RIBOSOMES

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MBOTCC-10
Unit-I

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Introduction:

Ribosomes are spheroidal particles which contain approximately equal amounts of RNA and proteins. They are found in all kinds of cells and serve as a scaffold for the ordered interaction of numerous molecules involved in protein synthesis. They can be found freely scattered in the cytoplasm or may be attached to the endoplasmic reticulum. They were first observed by Palade (1955) frequently associated with the ER in eukaryotic cells.

Shape, Size and Number of Ribosomes:

(i) Shape – Spheroidal

(ii) Average diameter – 20 nm in prokaryotes and 25-30 nm in eukaryotes with a molecular weight of 4×10^6 Daltons.

(iii) An *E. coli* cell contains 15,000 ribosomes, each one with a mol. wt. of about 2.7×10^6 Daltons

– A single actively replicating eukaryotic cell may contain 10 million ribosomes each of which is about twice as large as a prokaryotic ribosome.

(iv) As the ribosomes are made of two subunits they are a little longer in the hinge than in diameter.

(v) Size of the ribosomes within cells varies depending on the cell type and cell's status of rest or replication.

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Ribosomal Subunits:

(i) Ribosome is composed of a large and a small subunit, each of which has a characteristic shape.

(ii) Ribosomal subunits are typically referred to in terms of their sedimentation coefficient, which is measured in Svedberg units (S), in a centrifugal field.

(iii) Eukaryotic ribosomes have a sedimentation coefficient of 80S, and in the absence of Mg^{2+} they dissociate reversibly into subunits of 60S and 40S.

(iv) Prokaryotic ribosomes are smaller and sediment at 70S; they have sub-units of 50S and 30S.

(v) Ribosomes are also found in the mitochondria and chloroplasts of eukaryotic cells and are comparable to prokaryotic ribosomes in both size (70S) and sensitivity to antibiotics.

(vi) During protein synthesis, several ribosomes become attached to the mRNA molecule forming a polyribosome or polysome. In this way a single mRNA molecule can be translated by several ribosomes at the same time.

(vii) mRNA is located in the gap between the two ribosomal subunits, as a result of which the ribosome protects a stretch of 25 nucleotides of mRNA from degradation by ribonuclease.

(viii) Nascent peptide chain probably grows through a groove in the large ribosomal subunit; thus ribosomes protect a segment of 30-40 amino acids from degradation by proteolytic enzymes.

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Ribosomal RNAs:

(i) Major constituents of ribosomes are RNA and proteins present in approximately equal amounts.

(ii) Ribosomal RNA (rRNA) generally represents more than 80% of RNA present in cells.

(iii) Prokaryotic ribosomes contain three RNA molecules:
- 16S rRNA in the small subunit
- 23S and 5S in the larger subunit

(iv) In eukaryotic ribosomes there are four RNAs:
- 18S in the small subunit, and
- 28S, 5.8S and 5S in the larger subunit

(v) 28S, 5.8S and 18S rRNAs are synthesized in the nucleolus by cleavage of a single precursor RNA, while 5S RNA is synthesized outside the nucleolus.

(vi) Eukaryotic ribosomes and rRNAs are much larger than their prokaryotic counterparts.

(vii) Ribosomal RNA has a high degree of secondary structure; about 70% of it is double-stranded and helical due to base pairing.
- These double-stranded regions are formed by "hairpin loops" between complementary regions of the same linear RNA molecule.
- Various ribosomal proteins adhere at specific points on these loops and stems.

(viii) rRNA provides a three-dimensional matrix to which various enzymes of the protein synthesis machinery bind in an orderly manner.

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(ix) In addition to maintaining ribosomal structure, rRNA also participates in protein synthesis by virtue of its base-pairing properties.

(x) rRNAs may also provide some of the catalytic activities required for protein synthesis.

(xi) Processing of rRNA takes place on the RNA-protein complexes, and not on the naked RNA.

