CHAPTER 9

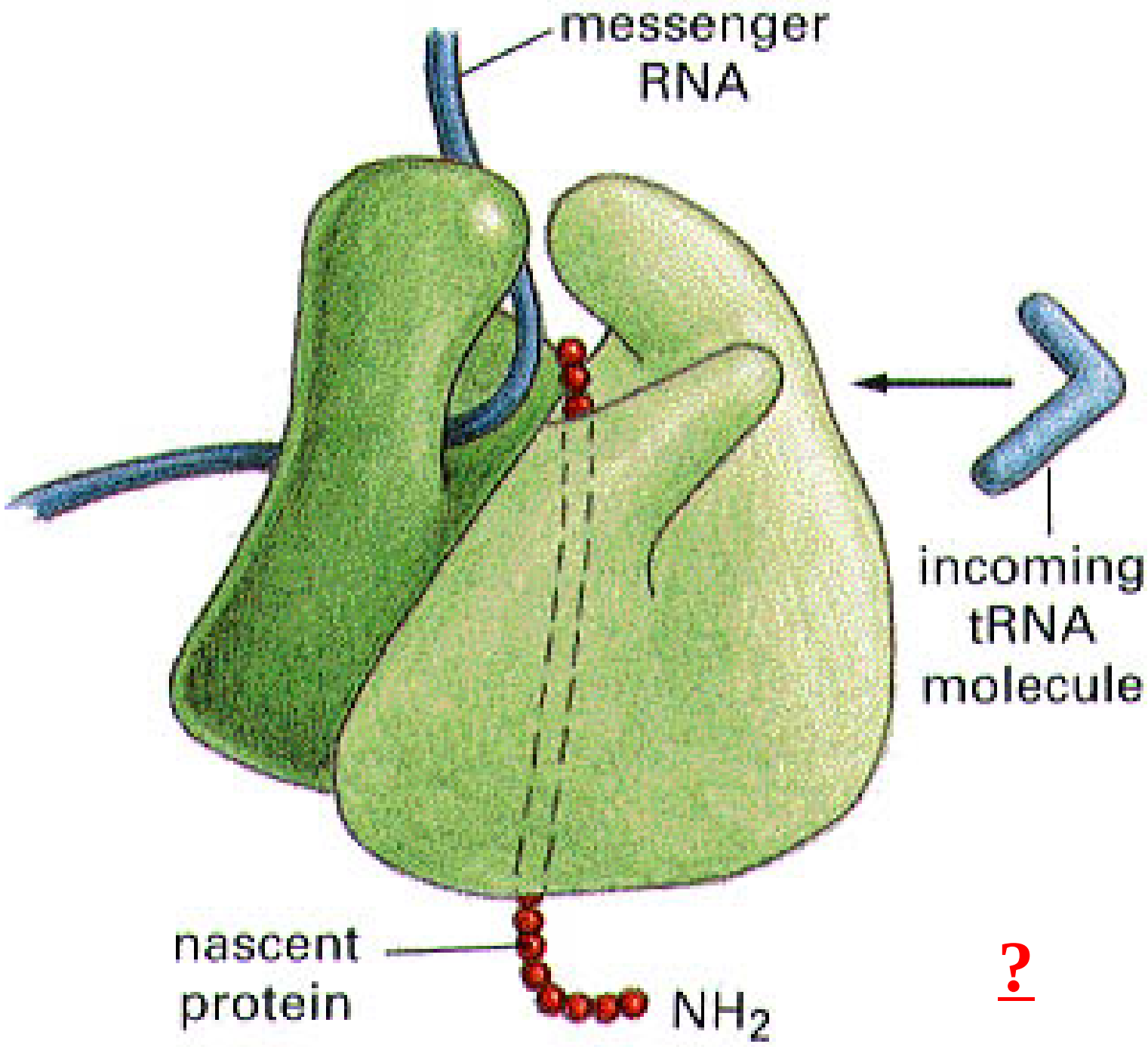
核糖体

Ribosome

OUTLINE

- **Ribosome structure**
- **Ribosome Function**
- **Polyribosome and Protein synthesis**

核糖体的形态结构



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Ribosome structure

- 核糖体(ribosome)是细胞内一种核糖核蛋白颗粒(ribonucleoprotein partical),是细胞内合成蛋白质的细胞器。
- 核糖体的主要成分是核糖体RNA(rRNA),占60%, 蛋白质(r蛋白质), 占40%。

核糖体的类型

➡细胞有两种主要类型的核糖体:

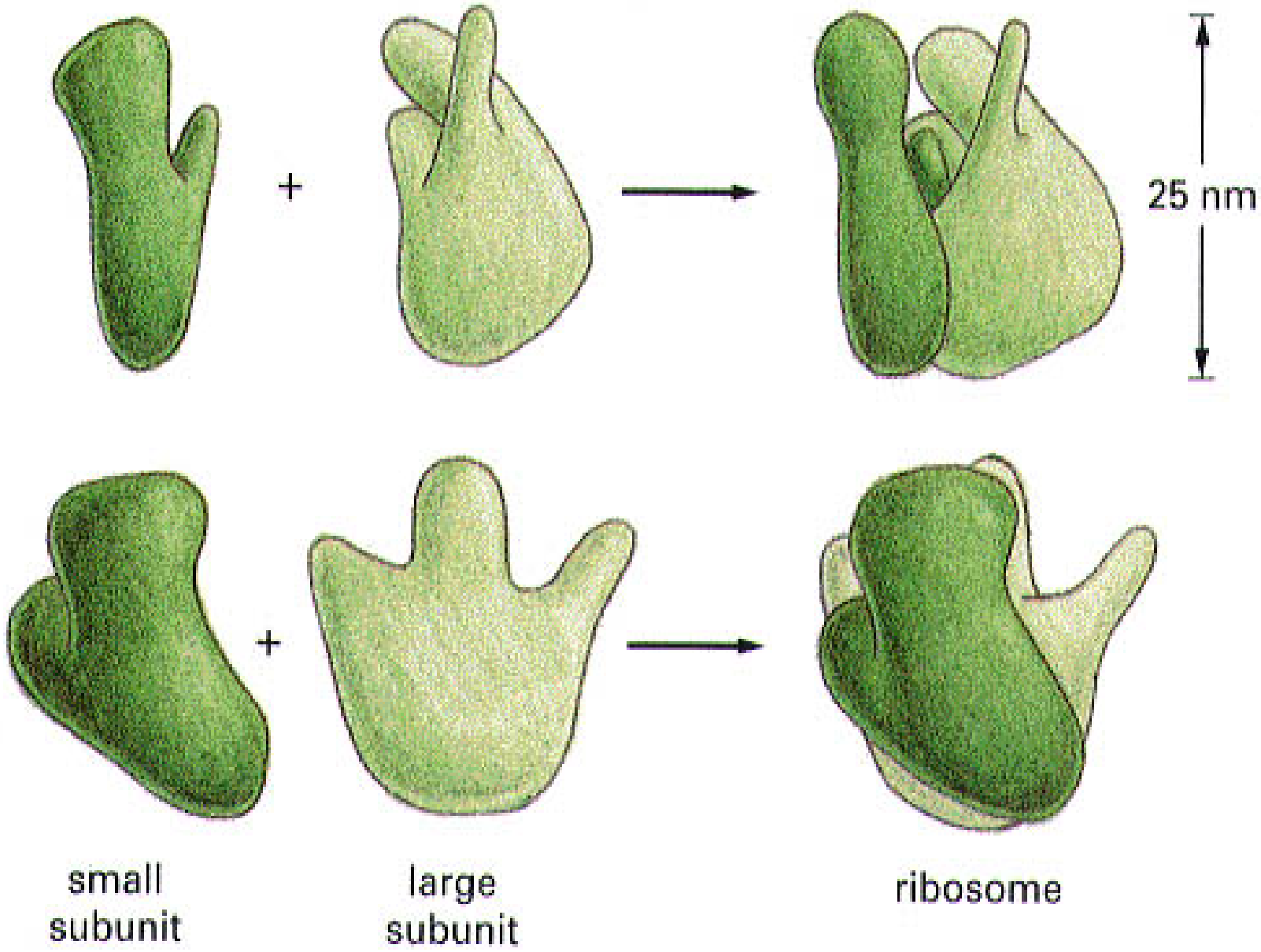
◆原核细胞的核糖体:

沉降系数为70S，分子量为$2.5x10^6$，由50S和30S两个亚基组成。

◆真核细胞的核糖体:

