The Synthesis of Functional Bacterial Wall

OUTLINE

THE CROSSLINKED FABRIC-LIKE STRUCTURE OF BACTERIAL WALL
WALL STRENGTH COMES FROM WALL STRUCTURE
WALL SYNTHESIS AND THE MAKE-BEFORE-BREAK STRATEGY
BIOSYNTHESIS OF PEPTIDOGLYCAN
   Outline of the Assembly of the Basic Unit
   Formation of the Disaccharide
   Formation of the Peptide Portion
   Transport and Linking
   The Assembly
   Conversion of Nascent Wall to Structurally Competent Wall

THE NECESSARY CLEAVAGE OF CELL WALL FOR GROWTH
   Reworking of the Wall Substance
   The Difference Between Hydrolases and Transferases
   Autolysins
   Geometry of Cleavage Action
   Strategies of Self-Protection Against Autolysin Action
   The Role of the Wall in Resisting Turgor Pressure

EVOLUTION OF EUBACTERIA
HISTORY

KEY IDEAS

Murein, or peptidoglycan, is the covalently linked fabric forming the exoskeleton, or sacculus, of most eubacteria.
Murein makes it possible for bacteria to resist osmotic challenges.
The wall fabric is strong and elastic.
Murein has an exotic sugar and unusual amino acids permitting crosslinks.
Murein is formed by multiple linking of disaccharide pentapeptide units through bonds between hexoses and between peptide groups.
Peptide bonds are made with specific synthases—by a process not akin to protein synthesis.
Precursor units are pre-energized so that they can be crosslinked after externalization.
Passage through the cytoplasmic membrane requires a lipid carrier.
Autolysins are necessary for enlargement of the sacculus.
Before stress-bearing covalent bonds are cleaved, new covalent bonds are formed to accept the stress.
Turgor leads to stresses, which in turn favor cleavages and enlargement.
Murein addition and cleavage patterns establish cellular morphology.
Turnover is essential for the elongation of the side wall of the Gram-positive rod.
Turnover may be essential for Gram-negative rod side wall elongation.
Turnover of poles is much slower than that of side walls.

The Crosslinked Fabric-Like Structure of Bacterial Wall

The chemical nature of the wall allows it to be a two-dimensional stress-resistant fabric forming the exoskeleton of most eubacteria. The key feature is that it is composed of functional units containing both carbohydrate chains and peptide chains such that a basic unit is capable of being connected to other units in at least three places. The formula for the peptidoglycan unit structure of *Escherichia coli* and *Bacillus subtilis* is shown in Fig. 4.1. This specific formula represents the most common structure in eubacteria, and is similar to the basic units used by all eubacteria, except for the wall-less mycoplasma. Many of these units are linked together to form the sacculus surrounding the growing bacterium. Thus, carbohydrate chains of many disaccharide units are formed via β(1→4) glycosidic bonds; such chains are chemically similar to the cellulose of plants or more similar to the chitin of insects. These substances are the major mechanical element in the external skeleton of those organisms. Murein contains a very special sugar (muramic acid) that has an appended D-lactyl group. The attached peptide, for example, L-alanyl-D-isoglutamyl-meso-diaminopimelyl-D-alanyl-D-alanine shown in Fig. 4.1, is quite different from peptides in proteins. This is due to the D-amino acids, the linkage of glutamic acid through its γ-carboxyl group, and the exotic diaminopimelic acid residue. However, most of the amino acids are connected via their α-amino group to the α-carboxyl group of the adjacent amino acid, as in normal proteins. The peptides of murein have properties similar to those found in the fibrous proteins of mammalian skin or hair. But peptidoglycans are profoundly different in their mechanical properties than either fibrous carbohydrates or proteins. The fundamental chemical difference of having both carbohydrate and protein features in the basic unit allows the development of multiple covalent crosslinks to form two- and three-dimensional structures. Both ends of the disaccharide are used to extend the carbohydrate chain and there are three carboxyl groups and one amino group in the peptide through which linkages can be formed. In the peptidoglycan unit structure of *Escherichia*