Ribosomal Proteins:

(i) E. coli ribosome contains 21 proteins in the small subunit (S1 - S21) and 34 in the larger subunit (L1 - L34).
- All the proteins are different with the exception of one that is present in both the subunits (S20 and L26).
- Therefore, the total number of proteins in one ribosome of E. coli is 54.

(ii) Eukaryotic ribosome has 47 proteins in the larger subunit (L1 - L47) and 32 proteins in the small subunit (S1 - S32).

(iii) All the ribosomal proteins of E. coli have been isolated and specific antibodies against them have been produced.

(iv) Ribosomal proteins can be dissociated from the ribosome and then added back to reconstitute active ribosomes.

(v) It is remarkable that such a complex organelle as a ribosome can assemble spontaneously by simple physico-chemical interactions.

(vi) Synthesis of ribosomal proteins

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in E. coli is controlled at the translational level.

—It is possible that such a translational regulation also exists in eukaryotes.

(vii) Nucleolus is the cellular site at which all the ribosomal components are assembled together into ribosomal subunits.

Prokaryotic & Eukaryotic Ribosomes:

(i) Prokaryotic and eukaryotic ribosomes have little homology but they do not differ functionally in a fundamental way; they perform the same functions.

(ii) Ribosomes of mitochondria and chloroplasts resemble those in bacteria.

(iii) Hybrid ribosomal studies for protein synthesis confirm these comparative features of ribosomes in prokaryotes and eukaryotes.

Functions of Ribosomes:

1. Ribosomes are the workplaces of protein biosynthesis and provide the sites for this translational process.
2. Ribosomes assemble amino acids to form proteins that are essential for carrying out cellular functions.
3. In the cytoplasm, the two ribosomal subunits are bound around the polymers of mRNA and proteins are then synthesized with the help of tRNA.
4. Ribosomes act as catalysts in two important biological processes called peptidyl transfer and peptidyl hydrolysis.

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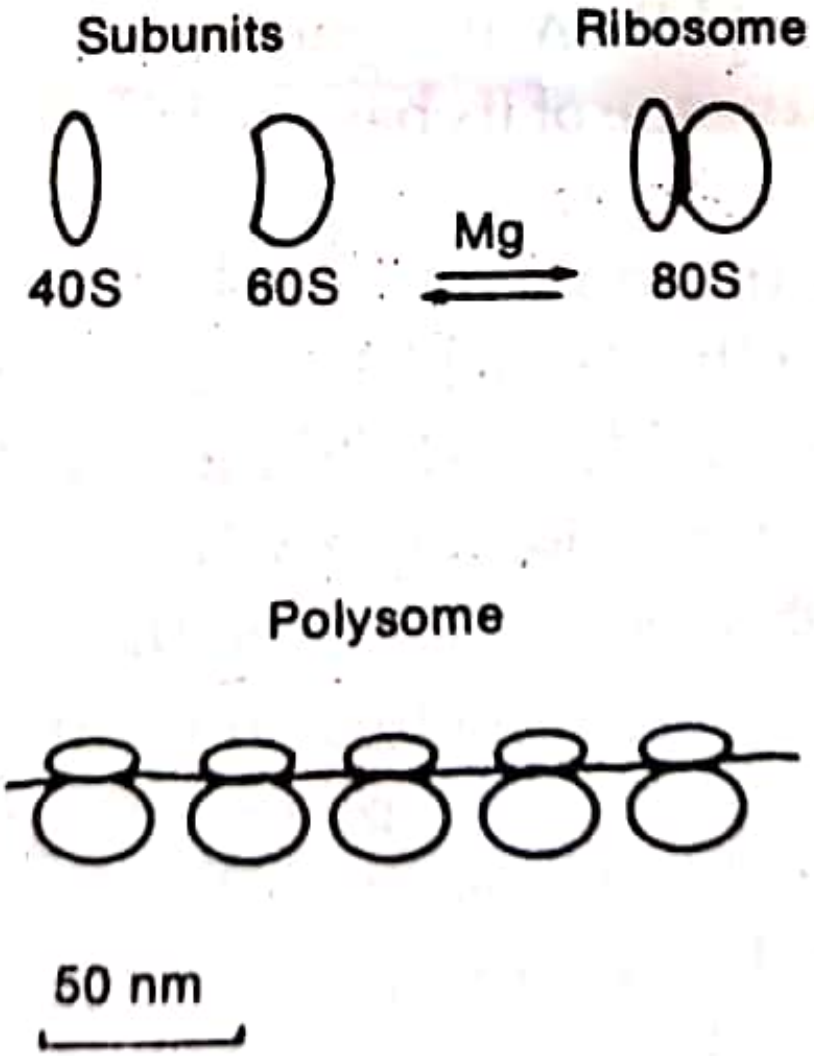