沉降系数是80S，分子量为$2.5x10^6$，由60S和40S两个亚基组成。

核糖体的大小亚基



➡Mg^{2+} 浓度对大小亚基的聚合和解离的影响:

◆70S核糖体在Mg^{2+}的浓度小于1mm/L的溶液中易解离;

◆当Mg^{2+} 浓度大于10mm/L，两个核糖体通常形成100S的二聚体。

镁离子浓度对核糖体的影响

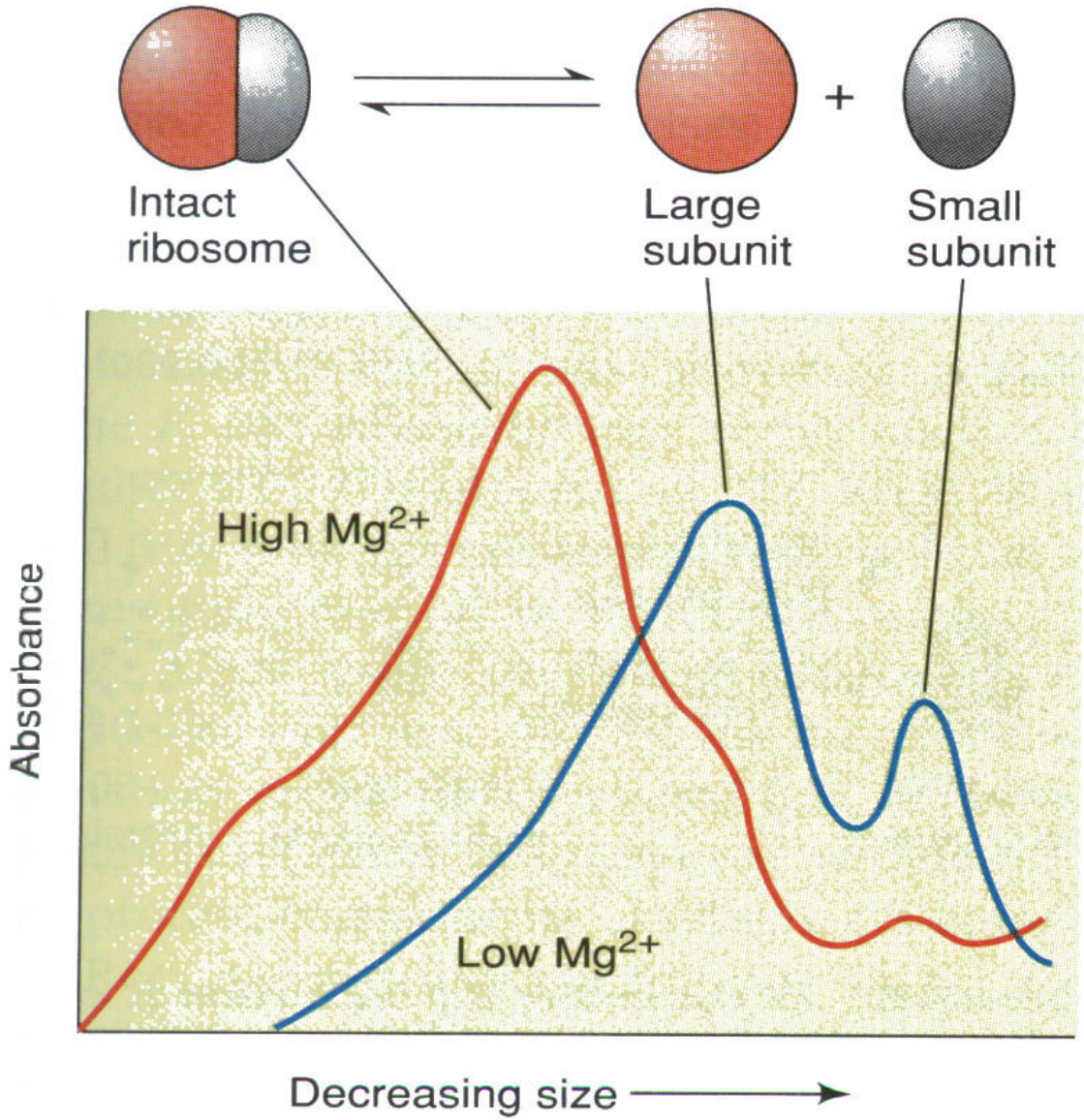
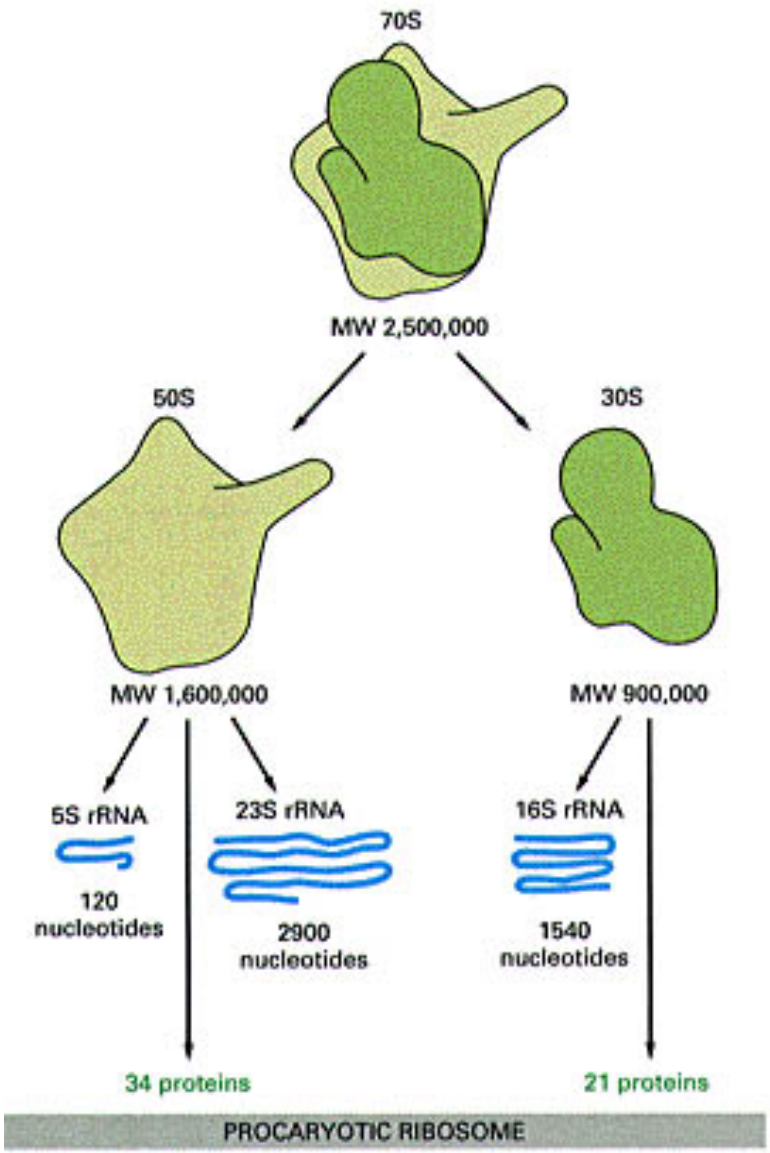


