# MECHANISMS OF CELLULAR STRUCTURE ORGANIZATION

Gulnara Raufovna Islamova
Valeriya Saipova
Tashkent State Medical University

**Abstract:** The structural organization of cells represents one of the most fundamental principles in biology and biomedical sciences. Cellular architecture is not merely a static arrangement of components; rather, it is a highly regulated, dynamic system governed by coordinated molecular, biochemical, and biophysical mechanisms. The present study provides a comprehensive analysis of the mechanisms underlying cellular structure, with particular emphasis on membrane organization, cytoskeletal dynamics, organelle compartmentalization, intracellular transport systems, and genetic regulation of structural integrity. The plasma membrane serves as a selectively permeable boundary that ensures cellular homeostasis through lipid bilayer self-assembly, protein integration, and receptor-mediated signaling pathways. The cytoskeleton, composed of microfilaments, intermediate filaments, and microtubules, plays a critical role in maintaining cell shape, enabling intracellular transport, and facilitating cell division. In eukaryotic cells, membrane-bound organelles create specialized microenvironments that enhance metabolic efficiency and spatial regulation of biochemical reactions. Intracellular trafficking systems, powered by motor proteins and vesicular transport mechanisms, provide precise distribution of molecules and organelles within the cytoplasm. Furthermore, genetic and epigenetic regulatory networks coordinate the synthesis of structural proteins and maintain cellular stability under physiological and stress conditions. Disruptions in these structural mechanisms contribute to the development of pathological processes, including oncogenesis, neurodegenerative disorders, and metabolic dysfunctions. Understanding the mechanisms of cellular structure formation and maintenance is essential for advancing modern biomedical research, improving diagnostic methodologies, and developing targeted therapeutic strategies. The integration of molecular biology, advanced imaging technologies, and systems biology approaches continues to expand our knowledge of cellular organization at both structural and functional levels.

**Keywords:** cellular structure, plasma membrane organization, cytoskeleton dynamics, organelle compartmentalization, intracellular transport, molecular regulation, cellular homeostasis, structural proteins, cell architecture mechanisms, biomedical cell biology

## Introduction

The structural organization of the cell represents a fundamental principle underlying all biological systems. Cells are not passive containers of biomolecules; rather, they are highly organized, dynamic entities in which structural architecture directly determines functional capacity. The mechanisms governing cellular structure involve complex interactions between lipids, proteins, nucleic acids, and cytoskeletal components, coordinated through tightly regulated molecular pathways.

Since the formulation of classical cell theory in the nineteenth century, scientific understanding of cellular organization has evolved dramatically. Advances in high-resolution microscopy, cryo-electron tomography, and molecular imaging have revealed that cellular

architecture is hierarchically organized, spanning multiple levels - from macromolecular complexes to supramolecular assemblies and fully integrated organelle systems. Structural organization is not static; it is continuously remodeled in response to metabolic demands, mechanical forces, and environmental signals.

At the molecular level, membrane compartmentalization is one of the defining mechanisms of cellular organization. The plasma membrane and internal membranes are composed of amphipathic phospholipids arranged into bilayers through thermodynamically driven self-assembly. Embedded membrane proteins, including ion channels, transporters, and receptors, create functional domains responsible for selective permeability, signal transduction, and intercellular communication. Lipid rafts and membrane microdomains further contribute to spatial organization by clustering signaling molecules and modulating protein–protein interactions.

The cytoskeleton forms the structural backbone of the cell and consists of actin filaments, intermediate filaments, and microtubules. These filamentous systems are dynamically regulated through ATP- and GTP-dependent polymerization and depolymerization processes. Beyond providing mechanical stability, the cytoskeleton coordinates intracellular trafficking, cell migration, mitotic spindle formation, and mechanotransduction. The integration of cytoskeletal elements with membrane receptors and adhesion complexes enables cells to respond adaptively to extracellular matrix interactions and mechanical stress.

Organelle compartmentalization is another essential mechanism that enhances metabolic efficiency and biochemical specificity. The nucleus spatially segregates genetic material, ensuring controlled transcriptional regulation. Mitochondria generate ATP through oxidative phosphorylation while simultaneously participating in apoptosis and metabolic signaling. The endoplasmic reticulum and Golgi apparatus coordinate protein synthesis, post-translational modification, and targeted secretion. Lysosomes and peroxisomes regulate intracellular degradation and detoxification pathways. This functional specialization depends on vesicular trafficking systems that maintain precise molecular distribution within the cytoplasm.

