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CELL ADHESION MECHANISMS: A WINDOW INTO THE EVOLUTION OF MULTICELLULARITY

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ABSTRACT

Background: The study explores how single-celled organisms evolved into multicellular, focusing on the mechanisms of cell adhesion as a determining factor in this transition. Volvocaceae algae have evolved to form multicellular colonies, where cells communicate via cytoplasmic bridges. In contrast, multicellular animals have evolved complex junctions, such as gap-like junctions and desmosomes, that allow for communication and adhesion between cells. Cell adhesion is crucial for the formation of multicellular structures, ensuring cohesion and communication between cells.

Methodology: A literature review was carried out between 2003 and 2024, using databases such as Web of Science, Zoological Record, and Google Scholar. Search terms included "Cell Adhesion," "Intercellular Junctions," "Tissues," and "Green Algae." Only peer-reviewed articles comparing the evolution of the mechanisms of communication between cells of Volvocaceae algae and multicellular animals were included, excluding narrative and editorial studies.

Results: The results indicate that Volvocaceae animals and algae followed different evolutionary trajectories in the development of cell junctions. Animals have evolved complex junctions, such as desmosomes and gap-like junctions, which are essential for cell communication and adhesion. In comparison, the Volvocaceae algae maintained simpler adhesion mechanisms, using cytoplasmic bridges and connections with the extracellular matrix to maintain cell cohesion in the colonies, without the sophistication of the junctions observed in the animals.

Conclusion: The comparative analysis reveals that, although both the animals and the Volvocaceae algae evolved for multicellularity, the animals developed more advanced cell junctions, while the algae opted for simpler communication and adhesion strategies. This illustrates the diversity of evolutionary pathways that underpin multicellularity in different groups.

Keywords: Cell Adhesion. Intercellular junctions. Tissues. Green algae. Cytology.

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INTRODUCTION

Cell adhesion is a basic property of animal cells (HARWOOD; COATES, 2004). It plays an important role in the emergence of multicellular animals (JOHNSON et al., 2013). The structure and functionality of multicellular organisms, as well as the viability of their survival, depend fundamentally on the ability to form and maintain stable cellular connections. This crucial ability allows previously autonomous cells to collaborate and operate as a unified entity, through specialized cell adhesion mechanisms. In addition to providing structural integrity, cell adhesion facilitates intercellular communication by allowing the exchange of chemical and electrical signals vital for the coordination of complex functions. This is especially evident in tissues and organs, where cellular cohesion is essential for maintaining homeostasis and response to external stimuli. A prerequisite for each origin of multicellularity was the evolution of mechanisms for stable cell-cell adhesion or fixation (ABEDIN; KING, 2010). Each junction performs a different function within the epithelium and contains a unique collection of proteins. Detailed studies of intercellular interactions in plants and animals have revealed dramatic differences, both in the types of molecules used to mediate cell adhesion and in the way these molecules interact with neighboring cells and the extracellular environment (JARVIS et al., 2003). Variations in the diversity and organization of junctions, as well as differences in the composition of junctional proteins, contribute to the development and differentiation of discrete tissue types and probably played a role in the evolution of new animal forms (ABEDIN; KING, 2010). Multicellular transitions in green algae, specifically in *Volvocaceae*, are elucidative when compared to single-celled organisms. These observations highlight the importance of *Volvocaceae* as a model to study these evolutionary processes (MURAMOTO et al., 2010). The evolution of *Volvocaceae* algae highlights a striking contrast to the structural and functional complexity found in animals. While animals have a characteristic epithelium that distinguishes animals from all other multicellular lineages (TYLER, 2003) facilitating adhesion and advanced communication both between cells and with the characteristic extracellular matrix, *Volvocaceae* algae use a simpler evolutionary pathway, forming physical connections between cells, such as cytoplasmic bridges resulting from incomplete cytokinesis and the transformation of cell wall components into a colonial limit (KIRK, 2005), mechanisms that allow cooperation and cellular integration within the colony, but without the sophistication of cellular connections observed in animal tissues.

METHOD

This study is a literature review conducted between May and July 2024, with the objective of analyzing the evolution of cell junctions and their importance in multicellularity in Volvocaceae animals and algae. The review used databases such as PubMed, Google Scholar, and Scopus, using keywords such as "Cell Adhesion", "Cell Junctions", "Tissue Evolution", "Multicellularity", and "*Volvocaceae* Algae", to identify relevant studies published between 2003 and 2024 in English or Portuguese. Peer-reviewed articles addressing the evolution and function of cell junctions were included, excluding narrative and editorial reviews. The selection of studies involved the screening of titles and abstracts, followed by the complete reading of the selected articles, with the extraction of relevant data on the specific cell adhesion mechanisms and their impacts on the evolution of multicellularity. The extracted data were analyzed qualitatively to identify junction patterns, comparing the evolutionary strategies adopted by Volvocaceae animals and algae.