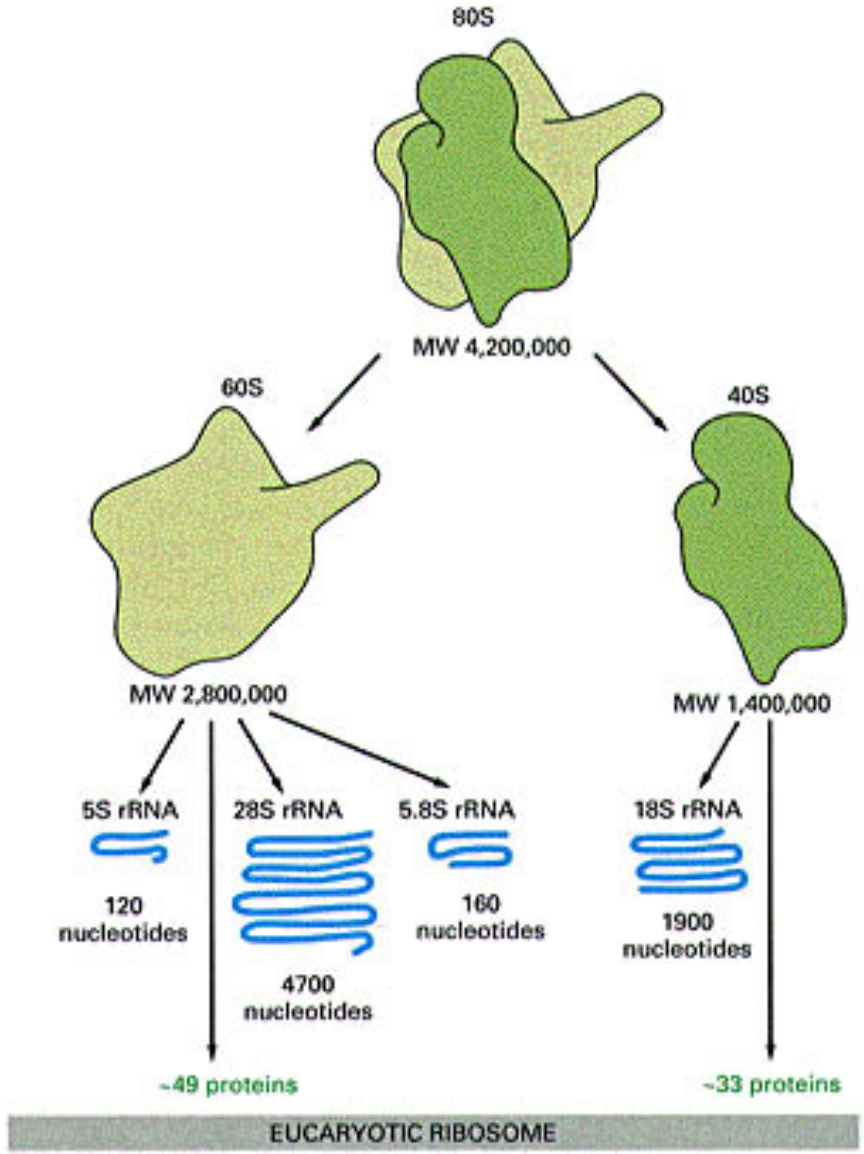
Figure 11-1 ***Identification of Ribosomal Subunits b***
Moving-Zone Centrifugation

➡各种来源的核糖体亚基组成

来源	完整核糖体	核糖体亚基	核糖体RNAs
细胞质	80S	60S(大亚基)	28S
(真核生物)		40S(小亚基)	18S，5.8S,5S
细胞质	70S	50S(大亚基)	23S
(原核生物)		30S(小亚基)	16S，5S
线粒体	55-60S	45S(大亚基)	16S
(哺乳动物)		35S(小亚基)	12S
线粒体	75S	53S(大亚基)	21S
(酵母)		35S(小亚基)	14S
线粒体	78S	60S(大亚基)	26S
(高等植物)		45S(小亚基)	18S，5S
叶绿体	70S	50S(大亚基)	23S
		30S(小亚基)	16S，5S

➡核糖体的化学组成


70S
MW 2,500,000
50S
30S
MW 1,600,000
MW 900,000
5S rRNA
23S rRNA
16S rRNA
120 nucleotides
2900 nucleotides
1540 nucleotides
34 proteins
21 proteins
PROCARYOTIC RIBOSOME


80S
MW 4,200,000
60S
40S
MW 2,800,000
MW 1,400,000
5S rRNA
28S rRNA
5.8S rRNA
18S rRNA
120 nucleotides
4700 nucleotides
160 nucleotides
1900 nucleotides
~49 proteins
~33 proteins
EUCARYOTIC RIBOSOME

核糖体的装配

➡原核生物核糖体的装配

◆小亚基的rRNA和蛋白质的装配关系：

组成核糖体的蛋白质和rRNA在大小亚基中均有一定的空间排布。

原核生物rRNA前体的加工

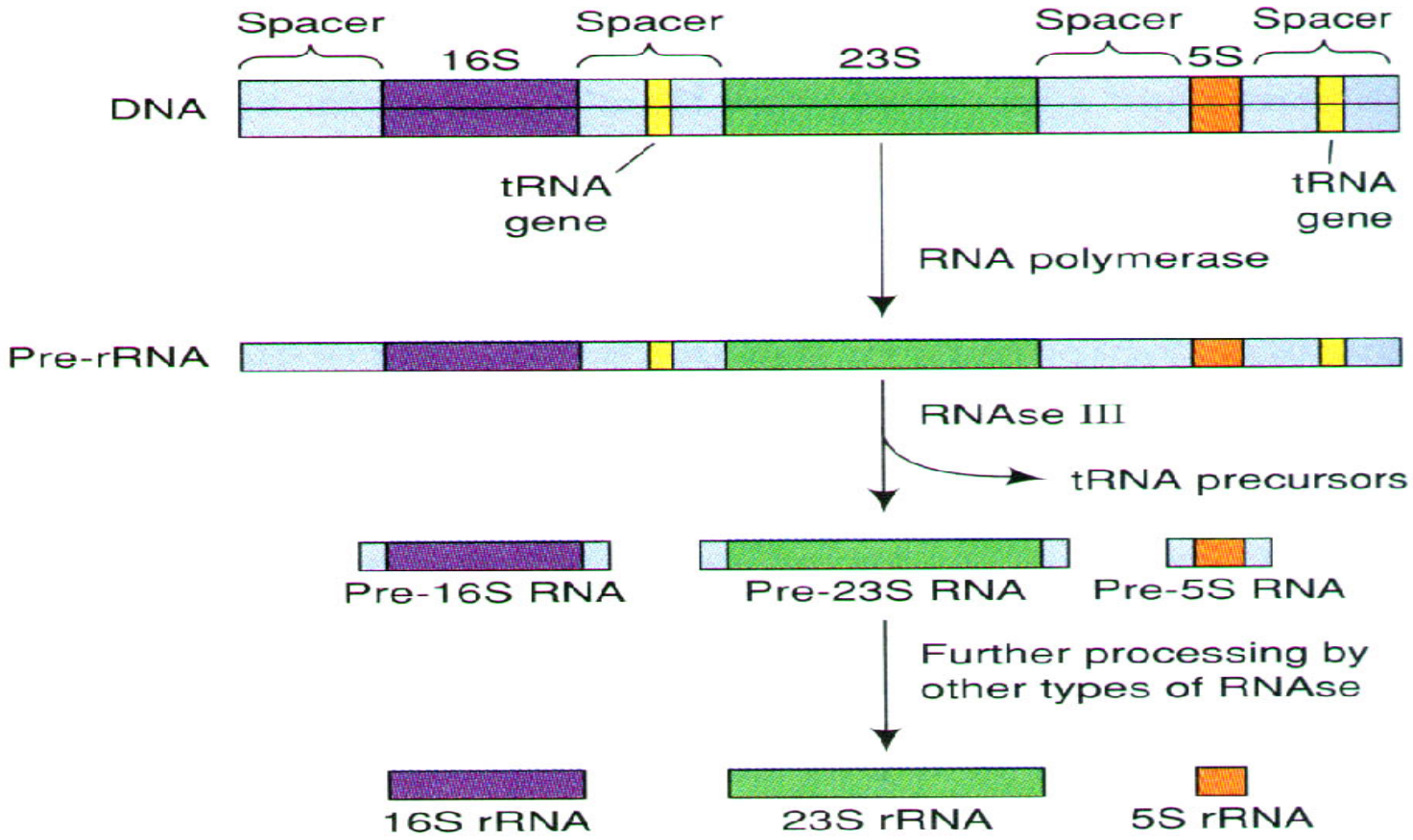
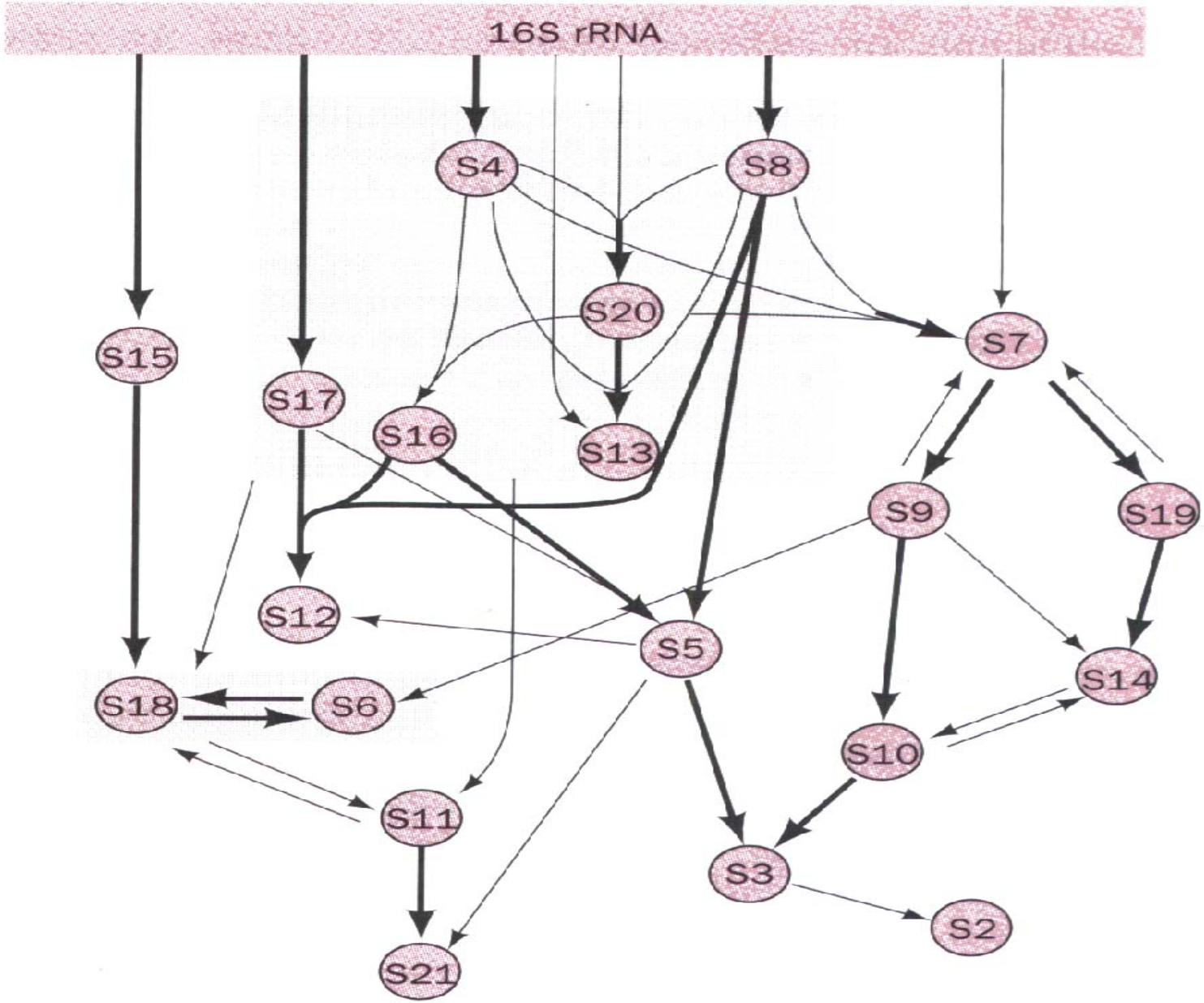


