Cytoplasm

By-

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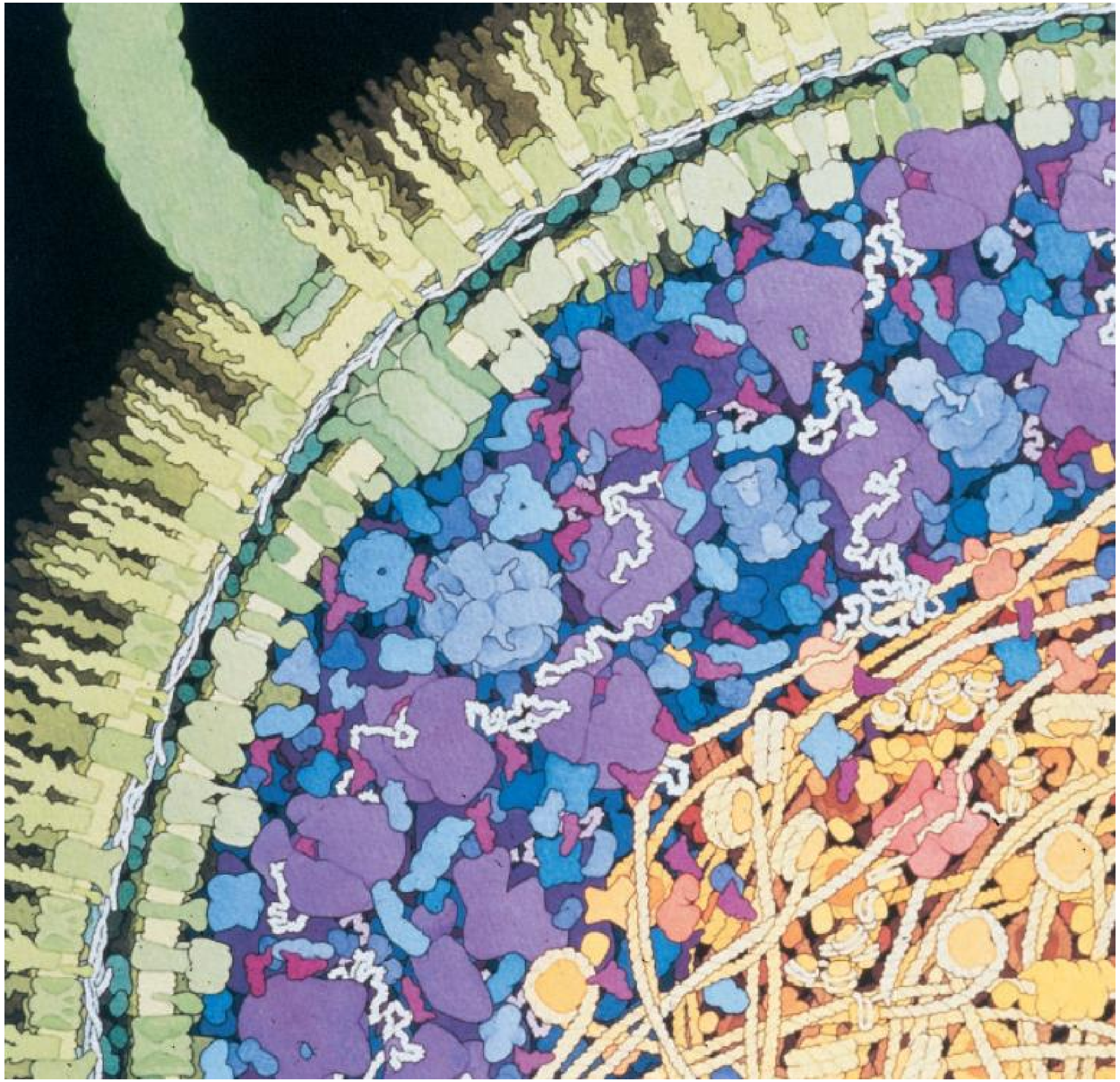
Cytoplasmic matrix

- Procaryotic cytoplasm, unlike that of eucaryotes, lacks unit membrane-bound organelles.
- The **cytoplasmic matrix** is the substance lying between the plasma membrane and the nucleoid.
- The matrix is largely water (about 70% of bacterial mass is water).
- It is featureless in electron micrographs but often is packed with ribosomes and highly organized (**figure 3.10**).
- Specific proteins are positioned at particular sites such as the cell pole and the place where the bacterial cell will divide.
- Thus although bacteria may lack a true cytoskeleton, they do have a cytoskeleton like system of proteins in their cytoplasmic matrix.
- The plasma membrane and everything within is called the **protoplast;** thus the cytoplasmic matrix is a major part of the protoplast.



