

# Prokaryotic Translation and Transcription

## Transcription

Transcription is the process of transcribing one strand of DNA into a complementary strand of RNA . It is catalyzed by the enzyme RNA polymerase. It takes place in the direction from the 5' end of the new RNA molecule to its 3' end.

Transcription in prokaryotes follows a similar basic mechanism to that of eukaryotes . For more information with an explanation, see the article [Transcription in Prokaryotes and the Operon Model](#) .

### RNA polymerase

Transcription in bacteria is ensured by a single RNA polymerase:

- 5 protein subunits  $\alpha$ ,  $\beta$ ,  $\beta'$ ,  $\omega$  and  $\sigma$ ;  $\alpha$  in two copies
- The  $\sigma$  subunit is used to bind n DNA, it dissociates after the start of synthesis

### Initiation

Initiation of RNA synthesis occurs in bacteria as follows:

- promoter recognition using the sigma factor (multiple promoter variants +  $\sigma$ )
- $\sigma$  recognizes  $-35$  and  $-10$  (TATA box/Pribnow box) of the consensus sequence
- opening of the transcription bubble
- synthesis of a short chain around 9 nt, dissociation of the  $\sigma$  factor
- energetically, transcription is driven by hydrolysis of the macroergic bond of the incoming ribonucleoside triphosphate

### Termination

Transcription termination of prokaryotes can be Rho ( $\rho$ ) independent or  $\rho$  dependent:

– Rho independent termination:

- a termination sequence containing inverted repeats separated by a non-repetitive stretch rich in GC pairs
- forming a transcription-stopping loop structure
- the following stretch of polyA (in DNA) allows easy dissociation

– Rho dependent

- The Rho factor recognizes a sequence in RNA
- it moves towards the polymerase and causes dissociation

## Translation

Translation is the process of synthesizing a polypeptide chain based on the information contained in mRNA . Triplets of nucleotides in RNA are translated into the form of individual amino acids of a polypeptide according to the rules of the genetic code . Translation in prokaryotes follows a similar basic mechanism to that of eukaryotes . Further information with an explanation can be found in the article [Translation in prokaryotes](#) , [Translation and the question Translation in eukaryotes](#) , the basic features and specificities of prokaryotic translation are presented here.

### Aminoacyl-tRNA synthesis

The tRNA molecule brings the amino acid residue to the ribosome. Bacterial tRNAs are characterized by:

- roughly 60 types of tRNA (versus 100–110 in a mammalian cell)
- 73–93 nucleotides in length
- secondary structure of the shape of a four-leaf clover, tertiary structure of the letter L
- acceptor arm terminated by a CCA triplet
- dihydrouridine arm (D or DHU), pseudouridine arm (T or T $\Psi$ C), variable arm
- anticodon arm

Activation of tRNA by binding to an amino acid residue occurs through the enzyme aminoacyl-tRNA-synthetase with the consumption of ATP:

- amino acid + ATP  $\leftrightarrow$  aminoacyl-AMP + pyrophosphate
- aminoacyl-AMP + tRNA  $\leftrightarrow$  aminoacyl-tRNA + AMP

The reaction is thermodynamically driven by pyrophosphate decomposition.

## Prokaryotic ribosome

The bacterial ribosome, like the eukaryotic ribosome, consists of two subunits:

– 30S subunit

- 16S rRNA (with 3' end complementary to Shine-Delgarno sequence)
- 21 proteins

– 50S subunit

- 5S rRNA, 23S rRNA (with peptidyltransferase activity – catalyzes peptide chain elongation)
- 31 proteins

## Translation initiation

Proteosynthesis itself can be divided into initiation, elongation and termination. Bacterial initiation proceeds as follows:

- the first amino acid of most bacteria is N-formylmethionine attached to the special tRNA<sup>fMet</sup>. Usually 1–3 N-terminal amino acids are cleaved post-translationally.
- N-formylmethionyl-tRNA<sup>fMet</sup> binds to the free 30S subunit of the ribosome
- The mRNA is bound by the interaction of the 3' end of the 16S rRNA with a Shine-Delgarno sequence near the 5' end (RBS - ribosome-binding site), usually 8 nucleotides from the initiation codon AUG
- fMet-tRNA interacts by anticodon with initiation codon AUG (sometimes GUG)
- The 50S subunit of the ribosome binds so that the fMet-tRNA is in the P site of the ribosome
- initiation of translation requires initiation factors IF1, IF2 and IF3 and consumes energy in the form of GTP

## Elongation

During elongation, amino acid residues are added to the C-terminus of the polypeptide through a repeating sequence of events:

- The P site of the ribosome (see translation ) is occupied by N-formylmethionyl-tRNA<sup>fMet</sup> or peptidyl tRNA, and the A site is empty
- aminoacyl-tRNA corresponding to the following codon binds to the A site with the help of EF-Tu factor and GTP consumption
- a **transpeptidase reaction** catalyzed by 23S rRNA takes place – the  $\alpha$ -amino group of the amino acid residue in the A site nucleophilically attacks the  $\alpha$ -carboxyl group of the C-terminal amino acid in the P site. The peptide thereby moves to the tRNA in the A site. The reaction does not consume any energy-rich molecules.
- translocation occurs: the peptidyl-tRNA moves from the A site to the P site, the ribosome moves one codon to the mRNA, and the previous tRNA moves to the E site. The process requires the EF-G factor and the hydrolysis of a GTP molecule
- The tRNA at the E site leaves the ribosome and the cycle repeats

## Termination

Termination of translation in a prokaryotic cell occurs as follows:

- one of the three (usually) termination (nonsense) codons – UAA, UAG or UGA – gets to A instead of the ribosome
- is recognized by one of three termination factors (RF-1, RF-2 or RF-3)
- the peptide is hydrolytically released by peptidyl transferase activity
- dissociation of ribosome subunits and translation proteins occurs.
- IF-3 remains bound to the 30S subunit, preventing reassociation with the 50S subunit

## Links

### Related articles

- Transcription
- Transcription in Prokaryotes
- Translation in Prokaryotes
- Translation in Eukaryotes
- Translation
- Regulation of gene expresion in Prokaryotes
- RNA
  - mRNA

## References

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- KOHOUTOVÁ, Milada, et al. *Lékařská biologie a genetika (II. díl)*. 1. edition. Karolinum, 2012. ISBN 978-80-246-1873-9.