Figure 11-23 ***Ribosomal RNA Processing in the Bacterium E. Coli***

核糖体RNA的位置关系



核糖体在组装过程中，某些蛋白质必须首先结合到rRNA上，其他蛋白才能组长上去即表现出先后层次。根据同rRNA结合的顺序，将核糖体蛋白分为两种：

◆初级结合蛋白(primary binding protein)

这些蛋白质直接同rRNA结合，其中同16S rRNA结合的初级蛋白有14种，它们是：S3，S4，S17，S20，S6，S15，S8，S18，S9，S11，S12，S13，S7，S1。

同5S rRNA结合的有11种。

◆次级结合蛋白(secondary binding protein)

这些蛋白质不直接同rRNA结合，而是同初级结合蛋白结合。它们是：S10，S16，S2，S6，S21，S14，S19。

核糖体结合蛋白

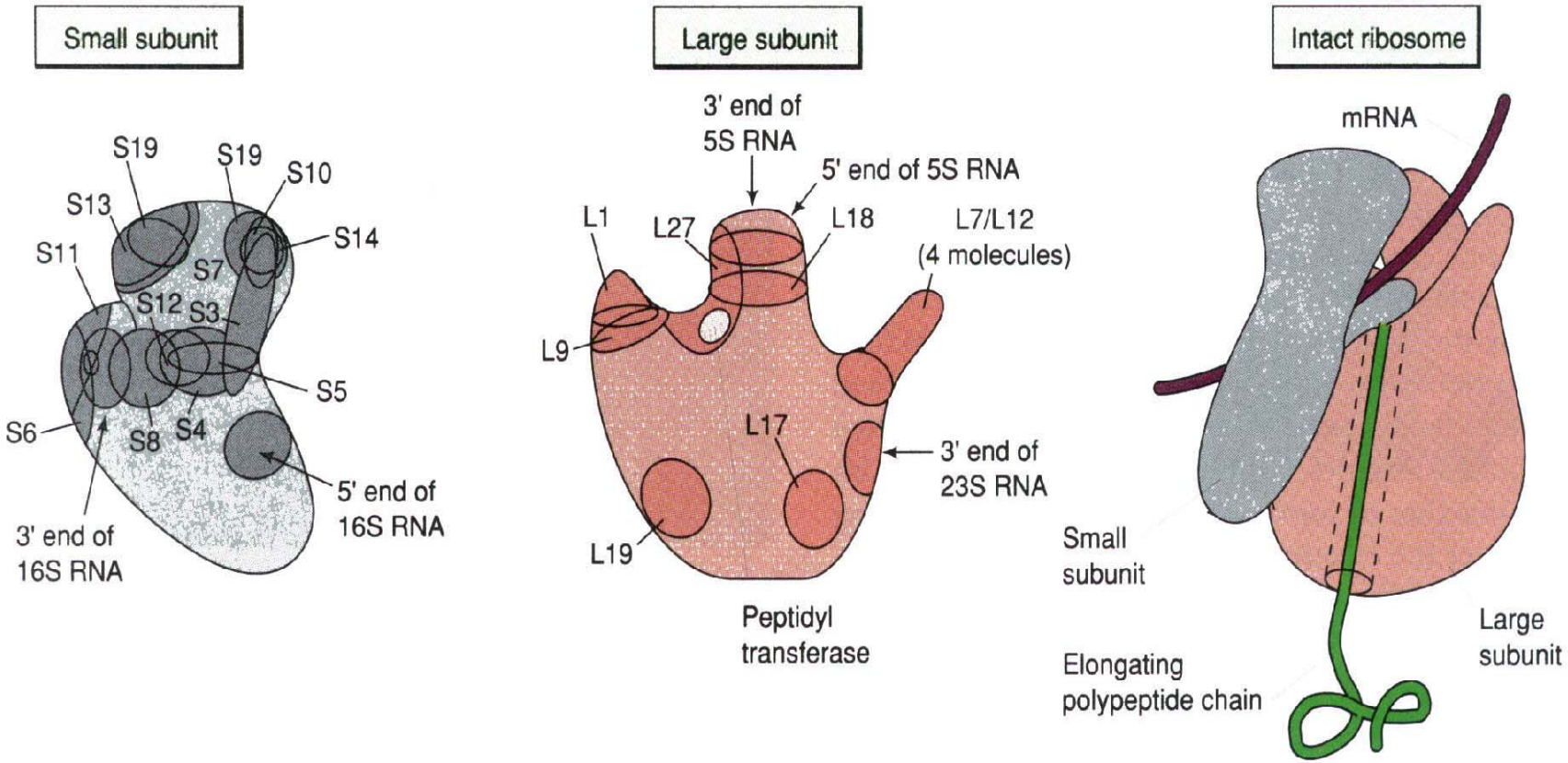


Figure 11-9 ***Model of the E. Coli Ribosome Indicating the Location of Several Ribosomal Proteins and RNAs***

