frontiers | Frontiers in Ecology and Evolution

TYPE Editorial
PUBLISHED 14 February 2025
DOI 10.3389/fevo.2025.1549081

OPEN ACCESS

EDITED AND REVIEWED BY
Stefano Tiozzo,
UMR7009 Laboratoire de Biologie du Développement de Villefranche sur Mer, France

*CORRESPONDENCE
Paolo Sordino
paolo.sordino@szn.it

RECEIVED 20 December 2024
ACCEPTED 27 January 2025
PUBLISHED 14 February 2025

CITATION
Anselmi C, Sepe RM, Manni L and Sordino P (2025) Editorial: Tunicates in evolutionary developmental biology.
Front. Ecol. Evol. 13:1549081.
doi: 10.3389/fevo.2025.1549081

Editorial: Tunicates in evolutionary developmental biology

Chiara Anselmi[1], Rosa Maria Sepe[2], Lucia Manni[1] and Paolo Sordino[3]*

[1]Department of Biology, University of Padova, Padova, Italy, [2]Department of Biology and Evolution of Marine Organisms, Anton Dohrn Zoological Station, Naples, Italy, [3]Sicily Marine Centre, Anton Dohrn Zoological Station, Messina, Italy

KEYWORDS

sensory inputs, torpor, regeneration, neurotransmitters, lumen formation, oogenesis, asexual reproduction

Editorial on the Research Topic
Tunicates in evolutionary developmental biology

Tunicates, the closest living relatives of vertebrates, offer an extraordinary window into the evolutionary processes that shape animal development (Ferrier, 2011; Johnson et al., 2024; Todorov et al., 2024). These marine invertebrates display remarkably diverse lifestyles (benthic, pelagic, solitary, gregarious, or colonial), life cycles (simple or complex), and development (direct, indirect, sexual, or asexual) (Ricci et al., 2022; Nanglu et al., 2023). This diversity, combined with their genetic similarities to vertebrates, makes tunicates valuable models for understanding how developmental mechanisms contribute to evolutionary novelties (Procaccini et al., 2011; Popsuj et al., 2024).

Recent advancements in tunicate genomics and expression profiling have made it possible to gain a deeper understanding of the molecular underpinnings of tunicate development (Oda and Satou, 2025; Sánchez-Serna et al., 2025). At the same time, there is much we do not yet know about specific research questions within tunicate Evo-Devo, e.g., the evolution of tunicate muscle types or the homology between vertebrate hair cells and tunicate coronal sensory cells. This research is crucial for identifying genes that are conserved between species and those that have diverged, providing insights into the genetic basis of morphological differences across tunicate species or among broader metazoans.

The studies compiled in this Research Topic speak to four major themes, pushing the boundaries of thought at the sub-cellular, cellular, organ, and organism levels. In short, they provide new insights into the molecular networks, cellular behaviors, and developmental processes that underpin the diversification of tunicates and their evolution in the context of chordate development. The Research Topic includes seven publications in *Frontiers in Ecology and Evolution* and four in *Frontiers in Cell and Developmental Biology*. It features a mix of five Original Research articles, one Brief Research Report, four Reviews, and one Perspective article.

The Research Topic showcases original research on a range of tunicate species, including *Ciona robusta*, *Oikopleura dioica*, *Botrylloides leachii*, and *Polyandrocarpa zorritensis*. Together with the tunicate species considered in all 11 publications, they

represent a broad spectrum of developmental biology, from mechanisms of regeneration to the evolution of cellular systems such as stem cells and the immune system. Altogether, these studies deepen our understanding of how morphological and physiological novelties emerge through changes in developmental programs

The Research Topic also dives into the genetic and cellular mechanisms at play in tunicates. Fritzsch and Glover provide a review of the gene networks involved in the development of sensory organs, including the evolution of olfactory receptors, eyes, and hair cells, which are key structures in both tunicates and vertebrates. These studies emphasize the conserved genetic pathways and their divergent roles in the development of sensory organs across chordates.

At the subcellular level, Bi et al. contribute an original research paper that explores the important role of a matrix metalloprotease, Nas15, in the vacuolation in the notochord of ascidians, and the role of tubular organ lumen formation in maintaining hydrostatic pressure, a feature that is conserved across tunicates, amphioxus, and vertebrates. It also serves as a reference for research on human abnormal lumenogenesis diseases. The study by Feng and Thompson focuses on the role of Aurora kinases during oogenesis in *O. dioica*, offering new insights into cell cycle regulation in this emerging model organism. This study highlights how Aurora kinases changed their interaction proteins by independent evolution, leading to a functional separation in spindle and chromosome regulations. Glover et al. further enhance our understanding of calcium signaling in tunicates, highlighting its importance in various developmental processes. What is clear is that, in all questions concerning the universal role of calcium signaling, the small larval size, low cell number, and rapid development of tunicates provide insights of developmental and evolutionary significance.

At the cellular level, Anselmi et al. review two decades of data on mechanoreceptor structures, focusing on the coronal organs of adult tunicates. These organs, located at the base of the oral siphon, detect potentially dangerous particles entering the pharynx, and their sensory cells serve as prime candidates for understanding the evolution of vertebrate hair cells of the inner ear and lateral line organ. Hyams et al. focus on the morphological, cellular, and molecular changes that *B. leachii* hemolymph undergoes under physiological stress in torpor conditions, contributing valuable insights for future studies on hibernation phenomena in other organisms.