Fig. 21–1. Diagram of the subunit structure of the ribosome and the influence of Mg. A polyribosome formed by five ribosomes is indicated. The filament uniting the ribosomes represents messenger RNA. The sedimentation constants (S) of the different particles are indicated.

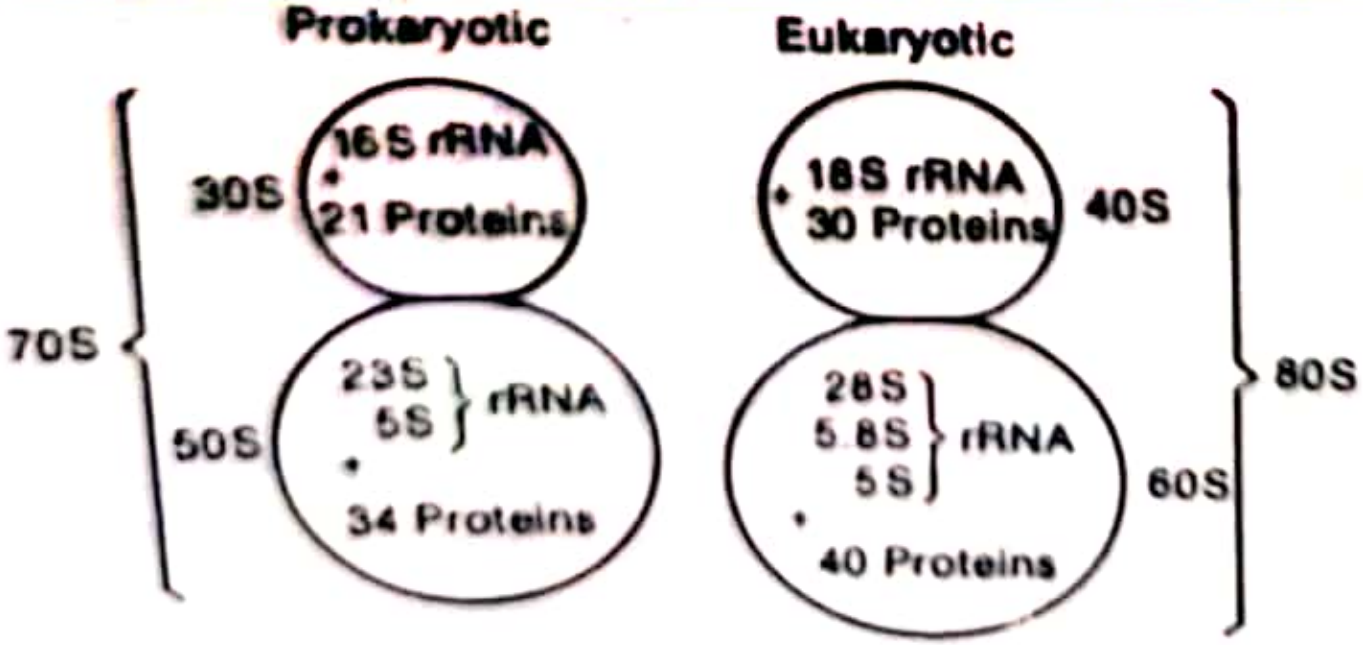

Fig. 21–2. The components of prokaryotic and eukaryotic ribosomal subunits.