核糖体的合成与装配

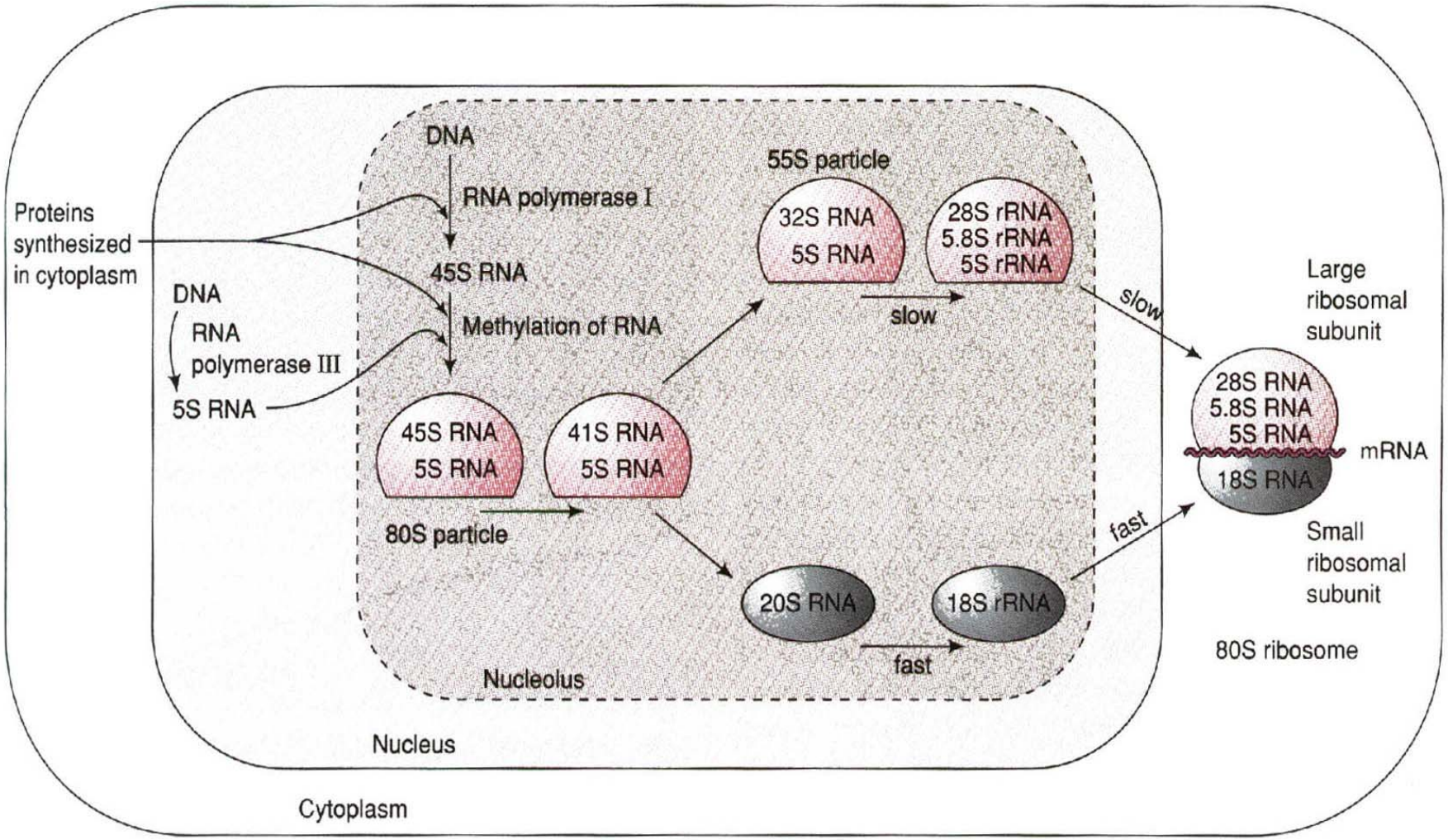
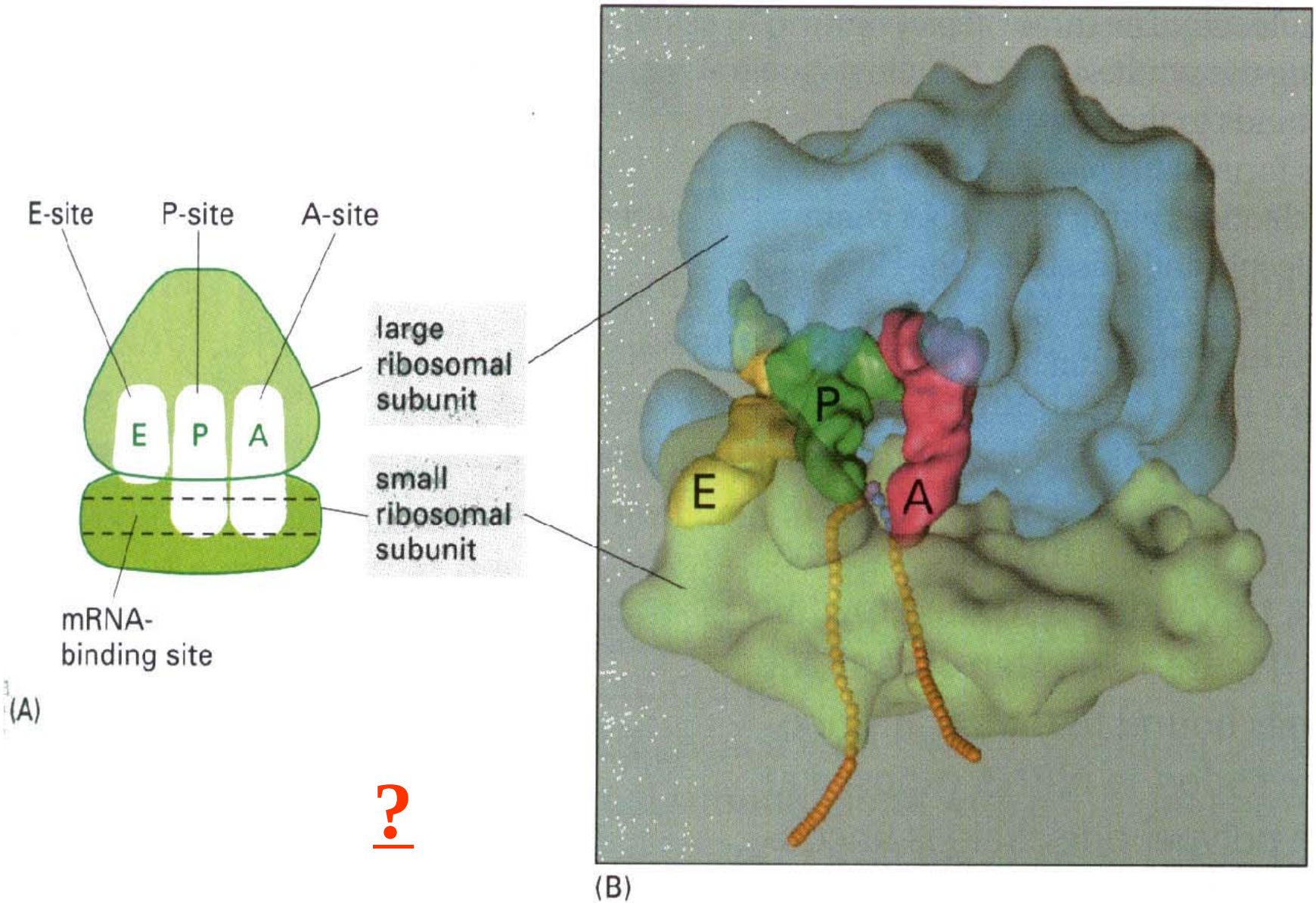


Figure 11-20 ***Summary of the Main Steps Involved in Ribosome Formation in Human Cells***

核糖体蛋白与rRNA的功能

核糖体上具有一系列与蛋白质合成有关的结合位点与催化位点

核糖体的功能位点


E-site
P-site
A-site
E
P
A
large ribosomal subunit
small ribosomal subunit
mRNA-binding site
(A)
P
E
A
(B)