At the organ level, Stokes et al. investigate myocardial regeneration in *Ciona* injured hearts, finding gene expression changes that include orthologous genes in vertebrates that are involved in cardiac development and disease processes. Thus, this article provides valuable insights into the conserved molecular mechanisms that facilitate heart tissue repair across chordates.

On a broader organism scale, Nydam et al. examine the evolution of allorecognition in Botryllid ascidians, shedding light on the molecular and ecological mechanisms that govern this process in colonial tunicates. Their research contributes to our understanding of how complex, multi-cellular interactions and immune responses have evolved in these fascinating organisms. Hotta et al. offer a perspective on the evolutionary and developmental biology of organismal transparency in tunicates, particularly in salps, larvaceans, and some ascidian species. The authors propose novel methodologies to evaluate transparency, giving rise to the interdisciplinary field of organismal transparency biology. The review by Pennati et al. highlights serotonin signaling in tunicates, comparing its roles across species and offering a broader evolutionary perspective in chordates. Likely due to events of loss and gain of functions, tunicates exhibit both ancient roles, such as the control of ciliary beating and locomotion coordination, and chordate-specific novelties, such as the modulation of various aspects of intestinal function. Similarly, Tobias-Santos et al. explore how environmental factors such as salinity limit the asexual reproduction of *P. zorritensis*, providing a unique perspective on the evolutionary adaptation of colonial tunicates to varying environmental conditions.

In conclusion, this Research Topic has advanced our understanding of tunicate Evo-Devo, shedding light on some of the molecular, cellular, and developmental processes driving tunicate diversification and evolution in the context of chordate development. Continued exploration of tunicates, alongside new techniques and experimental species (Walters et al., 2019; Daric et al., 2024), promises to deepen our understanding of the relationships between genotype, phenotype, and environment. As we continue to unravel the secrets of tunicate development and evolution, we may gain new insights into fundamental biological processes. We hope this Research Topic serves as a valuable reference and contributes to the evolving field of tunicate Evo-Devo.

Author contributions

CA: Writing – original draft, Writing – review & editing. RS: Writing – original draft, Writing – review & editing. LM: Writing – original draft, Writing – review & editing. PS: Writing – original draft, Writing – review & editing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Daric, V., Lanoizelet, M., Mayeur, H., Leblond, C., and Darras, S. (2024). Genomic resources and annotations for a colonial ascidian, the light-bulb sea squirt *Clavelina lepadiformis*. *Genome Biol. Evol.* 16, evae038. doi: 10.1093/gbe/evae038

Ferrier, D. E. (2011). Tunicates push the limits of animal evo-devo. *BMC Biol.* 9, 3. doi: 10.1186/1741-7007-9-3

Johnson, C. J., Zhang, Z., Zhang, H., Shang, R., Piekarz, K. M., Bi, P., et al. (2024). A change in cis-regulatory logic underlying obligate versus facultative muscle multinucleation in chordates. *Development* 151, dev202968. doi: 10.1242/dev.202968

Nanglu, K., Lerosey-Aubril, R., Weaver, J. C., and Ortega-Hernández, J. (2023). Mid-cambrian tunicate and the deep origin of the ascidiacean body plan. *Nat. Commun.* 14, 3832. doi: 10.1038/s41467-023-39012-4

Oda, I., and Satou, Y. (2025). A master regulatory loop that activates genes in a temporally coordinated manner in muscle cells of ascidian embryos. *Development* 152, dev204382. doi: 10.1242/dev.204382

Popsuj, S., Cohen, L., Ward, S., Lewis, A., Yoshida, S., Herrera, R. A., et al. (2024). CRISPR/cas9 protocols for disrupting gene function in the non-vertebrate chordate *Ciona*. *Integr. Comp. Biol.* 64, 1182–1193. doi: 10.1093/icb/icae108

Procaccini, G., Affinito, O., Toscano, F., and Sordino, P. (2011). "A new animal model for merging ecology and evolution," in *Evolutionary Biology – Concepts, Biodiversity, Macroevolution and Genome Evolution*. Ed. P. Pontarotti (Springer, Berlin, Heidelberg, Germany). doi: 10.1007/978-3-642-20763-1_

Ricci, L., Salmon, B., Olivier, C., Andreoni-Pham, R., Chaurasia, A., Alié, A., et al. (2022). The onset of whole-body regeneration in *Botryllus schlosseri*: morphological and molecular characterization. *Front. Cell Dev. Biol.* 10. doi: 10.3389/fcell.2022.843775

Sánchez-Serna, G., Badia-Ramentol, J., Bujosa, P., Ferrández-Roldán, A., Torres-Águila, N. P., Fabregà-Torrus, M., et al. (2025). Less, but more: new insights from appendicularians on chordate fgf evolution and the divergence of tunicate lifestyles. *Mol. Biol. Evol.* 42, msae260. doi: 10.1093/molbev/msae260

Todorov, L. G., Oonuma, K., Kusakabe, T. G., Levine, M. S., and Lemaire, L. A. (2024). Neural crest lineage in the protovertebrate model *Ciona*. *Nature* 635, 912–916. doi: 10.1038/s41586-024-08111-7

Walters, T. L., Gibson, D. M., and Frischer, M. E. (2019). Cultivation of the marine pelagic tunicate *Dolioletta gegenbauri* (Uljanin 1884) for experimental studies. *J. Vis. Exp.* 150, e59832. doi: 10.3791/59832