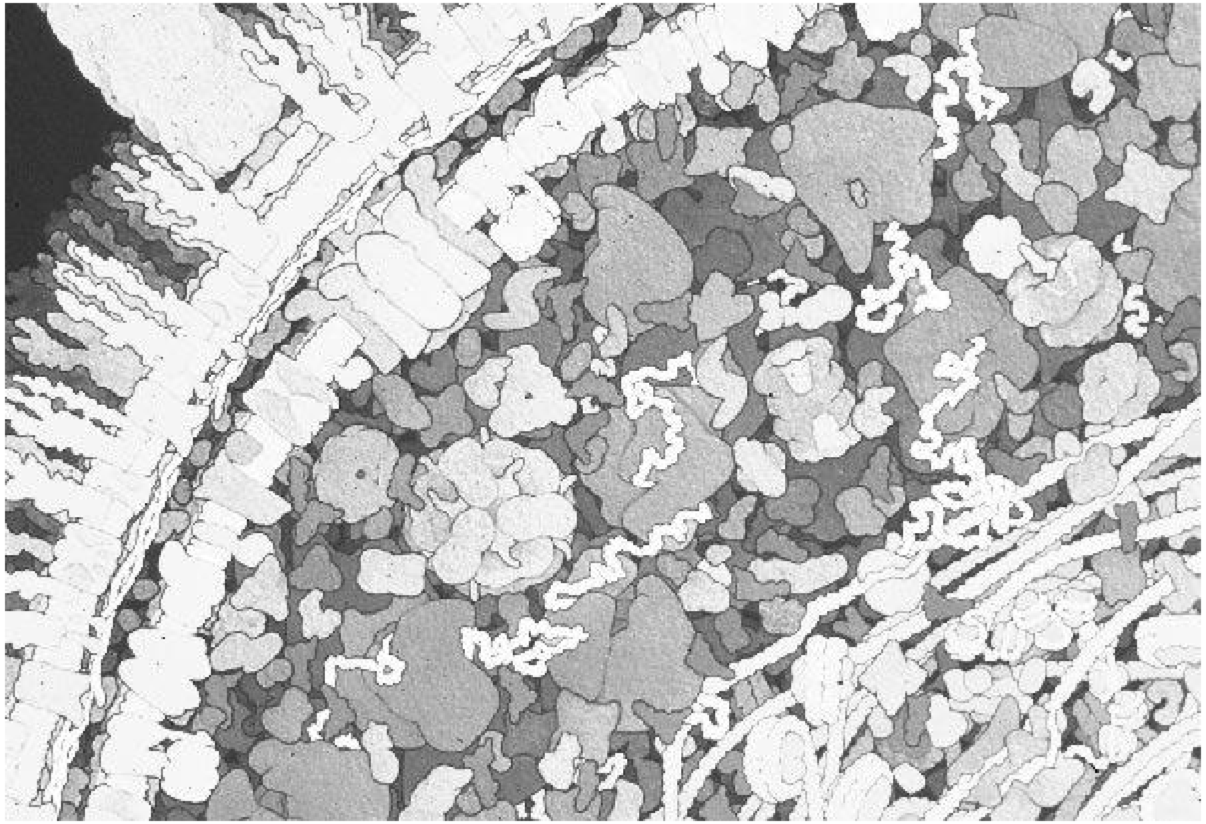


Figure 3.10
A Cross Section of the Bacterium *Escherichia coli*
Drawn at a Magnification of a Million Times. The glycocalyx, flagellum, gram-negative cell wall, and plasma membrane are at the top. Ribosomes synthesizing proteins fill the underlying cytoplasmic matrix. At the bottom is the nucleoid with its dense tangle of DNA and associated proteins

Ribosomes

- The cytoplasmic matrix often is packed with **ribosomes;** they also may be loosely attached to the plasma membrane.
- Ribosomes are actually very complex objects made of both protein and ribonucleic acid (RNA).
- They are the site of protein synthesis; matrix ribosomes synthesize proteins destined to remain within the cell, whereas the plasma membrane ribosomes make proteins for transport to the outside.
- The newly formed polypeptide folds into its final shape either as it is synthesized by the ribosome or shortly after completion of protein synthesis.
- The shape of each protein is determined by its amino acid sequence.
- Special proteins called molecular chaperones, or chaperones, aid the polypeptide in folding to its proper shape.