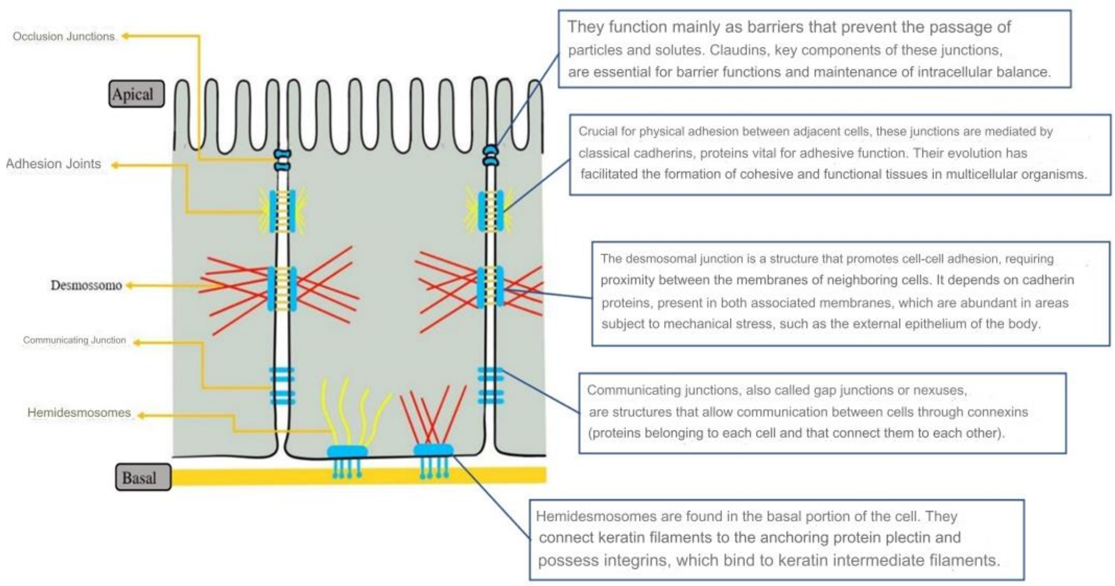
RESULTS

The evolution of multicellularity represents a crucial milestone in the development of biological diversity. While metazoans, multicellular animals descended from some single-celled eukaryotic protozoa, developed complex tissues with specialized cell junctions that facilitate advanced adhesion and communication between cells and with the extracellular matrix, *Volvocaceae* algae adopted a more basic evolutionary approach, relying on less sophisticated physical connections, such as cytoplasmic bridges resulting from incomplete cytokinesis (KIRK, 2005). This difference in the complexity of cell junctions can be attributed to the unique characteristics of the single-celled ancestors of each group. Animals evolved from protozoa that possessed the ability to form complex and permanent junctions, a trait that was essential for the development of highly organized and functionally differentiated multicellular organisms (TYLER, 2003). On the other hand, *Volvocaceae* algae, which also originated from single-celled ancestors, have maintained a simpler adhesion strategy that reflects their origins with cell walls, utilizing the extracellular matrix as a means to maintain cohesion and facilitate cellular interaction within colonies.

DISCUSSION

The comparison between cell adhesion mechanisms in *Volvocaceae algae* and animals highlights the adaptive variations in the evolution of multicellularity. Animals, derived from protozoa capable of establishing complex and permanent junctions, have evolved a wide range of specialized junctions, such as desmosomes, adherent junctions, and communication junctions. These junctions are vital for the structural and functional integrity of tissues, allowing both physical adhesion and the exchange of biochemical signals necessary for development and homeostasis. On the other hand, *Volvocaceae* algae demonstrate a simpler adhesion strategy, reflecting their origins with rigid cell walls. They rely primarily on an extracellular matrix to maintain cellular cohesion and facilitate communication within colonies. This matrix, although less complex than the junctions found in animals, is effective for cellular integration and cooperation, representing a preliminary stage in the transition to multicellular organisms.

Figure 1 - Adhesion and communication cell junctions.



Source: The author, 2024

FINAL CONSIDERATIONS

The final considerations of this study highlight the diversity and complexity of evolutionary strategies in the transition from single-celled to multicellular organisms. Comparative analysis between *Volvocaceae* algae and animals reveals distinct adaptations in cell structures to face similar challenges in multicellular environments. While animals have evolved highly specialized cell junctions for communication and adhesion, *Volvocaceae* algae have chosen to maintain and adapt simpler structures for equivalent functions. This contrast underlines the importance of the extracellular matrix in algae as an essential means of adhesion and communication, emphasizing how differences in cell adhesion mechanisms shape the evolutionary trajectories of diverse lineages. Understanding these variations provides valuable insights into the multiple pathways that multicellular life can take, reflecting life's adaptability and inventiveness in responding to evolutionary pressures.

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