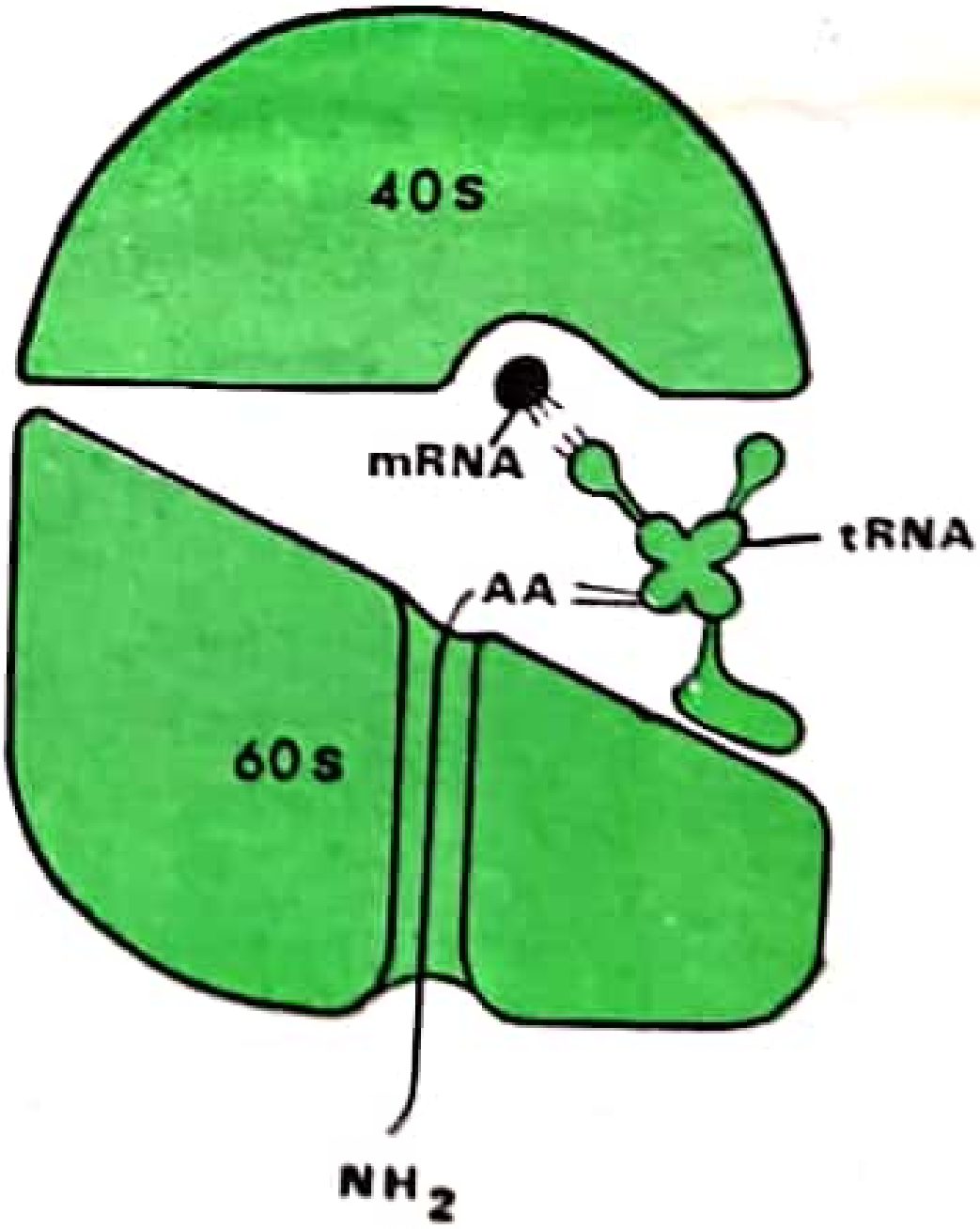

Fig. 21–3. Diagram of a ribosome showing the two subunits and the probable position of the mRNA and the tRNA. The nascent polypeptide chain passes through a kind of tunnel within the subunit. (Courtesy of D.D. Sabatini and G. Blobel.)