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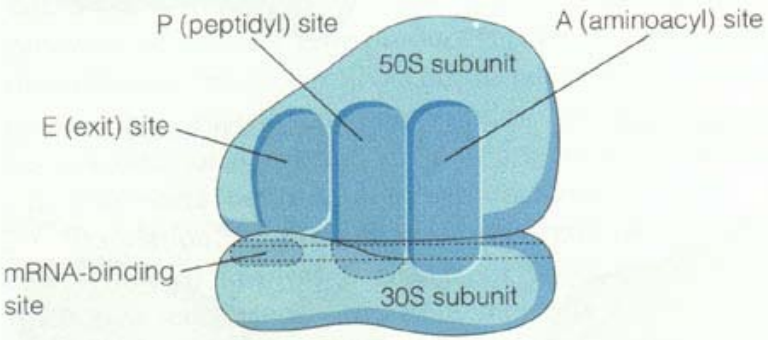
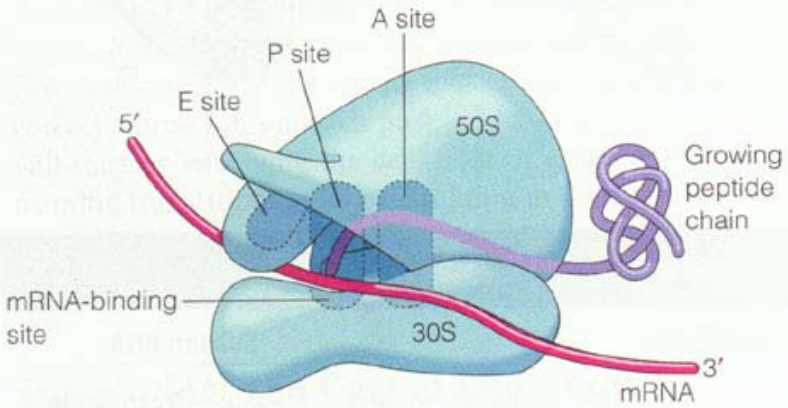
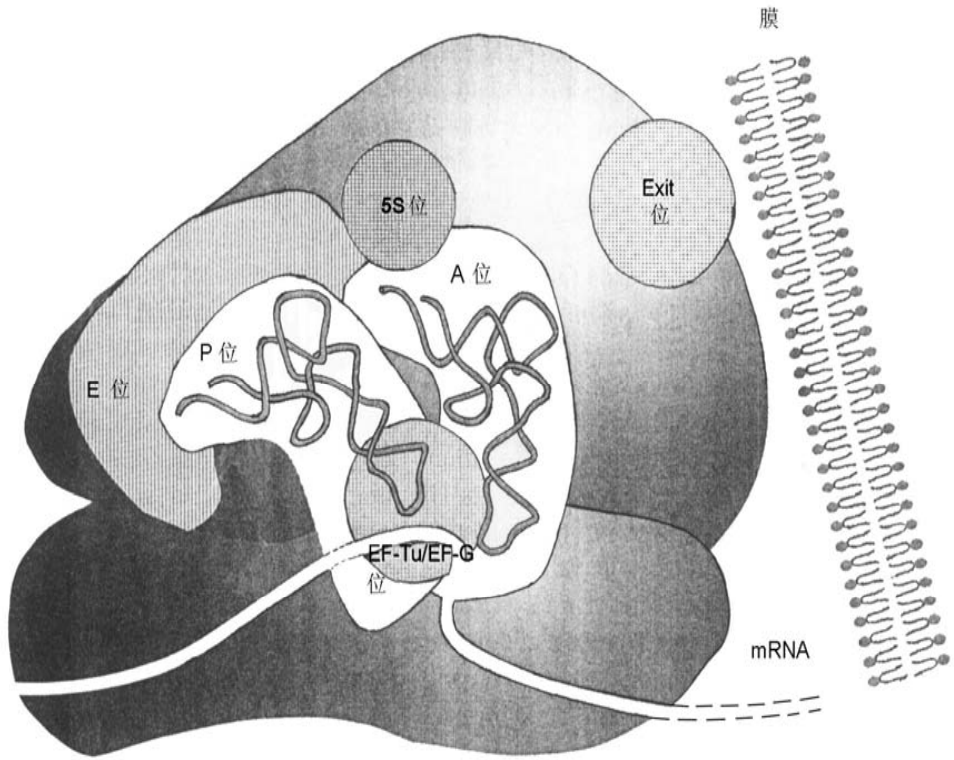


(a)



(b)

Figure 20-2 Important Binding Sites on the Prokaryotic Ribosome. This model of ribosome structure shows the A (aminoacyl) and P (peptidyl) sites as cavities on the ribosome where charged (amino acid–carrying) tRNA molecules bind during polypeptide synthesis. The more recently postulated E (exit) site is the site from which discharged tRNAs leave the ribosome. The mRNA-binding site binds a particular nucleotide sequence near the 5′ end of the mRNA, placing the mRNA in the proper position for the translation of its first codon. **(a)** The diagrammatic representation of a ribosome that is used in this chapter. The pair of horizontal dashed lines indicate where the mRNA molecule lies. **(b)** A more realistic representation. The binding sites are all located at or near the interface between the large and small subunits.



- 与mRNA的结合位点
- 与新掺入的氨酰-tRNA的结合位点—氨酰基位点，又称A位点
- 与延伸中的肽酰-tRNA的结合位点—肽酰基位点，又称P位点
- 肽酰转移后与即将释放的tRNA的结合位点—E位点(exit site)
- 与肽酰tRNA从A位点转移到P位点有关的转移酶(即延伸因子EF-G)的结合位点
- 肽酰转移酶的催化位点
- 与蛋白质合成有关的其它起始因子、延伸因子和终止因子的结合位点

在核糖体中rRNA是起主要作用的结构成分

- 具有肽酰转移酶的活性；
- 为**tRNA**提供结合位点**(A**位点、**P**位点和**E**位点**)**；
- 为多种蛋白质合成因子提供结合位点；
- 在蛋白质合成起始时参与同**mRNA**选择性地结合以及在肽链的延伸中与**mRNA**结合；
- 核糖体大小亚单位的结合、校正阅读**(proofreading)**、无意义链或框架漂移的校正、以及抗菌素的作用等都与**rRNA**有关。

r蛋白质的主要功能

◈对**rRNA** 折叠成有功能的三维结构是十分重要的；

◈在蛋白质合成中，某些**r**蛋白可能对核糖体的构象起“微调”作用；

◈在核糖体的结合位点上甚至可能在催化作用中，核糖体蛋白与**rRNA**共同行使功能。

多聚核糖体(polyribosome或polysome)

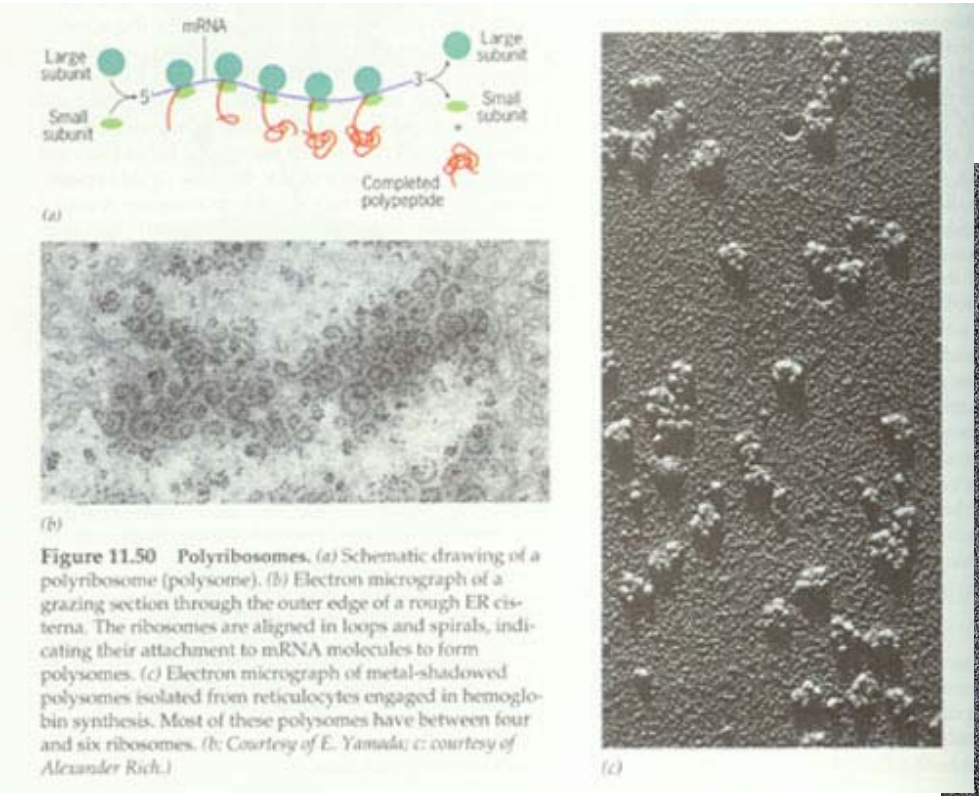


Figure 11.50 Polyribosomes. *(a)* Schematic drawing of a polyribosome (polysome). *(b)* Electron micrograph of a grazing section through the outer edge of a rough ER cisterna. The ribosomes are aligned in loops and spirals, indicating their attachment to mRNA molecules to form polysomes. *(c)* Electron micrograph of metal-shadowed polysomes isolated from reticulocytes engaged in hemoglobin synthesis. Most of these polysomes have between four and six ribosomes. *(b: Courtesy of E. Yamada; c: courtesy of Alexander Rich.)*