…Ribosomes

- Note that procaryotic ribosomes are smaller than eucaryotic ribosomes.
- They commonly are called 70S ribosomes, have dimensions of about 14 to 15 nm by 20 nm, a molecular weight of approximately 2.7 million, and are constructed of a 50S and a 30S subunit. The S in 70S and similar values stands for **Svedberg unit.**
- This is the unit of the sedimentation coefficient, a measure of the sedimentation velocity in a centrifuge; the faster a particle travels when centrifuged, the greater its Svedberg value or sedimentation coefficient.
- The sedimentation coefficient is a function of a particle’s molecular weight, volume, and shape.
- Heavier and more compact particles normally have larger Svedberg numbers or sediment faster.
- Ribosomes in the cytoplasmic matrix of eucaryotic cells are 80S ribosomes and about 22 nm in diameter.
- Despite their overall difference in size, both types of ribosomes are similarly composed of a large and a small subunit.

Inclusion Bodies

- Inclusion bodies usually are used for:
  - storage (e.g., carbon compounds, inorganic substances, and energy), and
  - also reduce osmotic pressure by tying up molecules in particulate form.
- Some inclusion bodies are not bounded by a membrane and lie free in the cytoplasm—for example:
  - polyphosphate granules,
  - cyanophycin granules, and
  - some glycogen granules.
- Other inclusion bodies are enclosed by a membrane about 2.0 to 4.0 nm thick, which is single-layered and not a typical bilayer membrane—for example:
  - poly-β-hydroxybutyrate granules,
  - some glycogen
  - sulfur granules,
  - carboxysomes, and
  - gas vacuoles.
- Inclusion body membranes vary in composition. Some are protein in nature, whereas others contain lipid.

…Inclusion bodies

- Glycogen and PHB inclusion bodies are carbon storage reservoirs providing material for energy and biosynthesis. Many bacteria also store carbon as lipid droplets.
- **Glycogen** is a polymer of glucose units composed of long chains formed by α(1→4) glycosidic bonds and branching chains connected to them by α(1→6) glycosidic bonds.
- Glycogen is dispersed more evenly throughout the matrix as small granules (about 20 to 100 nm in diameter) and often can be seen only with the electron microscope.
- If cells contain a large amount of glycogen, staining with an iodine solution will turn them reddish-brown.
- **Poly-β -hydroxybutyrate (PHB)** contains β -hydroxybutyrate molecules joined by ester bonds between the carboxyl and hydroxyl groups of adjacent molecules.
- Usually only one of these polymers is found in a species, but purple photosynthetic bacteria have both.
- Poly-β -hydroxybutyrate accumulates in distinct bodies, around 0.2 to 0.7 μm in diameter, that are readily stained with Sudan black for light microscopy and are clearly visible in the electron microscope.

Cyanobacteria have two distinctive organic inclusion bodies

- **Cyanophycin granules** are composed of large polypeptides containing approximately equal amounts of the amino acids arginine and aspartic acid.
- The granules often are large enough to be visible in the light microscope and store extra nitrogen for the bacteria.
- **Carboxysomes** are present in many cyanobacteria, nitrifying bacteria, and thiobacilli.
- They are polyhedral, about 100 nm in diameter, and contain the enzyme ribulose-1,5-bisphosphate carboxylase in a paracrystalline arrangement.
- They serve as a reserve of this enzyme and may be a site of CO_2 fixation.