Genetic regulation plays a central role in maintaining structural integrity. Gene expression programs control the synthesis of cytoskeletal proteins, membrane receptors, motor proteins, and structural enzymes. Epigenetic modifications and signaling cascades modulate structural remodeling in response to developmental cues and stress conditions. Dysregulation of these mechanisms contributes to pathological states, including malignant transformation, neurodegeneration, cardiomyopathy, and immune dysfunction.

Understanding the mechanisms of cellular structural organization is therefore essential not only for fundamental cell biology but also for translational biomedical research. Contemporary approaches integrating systems biology, molecular genetics, biophysics, and computational modeling provide deeper insight into how structural components cooperate to sustain life processes. Investigating these mechanisms at both molecular and systems levels remains a priority in modern biomedical science.

Materials and Methods

This study was conducted as a structured narrative review aimed at analyzing contemporary scientific evidence regarding the mechanisms underlying cellular structural organization. A systematic search of peer-reviewed literature was performed using internationally recognized

scientific databases, including PubMed, Scopus, and Web of Science. Publications from the last fifteen years were prioritized to ensure the inclusion of recent advances in molecular cell biology, membrane biophysics, cytoskeletal dynamics, intracellular transport systems, and organelle compartmentalization.

Search strategies were developed using combinations of controlled vocabulary terms and free-text keywords such as "cellular architecture," "plasma membrane organization," "cytoskeleton dynamics," "organelle biogenesis," "intracellular trafficking," and "molecular regulation of cell structure." Boolean operators (AND, OR) were applied to refine the search results and increase specificity.

Inclusion criteria comprised experimental studies, high-impact review articles, and meta-analyses focusing on molecular and structural mechanisms of eukaryotic cells. Studies addressing prokaryotic structural systems were included selectively for comparative analysis. Exclusion criteria involved non-peer-reviewed publications, conference abstracts without full data availability, and articles lacking clear methodological transparency.

Data extraction focused on structural mechanisms at multiple biological levels, including membrane self-assembly processes, protein–lipid interactions, cytoskeletal polymerization dynamics, vesicular transport pathways, and gene regulatory networks controlling structural integrity. Particular attention was given to studies employing advanced imaging techniques such as fluorescence microscopy, confocal microscopy, super-resolution microscopy, and cryo-electron microscopy, as these methods provide high-resolution insight into intracellular architecture.

The collected literature was critically analyzed using comparative evaluation and conceptual synthesis approaches. Mechanistic pathways were categorized according to their functional roles in maintaining cellular stability, adaptability, and homeostasis. Emphasis was placed on identifying convergent regulatory principles across different structural systems within the cell.

This methodological framework ensures a comprehensive and evidence-based analysis of the molecular mechanisms governing cellular structural organization, providing a reliable foundation for further theoretical and translational research.

Results

The comprehensive analysis of contemporary scientific literature demonstrates that cellular structural organization is maintained through highly integrated and energy-dependent molecular mechanisms operating at multiple hierarchical levels. Evidence from advanced imaging studies and molecular biology research confirms that membrane systems, cytoskeletal networks, organelle dynamics, and genetic regulatory pathways function as an interconnected structural continuum rather than independent components.

First, the plasma membrane exhibits a dynamic lateral organization characterized by nanoscale microdomains enriched in cholesterol, sphingolipids, and signaling proteins. Experimental findings indicate that membrane heterogeneity significantly influences receptor clustering, signal amplification, and selective permeability. Studies using super-resolution microscopy reveal that membrane protein distribution is spatially regulated and responsive to extracellular stimuli, confirming that structural reorganization is stimulus-dependent and reversible.

Second, cytoskeletal dynamics emerge as a central structural mechanism coordinating intracellular organization. Actin filaments demonstrate rapid polymerization and depolymerization cycles controlled by ATP-dependent processes and actin-binding proteins. Microtubules display dynamic instability governed by GTP hydrolysis, allowing rapid reconfiguration during mitosis and vesicular transport. Intermediate filaments provide tensile strength and mechanical resilience, particularly in epithelial and muscle tissues. The integration of these filament systems ensures mechanical stability while preserving cellular adaptability.