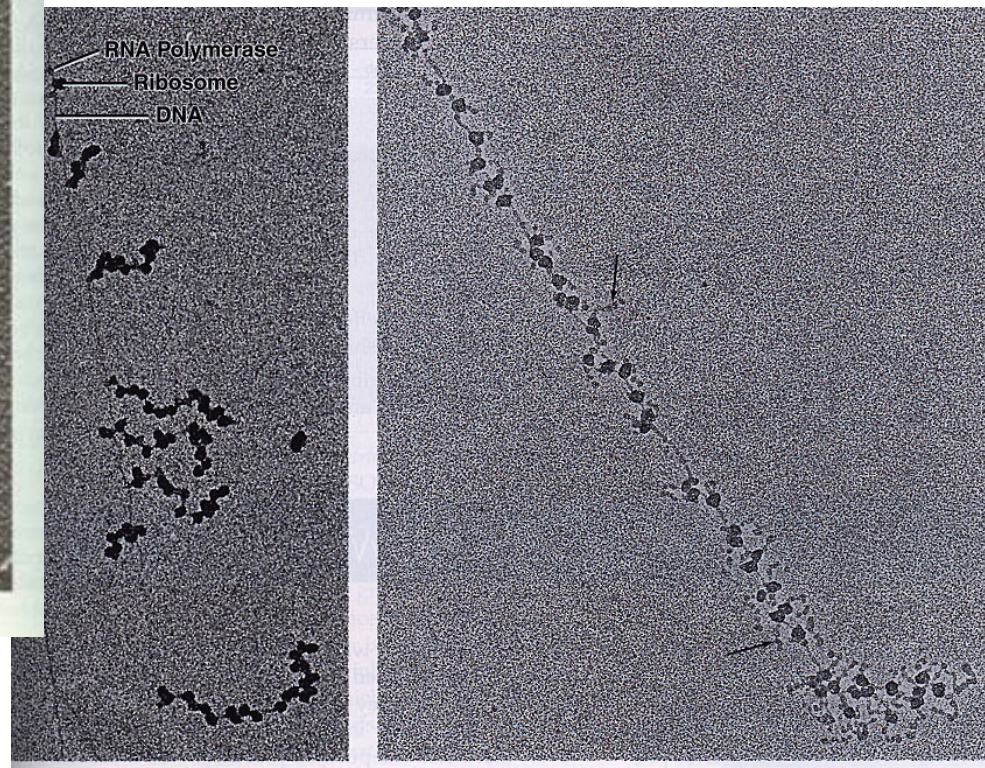
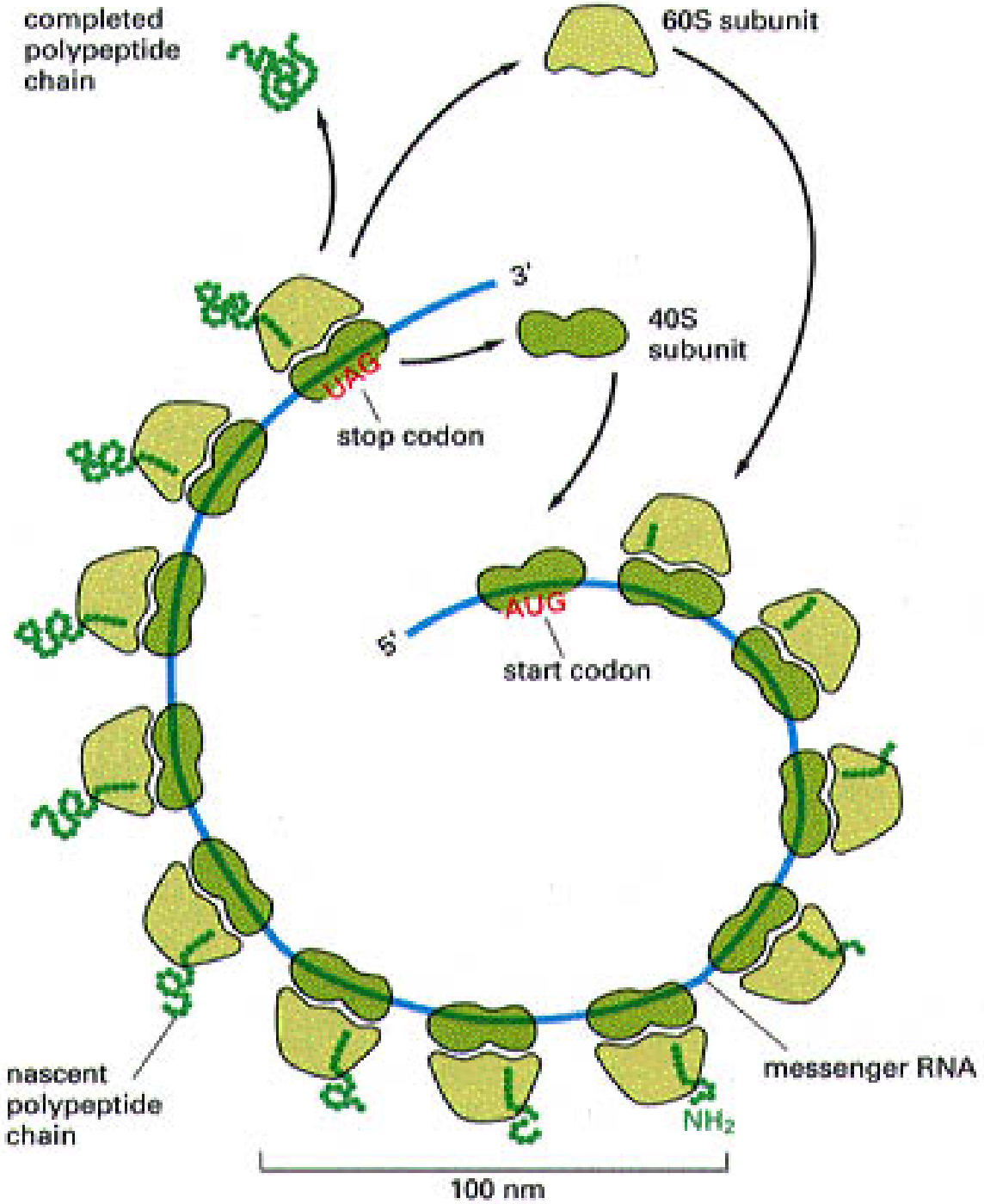


Figure 11.51 Visualizing transcription and translation.

蛋白质正在合成时的一种状态。

多聚核糖体


completed
polypeptide
chain
60S subunit
3'
40S
subunit
UAG
stop codon
5'
AUG
start codon
nascent
polypeptide
chain
messenger RNA
NH2
100 nm

多聚核糖体(polyribosome或polysome)

◆概念

核糖体在细胞内并不是单个独立地执行功能，而是由多个甚至几十个核糖体串连在一条**mRNA**分子上高效地进行肽链的合成，这种具有特殊功能与形态结构的核糖体与**mRNA**的聚合体称为多聚核糖体。

