certain amino acid groups naturally interact with one another. Afterward, the folded protein then assumes its necessary function in the organism.

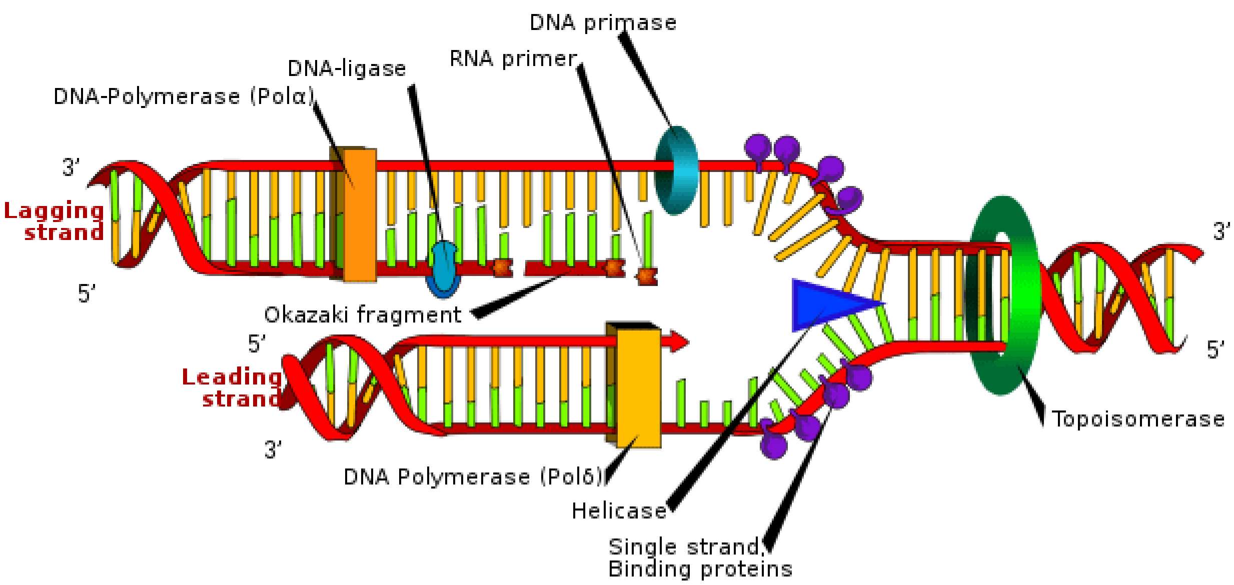
Special Cases of the Central Dogma

Aside from transcription and translation, which constitute the "unidirectional" version of the Central Dogma, many other transfers of biological information occur. However, each of these "special cases" involves transfers between nucleic acids other than DNA to RNA.

DNA to DNA: DNA Replication

As mentioned before, the most common form of information transfer not included in the "unidirectional" interpretation is DNA replication. In this process, the information of one DNA double helix transfers to two semi-conserved DNA helices. Check out this article to read more about DNA replication.

Like with transcription, DNA replication depends on complementary base pairings. The process requires numerous different proteins, including polymerases, ligases, primases, gyrases, and topoisomerases. In essence, the DNA double helix becomes separated, and two new DNA strands become synthesized through base-pairing the parent strands. This ultimately results in two complete double helices, from one original.