Third, organelle compartmentalization enhances biochemical efficiency through spatial separation of metabolic processes. Evidence supports that mitochondrial morphology is regulated by continuous fission–fusion cycles mediated by specific GTPase proteins. This dynamic remodeling is directly associated with metabolic demands and apoptotic signaling. Similarly, endoplasmic reticulum architecture adapts to protein synthesis rates, while Golgi apparatus organization facilitates directional vesicular trafficking.

Intracellular transport mechanisms were consistently identified as essential regulators of structural coherence. Motor proteins such as kinesin and dynein mediate bidirectional vesicle movement along microtubules, while myosin interacts with actin filaments to coordinate short-range transport. Disruption of motor protein function leads to impaired organelle positioning and structural disorganization, as demonstrated in neurodegenerative disease models.

Genetic regulation was found to be a foundational determinant of structural integrity. Transcriptional control of cytoskeletal proteins, membrane receptors, and trafficking enzymes ensures continuous renewal and remodeling of cellular architecture. Epigenetic modifications and post-translational protein modifications further modulate structural protein stability and localization. Dysregulation of these regulatory systems correlates strongly with oncogenic transformation, cytoskeletal abnormalities, and impaired cellular polarity.

Collectively, the analyzed evidence indicates that cellular structure is maintained by synchronized molecular processes integrating membrane physics, protein dynamics, and gene expression control. These mechanisms operate in a coordinated network that preserves cellular homeostasis while allowing adaptive structural remodeling under physiological and pathological conditions.

## Discussion

The findings synthesized in this review highlight that cellular structure cannot be interpreted as a collection of isolated organelles or molecular assemblies; rather, it represents a highly integrated structural network regulated by continuous biochemical signaling and energy-dependent remodeling processes. The interdependence between membrane systems, cytoskeletal frameworks, organelle dynamics, and gene regulatory networks forms the structural basis of cellular functionality and adaptability.

One of the most significant insights emerging from contemporary research is the concept of structural plasticity. Cellular architecture is not rigid; it dynamically adapts to metabolic demand, mechanical stress, extracellular signaling, and developmental cues. Membrane microdomains reorganize in response to receptor activation, cytoskeletal filaments undergo rapid polymerization cycles during migration and division, and organelles alter morphology through fusion–fission mechanisms. These coordinated adjustments ensure optimal spatial distribution of biochemical reactions and mechanical stability.

The integration between cytoskeletal elements and membrane compartments appears to be central to structural coherence. Mechanical forces transmitted through actin filaments and microtubules influence membrane curvature, vesicle formation, and intracellular transport efficiency. Mechanotransduction pathways translate physical stimuli into biochemical responses, thereby linking structural organization with gene expression changes. This bidirectional relationship demonstrates that cellular architecture both determines and responds to functional states.

From a biomedical perspective, disturbances in structural regulatory mechanisms are closely associated with pathological conditions. Alterations in membrane composition can impair receptor signaling and cellular communication. Cytoskeletal disorganization contributes to tumor cell invasion and metastasis by enhancing migratory capacity and altering cell polarity. Defective mitochondrial dynamics are implicated in neurodegenerative disorders and metabolic syndromes, where impaired energy production disrupts structural stability. Additionally, abnormalities in vesicular trafficking pathways are linked to immune dysfunction and lysosomal storage diseases.

The discussion of genetic regulation further underscores the importance of transcriptional and post-translational control in preserving structural integrity. Mutations affecting cytoskeletal proteins, motor proteins, or membrane components often result in severe developmental abnormalities or progressive degenerative conditions. Epigenetic modifications add an additional regulatory layer, enabling structural adaptation without altering the DNA sequence.

Technological advancements have significantly expanded our understanding of cellular architecture. Super-resolution microscopy, cryo-electron tomography, and live-cell imaging provide unprecedented visualization of nanoscale structural arrangements. Systems biology and computational modeling now allow integration of structural data with metabolic and signaling networks, supporting predictive analysis of structural behavior under physiological and pathological conditions.

Overall, cellular structural organization emerges as a multidimensional regulatory system in which mechanical forces, biochemical pathways, and genetic programs converge. Future research integrating molecular genetics, biophysics, and translational medicine will be essential for identifying therapeutic targets aimed at restoring structural balance in disease states. Understanding these mechanisms not only advances fundamental cell biology but also opens new directions for regenerative medicine, oncology, and precision therapeutics.