◆多聚核糖体的生物学意义

◈细胞内各种多肽的合成，不论其分子量的大小或是**mRNA**的长短如何，单位时间内所合成的多肽分子数目都大体相等。

◈以多聚核糖体的形式进行多肽合成，对**mRNA**的利用及对其浓度的调控更为经济和有效。

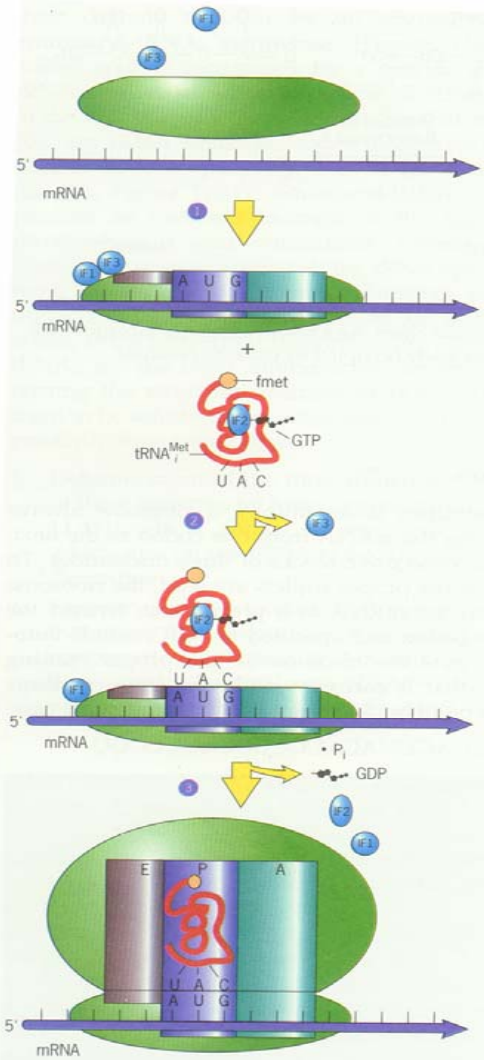
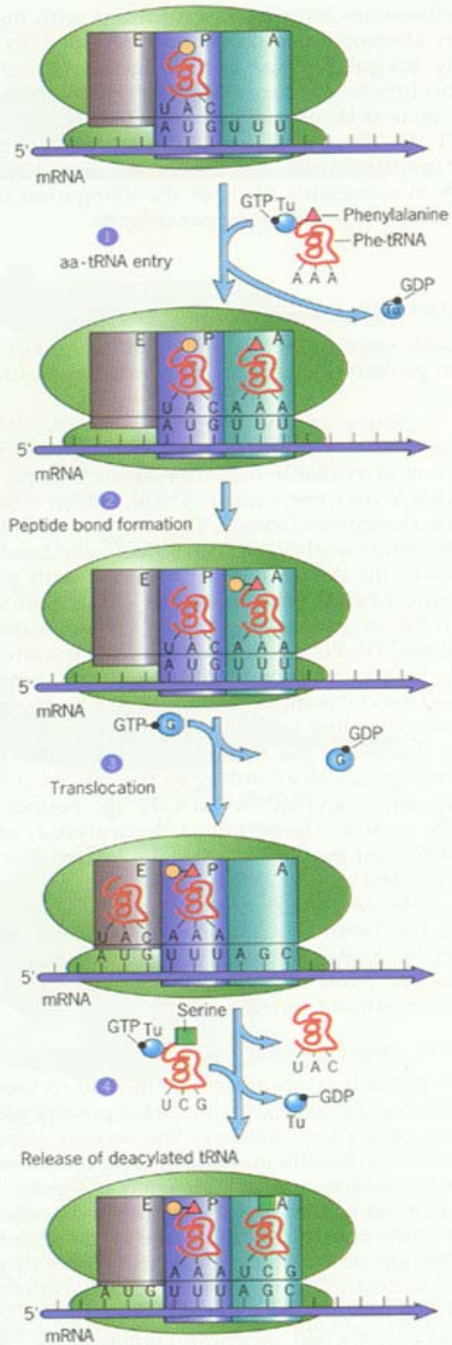
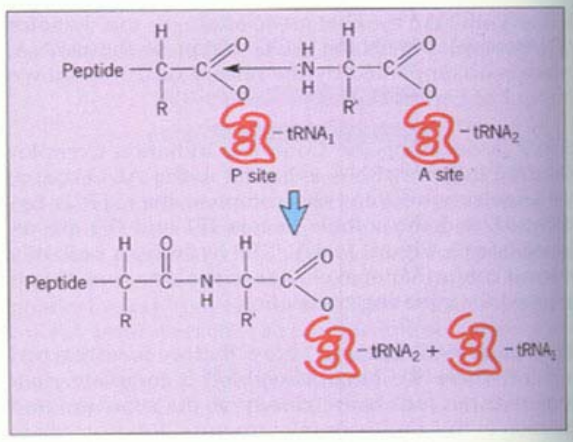


Figure 11.47 The initiation of protein synthesis in prokaryotes. In step 1, initiation of translation begins with the association of the 30S ribosomal subunit with the mRNA at the AUG initiation codon, a step that requires IF1 and IF3. The 30S ribosomal subunit binds to the mRNA at the AUG initiation codon as the result of an interaction between a complementary nucleotide sequence on the rRNA and mRNA, as discussed in the text. In step 2, a ternary (three-membered) complex consisting of formylmethionyl-tRNA–IF2–GTP becomes associated with the mRNA–30S ribosomal subunit complex accompanied by the release of IF3. In step 3, the 50S subunit joins the complex with the accompanying release of IF1, IF2, and the products of GTP hydrolysis (GDP and P_i).





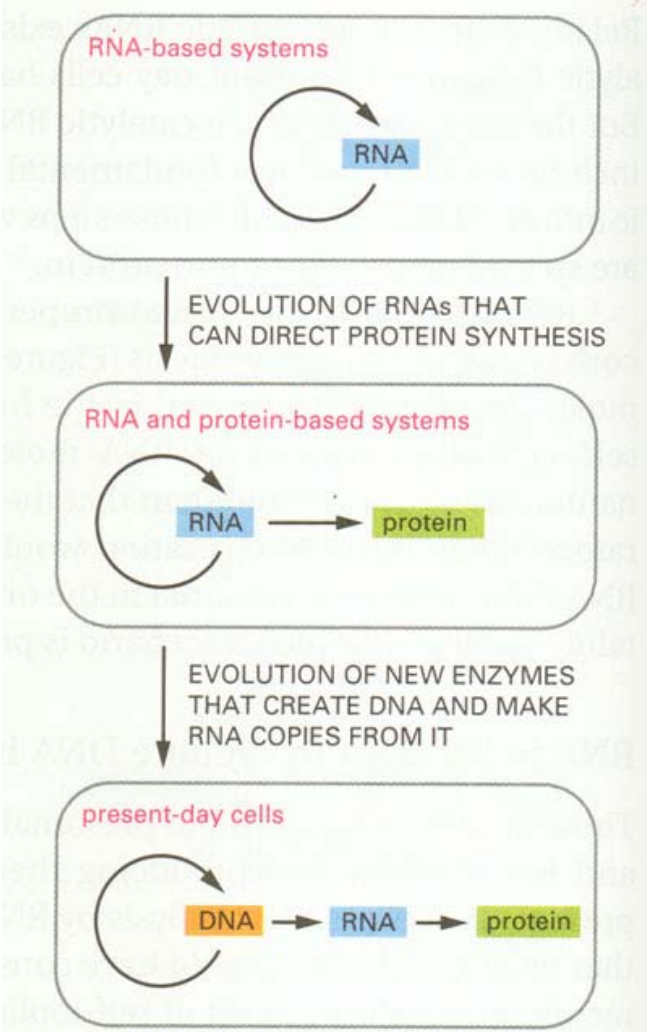
(b)

Figure 11.49 Steps in the elongation of the nascent polypeptide during translation in prokaryotes. *(a)* In step 1, an aminoacyl-tRNA whose anticodon is complementary to the second codon of the mRNA enters the empty A site of the ribosome. The binding of the tRNA is accompanied by the release of GDP–Tu. In step 2, peptide bond formation is accomplished by the transfer of the nascent polypeptide chain from the tRNA in the P site to the aminoacyl-tRNA of the A site, forming a peptidyl-tRNA in the A site and a deacylated tRNA in the P site. The reaction is catalyzed by a part of the 28S rRNA acting as a ribozyme. In step 3, the binding of factor G and the hydrolysis of its associated GTP results in the translocation of the ribosome relative to the mRNA. Translocation is accompanied by the movement of the deacylated tRNA and peptidyl-tRNA into the E and P sites, respectively. In step 4, the deacylated tRNA leaves the ribosome, and a new aminoacyl-tRNA enters the A site. *(b)* Peptide bond formation and the subsequent displacement of the deacylated tRNA.

component of the large subunit of the ribosome. For years it was assumed that the peptidyl transferase was one of the proteins of the ribosome. Then, as the catalytic powers of RNA became apparent, attention shifted to the ribosomal RNA as the catalyst for peptide bond formation. It has now been shown that peptidyl transferase activity does indeed reside in the large ribosomal RNA molecule of the large ribosomal subunit. In other words, peptidyl transferase is a ribozyme, a subject discussed in the Experimental Pathways on page 508.

Step 3: Translocation The formation of the first peptide bond leaves one end of the tRNA molecule of the A site still attached to its complementary codon on the mRNA and the other end of the molecule attached to a dipeptide. The tRNA of the P site is now devoid of any

RNA在生命起源中的地位及其演化过程



Question 7–7 Discuss the following: "During the evolution of life on earth, RNA has been demoted from its glorious position as the first self-replicating catalyst. Its role now is as a mere messenger in the information flow from DNA to protein."

生命是自我复制的体系

◈三种生物大分子，只有**RNA**既具有信息载体功能又具有酶的催化功能。因此，推测**RNA**可能是生命起源中最早的生物大分子。

◈核酶**(ribozyme)**：具有催化作用的**RNA**。

◈由**RNA**催化产生了蛋白质

DNA代替了RNA的遗传信息功能

- DNA双链比RNA单链稳定；
- DNA链中胸腺嘧啶代替了RNA链中的尿嘧啶，使之易于修复。

蛋白质取代了绝大部分RNA酶的功能

- 蛋白质化学结构的多样性与构象的多变性；
- 与**RNA**相比，蛋白质能更为有效地催化多种生化反应，并提供更为复杂的细胞结构成分，逐渐演化成今天的细胞。