



Electron Microscopic Structural Analysis: Mesosomal Development in Heterotrophic Bacteria

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DESCRIPTION

Mesosomes are complex, folded membrane structures found within the cytoplasm of many bacteria, especially gram-positive types. These invaginations of the plasma membrane have excited considerable debate regarding their function and significance. Although initially thought to be artifacts of chemical fixation processes during electron microscopy, further studies have revealed their potential roles in cellular processes such as DNA replication, cell division, and respiration.

Structure of mesosomes

Mesosomes appear as convoluted, membranous invaginations within the bacterial cell, often located near the site of DNA attachment to the membrane. They vary in size and complexity, with structures ranging from simple vesicles to highly elaborate, branched networks. Electron microscopy has been essential in elucidating their detailed morphology.

Central mesosomes: These mesosomes are usually found near the center of the cell and are associated with the nucleoid region. They often appear as coiled or looped structures and are thought to play a role in the segregation of daughter chromosomes during cell division.

Peripheral mesosomes: Located at the cell periphery, these mesosomes are less complex than central mesosomes and may assist in the formation of the septum during cytokinesis. They also participate in the organization of the cell membrane and its associated proteins.

Septal mesosomes: Found at the sites of septum formation, these mesosomes are involved in the cell division process. They are believed to report the bacterial chromosome during replication and ensure proper segregation into daughter cells.

Development of mesosomes

The development of mesosomes is influenced by various factors, including the type of bacteria, growth conditions, and the stage of the cell cycle. In heterotrophic bacteria, mesosome formation is often linked to the metabolic activity and division process.

Gram-positive bacteria: In gram-positive bacteria like *Bacillus subtilis* and *Staphylococcus aureus*, mesosomes are more prominently observed. These bacteria have a thicker peptidoglycan layer, which may support the formation and stabilization of mesosomal structures. During the exponential phase of growth, mesosomes are more pronounced, reflecting their role in active cell division and DNA replication.

Gram-negative bacteria: Although less common, mesosomes have also been reported in gram-negative bacteria like *Escherichia coli* under certain conditions. The presence of an outer membrane and a thinner peptidoglycan layer in these bacteria may limit the development of mesosomes. However, under stress conditions or specific growth phases, mesosomal-like structures can be induced.

Influence of growth conditions: Nutrient availability, pH, temperature, and other environmental factors can influence mesosome development. For instance, nutrient-rich environments tend to promote more extensive mesosomal structures, aligning with the increased metabolic activity and cellular processes.

Electron microscopic studies

Electron microscopy has been the fundamental technique for studying mesosomes. The high-resolution images obtained from Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM) provide detailed insights into the ultrastructure of mesosomes.

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Transmission Electron Microscopy (TEM): TEM has been extensively used to visualize mesosomes in thin sections of bacterial cells. The contrast provided by heavy metal staining highlights the membranous nature of mesosomes. TEM studies have revealed the complex folding patterns and connections of mesosomes with the plasma membrane and nucleoid region.

Scanning Electron Microscopy (SEM): SEM provides a three-dimensional perspective of mesosomal structures. While SEM is less commonly used than TEM for mesosome studies, it provides valuable information on the surface topology and spatial arrangement of mesosomes within the cell.

Cryo-electron microscopy: Recent advancements in cryo-Electron Microscopy (cryo-EM) have allowed for the visualization of mesosomes in their near-native state, avoiding potential artifacts from chemical fixation. Cryo-EM studies have confirmed the existence of mesosomes in living cells and provided insights into their dynamic nature and functional interactions.

Functional significance

The exact functions of mesosomes remain a subject of ongoing research and debate. Several hypotheses have been proposed based on electron microscopic observations and experimental data.

Cell division: Mesosomes are thought to play a critical role in cell division by reporting the bacterial chromosome to the cell membrane and ensuring its proper segregation during cytokinesis. Their association with the septum suggests a direct involvement in the division process.

DNA replication and repair: The proximity of mesosomes to the nucleoid region implies a role in DNA replication and repair. Mesosomes may serve as base for the assembly of replication machinery and facilitate the organization and distribution of genetic material.

Respiratory activity: In some bacteria, mesosomes are associated with respiratory enzymes, suggesting a role in cellular respiration. The increased surface area provided by mesosomal folds could enhance the efficiency of metabolic processes involving membrane-bound proteins.

The study of mesosomes in heterotrophic bacteria through electron microscopy has provided valuable insights into their structure, development, and potential functions. Advances in electron microscopy techniques, such as cryo-EM, potential to further understand the mysteries of these intriguing membrane structures, focus on their contributions to bacterial survival and adaptability.