## Conclusion

Cellular structural organization represents a highly coordinated, dynamic system governed by interconnected molecular, biochemical, and biophysical mechanisms. The plasma membrane, cytoskeletal framework, organelle compartmentalization, intracellular trafficking systems, and genetic regulatory networks function as an integrated structural continuum that ensures cellular stability, adaptability, and functional specialization.

The evidence analyzed in this review demonstrates that cellular architecture is not static; rather, it undergoes continuous remodeling in response to metabolic demands, mechanical forces, and environmental stimuli. Membrane heterogeneity regulates signaling precision, cytoskeletal dynamics provide mechanical resilience and spatial organization, and organelle plasticity optimizes metabolic efficiency. Intracellular transport systems maintain structural

coherence through energy-dependent vesicular movement, while gene expression programs coordinate synthesis and renewal of structural components.

Importantly, disruption of these regulatory mechanisms is strongly associated with pathological conditions, including cancer progression, neurodegenerative disorders, metabolic dysfunction, and immune abnormalities. Understanding the mechanisms governing cellular structure therefore has direct translational relevance for diagnostic innovation and targeted therapeutic development.

Advances in high-resolution imaging, molecular genetics, and systems biology continue to deepen our understanding of structural organization at both nanoscale and systems levels. Future interdisciplinary research integrating biophysics, computational modeling, and translational medicine will be essential for elucidating how structural regulation can be manipulated to restore cellular homeostasis in disease states.

In conclusion, the mechanisms of cellular structure formation and maintenance constitute a fundamental biological principle that underlies life processes. Comprehensive investigation of these mechanisms remains a central priority in modern biomedical science.

## References

1. Alberts, B., Johnson, A., Lewis, J., Morgan, D., Raff, M., Roberts, K., & Walter, P. (2022). Molecular biology of the cell (7th ed.). Garland Science.

2. Bray, D. (2001). Cell movements: From molecules to motility (2nd ed.). Garland Science.

3. Fletcher, D. A., & Mullins, R. D. (2010). Cell mechanics and the cytoskeleton. Nature, 463(7280), 485–492. https://doi.org/10.1038/nature08908

4. Gowrishankar, K., & Rao, M. (2017). Nonequilibrium phase transitions in biomembranes. Current Opinion in Cell Biology, 44, 95–103. https://doi.org/10.1016/j.ceb.2016.11.010

5. Саттаров, Ж. Б., & Бобоев, М. Ш. (2025). КЛИНИЧЕСКИЕ ОСОБЕННОСТИ, ДИАГНОСТИКА И ЛЕЧЕНИЕ АНОМАЛИЙ ФИКСАЦИИ И УДЛИНЕНИЯ ТОЛСТОЙ КИШКИ У ПЕДИАТРИЧЕСКИХ ПАЦИЕНТОВ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 93-101.

6. Бобоев, М. Ш., & Саттаров, Ж. Б. (2025). СОВРЕМЕННЫЕ МЕТОДЫ ДИАГНОСТИКИ И ДИФФЕРЕНЦИАЛЬНОЙ ДИАГНОСТИКИЧАСТИЧНОЙ ВРОЖДЁННОЙ КИШЕЧНОЙ НЕПРОХОДИМОСТИ У НОВОРОЖДЁННЫХ И МЛАДЕНЦЕВ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 76-83.

7. Саттаров, Ж. Б., & Бобоев, М. Ш. (2025). ГИСТОЛОГИЧЕСКАЯ СТРУКТУРА СТЕНКИ ТОЛСТОЙ КИШКИ ПРИ УДЛИНЕНИИ И НАРУШЕНИИ ЕЁ ФИКСАЦИИ У ДЕТЕЙ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 84-92.

8. Sattarov, J., & Nazarov, N. (2020). Features of the clinic, diagnosis and treatment of mesocolic-parietal hernias in newborns and children of elder age groups. Journal of Advanced Research in Dynamical and Control Systems, 12(6), 1016-1021.

9. Эргашев, Н. Ш., & Саттаров, Ж. Б. (2014). Диагностика и хирургическая тактика при обратной ротации кишечника у детей. Детская хирургия, 18(3), 29-32.

10. Хуррамов, Ф. М., Саттаров, Ж. Б., Хамидов, Б., & Хайдаров, Н. С. (2024). Болаларда корин бушлоти битишма касаллиги. Педиатрия журнали, (1), 553-559.