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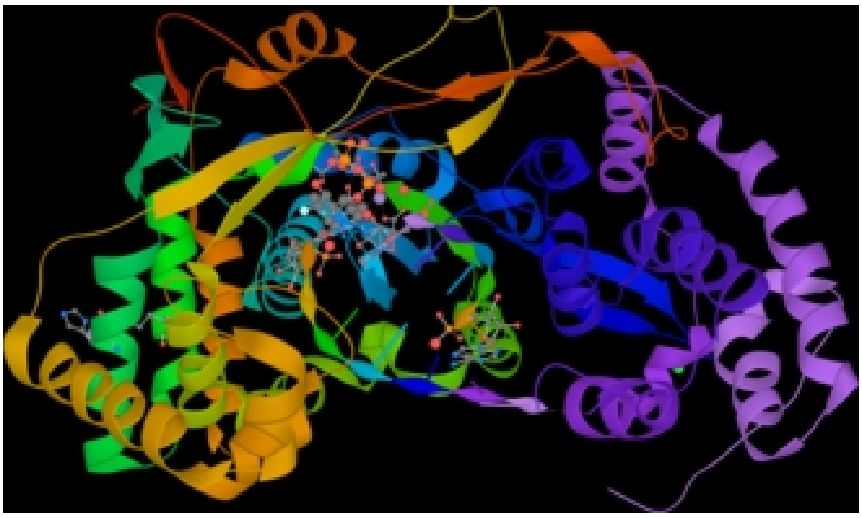
RNA to RNA: RNA Replication

Less common and well-known than DNA replication, RNA replication also involves transferring information from one type of nucleic acid to a new strand of the same type, this time with RNA.

Like DNA replication and transcription, RNA replication also involves complementary base pairing to synthesize a new strand. The process requires an enzyme called RNA-dependent RNA Polymerase (RdRp).



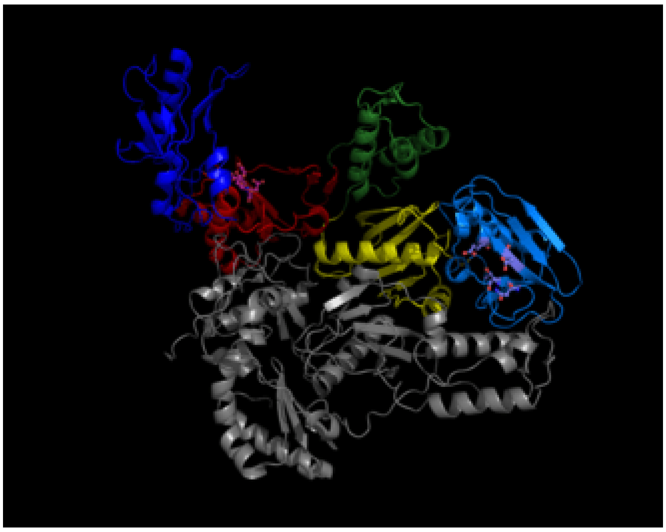
Eukaryotic organisms primarily use RdRp to synthesize guide RNA strands for RNA interference. These new complementary RNA strands then bind to mRNAs of specific sequences, forming double-stranded RNA (dsRNA). The protein Dicer then binds to the dsRNA and cleaves the strands into short, untranslateable sequences. With RNA interference, eukaryotes can alter the expression of certain genes by inhibiting their translation into proteins.

RNA replication by RdRp also occurs in cells infected with a retrovirus. The RdRp gene often occurs on retrovirus RNA plasmids. This serves the virus because the production of RdRp in infected cells allows replication and amplification of the RNA plasmid without the need for DNA.

RNA to DNA: Reverse Transcription

Completely contradicting the "unidirectional" model of the Central Dogma, RNA has demonstrated reverse transcription to DNA in certain situations.

Once again, like with transcription and replication of both RNA and DNA, reverse transcription involves complementary base pairing. This process requires the enzyme Reverse Transcriptase (RT). Like RdRp, the RT gene frequently occurs in the plasmids of retroviruses. However, instead of bypassing DNA, retroviruses use RT to encode their genome into the DNA of their host.



Reverse transcription also occurs in uninfected germline eukaryotic cells in the form of telomere synthesis. At the end of a chromosome, called the telomere, the enzyme telomerase lengthens one strand of the DNA. Telomerase does this using a short strand of RNA as the template to synthesize a repeating strand of complementary DNA attached to the telomere. This lengthening prevents the shortening of DNA chromosomes during DNA replication.