Gas vacuole

- A most remarkable organic inclusion body, the **gas vacuole,** is present in many cyanobacteria (*see section 21.3*), purple and green photosynthetic bacteria, and a few other aquatic forms such as *Halobacterium* and *Thiothrix.*
- These bacteria float at or near the surface, because gas vacuoles give them buoyancy.
- Gas vacuoles are aggregates of enormous numbers of small, hollow, cylindrical structures called **gas vesicles**.
- Gas vesicle walls do not contain lipid and are composed entirely of a single small protein.
- These protein subunits assemble to form a rigid enclosed cylinder that is hollow and impermeable to water but freely permeable to atmospheric gases.
- Bacteria with gas vacuoles can regulate their buoyancy to float at the depth necessary for proper light intensity, oxygen concentration, and nutrient levels.
- They descend by simply collapsing vesicles and float upward when new ones are constructed.

Inorganic inclusion bodies

- Many bacteria store phosphate as **polyphosphate granules** or **volutin granules.**
- Polyphosphate is a linear polymer of orthophosphates joined by ester bonds.
- Thus volutin granules function as storage reservoirs for phosphate, an important component of cell constituents such as nucleic acids.
- In some cells they act as an energy reserve, and polyphosphate can serve as an energy source in reactions.
- These granules are sometimes called **metachromatic granules** because they show the metachromatic effect; that is, they appear red or a different shade of blue when stained with the blue dyes methylene blue or toluidine blue.
- Some bacteria also store sulfur temporarily as **sulfur granules,** a second type of inorganic inclusion body.
- For example, purple photosynthetic bacteria can use hydrogen sulfide as a photosynthetic electron donor and accumulate the resulting sulfur in either the periplasmic space or in special cytoplasmic globules.
- Inorganic inclusion bodies can be used for purposes other than storage.
- An excellent example is the **magnetosome,** which is used by some bacteria to orient in the earth's magnetic field.
- These inclusion bodies contain iron in the form of magnetite.

The Nucleoid

- Probably the most striking difference between procaryotes and eucaryotes is the way in which their genetic material is packaged.
- Eucaryotic cells have two or more chromosomes contained within a membrane-delimited organelle, the nucleus.
- In contrast, procaryotes lack a membrane-delimited nucleus.
- The procaryotic chromosome is located in an irregularly shaped region called the **nucleoid** (other names are also used: the nuclear body, chromatin body, nuclear region).
- Usually procaryotes contain a single circle of double-stranded **deoxyribonucleic acid (DNA),** but some have a linear DNA chromosome.
- Recently it has been discovered that some bacteria such as *Vibrio cholerae* have more than one chromosome.
- Although nucleoid appearance varies with the method of fixation and staining, fibers often are seen in electron micrographs (figure 3.11 and **figure 3.14**) and are probably DNA.
- The nucleoid also is visible in the light microscope after staining with the Feulgen stain, which specifically reacts with DNA.
- A cell can have more than one nucleoid when cell division occurs after the genetic material has been duplicated (figure 3.14*a*).
- In actively growing bacteria, the nucleoid has projections that extend into the cytoplasmic matrix (figure 3.14*b,c*).
- Presumably these projections contain DNA that is being actively transcribed to produce mRNA.

…Nucleoid

- Careful electron microscopic studies often have shown the nucleoid in contact with either the mesosome or the plasma membrane.
- Membranes also are found attached to isolated nucleoids.
- Thus there is evidence that bacterial DNA is attached to cell membranes, and membranes may be involved in the separation of DNA into daughter cells during division.
- Nucleoids have been isolated intact and free from membranes.
- Chemical analysis reveals that they are composed of about 60% DNA, 30% RNA, and 10% protein by weight.
- It must be very efficiently packaged to fit within the nucleoid. The DNA is looped and coiled extensively, probably with the aid of RNA and nucleoid proteins (these proteins differ from the histone proteins present in eucaryotic nuclei).

Plasmids

- Many bacteria possess **plasmids** in addition to their chromosome.
- These are double-stranded DNA molecules, usually circular, that can exist and replicate independently of the chromosome or may be integrated with it; in either case they normally are inherited or passed on to the progeny.
- However, plasmids are not usually attached to the plasma membrane and sometimes are lost to one of the progeny cells during division.
- Plasmids are not required for host growth and reproduction, although they may carry genes that give their bacterial host a selective advantage.
- Plasmid genes can render bacteria drug-resistant, give them new metabolic abilities, make them pathogenic, or endow them with a number of other properties.
- Because plasmids often move between bacteria, properties such as drug resistance can spread throughout a population.