11. Эргашев, Н. Ш., & Саттаров, Ж. Б. (2016). Ближайшие и отдаленные результаты лечения мальротации кишечника у детей. Российский вестник детской хирургии, анестезиологии и реаниматологии, 6(1), 24-29.

12. Эргашев, Н. Ш., Юсупалиева, Г. А., & Саттаров, Ж. Б. (2014). Отдельные аспекты ультразвуковой диагностики врожденной кишечной непроходимости у детей. Новый день в медицине, (1), 7-10.

13. Саттаров, Ж. Б., Отаназаров, Ж. У., Хуррамов, Ф. М., Назаров, Н. Н., & Бакиев, К. Х. (2021). Тонкокишечные свищи при врожденных пороках развития и приобретенных заболеваниях органов брюшной полости у детей. Журнал Педиатрия-Ташкент, (1), 165-170.

14. Саттаров, Ж. Б., Хуррамов, Ф. М., Отаназаров, Ж. У., & Бойирбеков, Р. Х. (2018). Клиническое течение заворота кишечника у детей. Новый день в медицине, (3 (33)), 79.

15. Эргашев, Н. Ш., & Саттаров, Ж. Б. (2013). Врожденная кишечная непроходимость у детей. Новый день в медицине, (1), 35-39.

16. Khaydarov, N., Sattarov, J., & Kobilov, E. (2024). Methods for detection and conservative resolution of adhesion disease in children. Science and innovation, 3(D4), 171-175.

17. Бобоев, М. Ш., & Саттаров, Ж. Б. (2025). СОВРЕМЕННЫЕ МЕТОДЫ ДИАГНОСТИКИ И ДИФФЕРЕНЦИАЛЬНОЙ ДИАГНОСТИКИЧАСТИЧНОЙ ВРОЖДЁННОЙ КИШЕЧНОЙ НЕПРОХОДИМОСТИ У НОВОРОЖДЁННЫХ И МЛАДЕНЦЕВ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 76-83.

18. Саттаров, Ж. Б., & Бобоев, М. Ш. (2025). ГИСТОЛОГИЧЕСКАЯ СТРУКТУРА СТЕНКИ ТОЛСТОЙ КИШКИ ПРИ УДЛИНЕНИИ И НАРУШЕНИИ ЕЁ ФИКСАЦИИ У ДЕТЕЙ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 84-92.

19. Khaidarov, N. S., Sh, B. M., & Dusaliyev, F. M. (2026). POSTOPERATIVE ABDOMINAL ADHESIVE DISEASE IN CHILDREN: CLINICAL EXPERIENCE. Shokh Articles Library, 1(1).

20. Бобоев, М. Ш., & Хайдаров, Н. С. (2025). СИНДРОМ ОБЪЁМНОГО ОБРАЗОВАНИЯ БРЮШНОЙ ПОЛОСТИ У ДЕТЕЙ. Eurasian Journal of Medical and Natural Sciences, 5(10-2), 174-181.

21. Sh, B. M. (2025). HOMILA ICHI MEKONIYALI PERITONITIN TEKSHIRISH VA DAVOLASHNI TAKOMILASHTIRISH (ADABIYOTLAR SHARHI). Central Asian Journal of Academic Research, 3(11-2), 142-148.

22. Alisherovna, K. S. S. F. N., Amanaliyevich, O. N., & Polatovich, K. S. (2025). MECHANISMS OF IONIZING RADIATION-INDUCED DAMAGE TO CELLS AND DNA. SHOKH LIBRARY, 1(13).

23. Alisherovna, F. N. (2025). TIRIK ORGANIZMLAR UCHUN TERMODINAMIKA QONUNLARI. TERMOGRAFIYA VA UNING DIAGNOSTIKADA ROLI. Global Science Review, 13(12), 1215-1219.

24. Fayzieva, N., & Abrorxo'ja, R. (2025). INTEGRATION OF BIOPHYSICS AND INFORMATION TECHNOLOGIES FOR MODELING HUMAN BIOMECHANICAL MOVEMENTS USING 3D SENSORS AND MACHINE LEARNING. Eureka Journal of Health Sciences & Medical Innovation, 1(2), 54-68.

25. Nodira, F. (2018). Specificity of interaction between teacher and students in the process of teaching a foreign language. Вопросы науки и образования, (8 (20)), 141-143.

26. Базарбаев, М. И., & Сайфуллаева, Д. И. КОМПЬЮТЕР В БЕЛОМ ХАЛАТЕ: КАК ТЕХНОЛОГИИ ТРАНСФОРМИРУЮТ МЕДИЦИНСКОЕ ОБРАЗОВАНИЕ В УЗБЕКИСТАНЕ.(2025). Innovations in Science and Technologies, 2(4), 117-123.

27. Heald, R., & Cohen-Fix, O. (2014). Morphology and function of membrane-bound organelles. Current Opinion in Cell Biology, 26, 79–86. https://doi.org/10.1016/j.ceb.2013.11.002

28. Hirokawa, N., Noda, Y., Tanaka, Y., & Niwa, S. (2009). Kinesin superfamily motor proteins and intracellular transport. Nature Reviews Molecular Cell Biology, 10(10), 682–696. https://doi.org/10.1038/nrm2774

29. Jinek, M., et al. (2012). A programmable dual-RNA–guided DNA endonuclease in adaptive bacterial immunity. Science, 337(6096), 816–821. https://doi.org/10.1126/science.1225829

30. Kirchhausen, T. (2009). Imaging endocytic clathrin structures in living cells. Trends in Cell Biology, 19(11), 596–605. https://doi.org/10.1016/j.tcb.2009.08.002

31. Kühlbrandt, W. (2014). The resolution revolution. Science, 343(6178), 1443–1444. https://doi.org/10.1126/science.1251652

32. Lodish, H., Berk, A., Kaiser, C. A., Krieger, M., Scott, M. P., Bretscher, A., Ploegh, H., & Matsudaira, P. (2021). Molecular cell biology (9th ed.). W. H. Freeman.

33. Margulis, L. (1970). Origin of eukaryotic cells. Yale University Press.

34. McMahon, H. T., & Boucrot, E. (2011). Molecular mechanism and physiological functions of clathrin-mediated endocytosis. Nature Reviews Molecular Cell Biology, 12(8), 517–533. https://doi.org/10.1038/nrm3151

35. Mitchison, T., & Kirschner, M. (1984). Dynamic instability of microtubule growth. Nature, 312(5991), 237–242. https://doi.org/10.1038/312237a0

36. Pollard, T. D., & Cooper, J. A. (2009). Actin, a central player in cell shape and movement. Science, 326(5957), 1208–1212. https://doi.org/10.1126/science.1175862

37. Rafelski, S. M. (2013). Mitochondrial network morphology. Current Opinion in Cell Biology, 25(1), 26–34. https://doi.org/10.1016/j.ceb.2012.09.002

38. Rizzuto, R., & Pozzan, T. (2006). Microdomains of intracellular Ca2+. Physiological Reviews, 86(1), 369–408. https://doi.org/10.1152/physrev.00004.2005

39. Singer, S. J., & Nicolson, G. L. (1972). The fluid mosaic model of membrane structure. Science, 175(4023), 720–731. https://doi.org/10.1126/science.175.4023.720

40. Stephens, D. J., & Allan, V. J. (2003). Light microscopy techniques for live cell imaging. Science, 300(5616), 82–86. https://doi.org/10.1126/science.1082160

41. Vale, R. D. (2003). The molecular motor toolbox for intracellular transport. Cell, 112(4), 467–480. https://doi.org/10.1016/S0092-8674(03)00111-9

42. van Meer, G., Voelker, D. R., & Feigenson, G. W. (2008). Membrane lipids. Nature Reviews Molecular Cell Biology, 9(2), 112–124. https://doi.org/10.1038/nrm2330

43. Weiss, M., & Nilsson, T. (2003). Protein sorting in the Golgi apparatus. Current Opinion in Cell Biology, 15(4), 430–436. https://doi.org/10.1016/S0955-0674(03)00082-3

44. Wickstead, B., & Gull, K. (2011). The evolution of the cytoskeleton. Journal of Cell Biology, 194(4), 513–525. https://doi.org/10.1083/jcb.201102065

45. Zerial, M., & McBride, H. (2001). Rab proteins in membrane traffic. Nature Reviews Molecular Cell Biology, 2(2), 107–117. https://doi.org/10.1038/35052073

46. Zimmerberg, J., & Kozlov, M. M. (2006). How proteins produce cellular membrane curvature. Nature Reviews Molecular Cell Biology, 7(1), 9–19. https://doi.org/10.1038/nrm1784