

## Biological Functions of Complex Lipids Revealed Through Integrated Omics Technologies

Irina Petrova\*

Laboratory of Functional Omics and Metabolic Networks, Northern Biomedical Research Center, Novosibirsk, Russia

### DESCRIPTION

Complex lipids are essential biomolecules that play critical roles in maintaining cellular structure, regulating metabolic activities and controlling signaling networks within living organisms. Unlike simple lipids that mainly serve as energy reserves, complex lipids contain additional functional groups such as carbohydrates, phosphates, or nitrogen-containing moieties that enable them to participate in diverse biological processes. Advances in integrated omics technologies have significantly expanded scientific understanding of the biological functions of complex lipids by allowing comprehensive analysis of lipid composition, biosynthesis, regulation and interaction with other biomolecules. Through the combined application of genomics, transcriptomics, proteomics, glycomics and lipidomics, researchers are now able to uncover the multifaceted roles of complex lipids in cellular physiology and disease mechanisms.

One of the most fundamental biological functions of complex lipids is their contribution to cellular membrane architecture. Phospholipids, glycolipids and sphingolipids collectively form the lipid bilayer that defines cell boundaries and compartmentalizes intracellular organelles. Integrated omics approaches have revealed that the precise composition of complex lipids within membranes is tightly regulated and varies according to cell type, developmental stage and environmental conditions. Genomic and transcriptomic analyses help identify genes responsible for lipid biosynthesis and modification, while lipidomic profiling provides detailed information on lipid species distribution. Together, these technologies demonstrate how variations in complex lipid composition influence membrane fluidity, permeability and curvature, thereby affecting essential cellular processes such as transport, division and communication.

Complex lipids also play a central role in cellular signaling pathways. Certain lipid species function as signaling molecules or as platforms that organize signaling proteins within membranes. Integrated omics studies have shown that sphingolipids and phosphoinositides are key regulators of signal transduction pathways that control cell growth, differentiation,

survival and programmed cell death. Proteomic analyses reveal how lipid-binding proteins interact with specific lipid species, while lipidomics identifies changes in lipid signaling molecules in response to external stimuli. This integrative approach has clarified how complex lipids act as dynamic regulators rather than passive structural components, allowing cells to rapidly adapt to changing physiological conditions.

Another important biological function of complex lipids is their involvement in energy metabolism and metabolic regulation. While neutral lipids primarily store energy, complex lipids regulate metabolic pathways by influencing enzyme activity, organelle function and intracellular signaling. Integrated omics technologies enable the simultaneous analysis of lipid metabolism genes, enzyme expression levels and lipid intermediates. This comprehensive view has revealed that alterations in complex lipid metabolism can disrupt cellular energy balance and contribute to metabolic disorders. For example, changes in phospholipid and sphingolipid composition have been linked to insulin resistance, obesity and cardiovascular diseases, highlighting the importance of lipid homeostasis in maintaining metabolic health.

Complex lipids are also essential for cell recognition, adhesion and immune responses. Glycolipids located on the outer surface of the plasma membrane participate in cell cell interactions and serve as recognition markers for immune cells. Glycomics combined with lipidomics has revealed the structural diversity of glycolipids and their specific roles in immune signaling and pathogen recognition. Integrated omics studies have shown that immune cell activation is accompanied by dynamic remodeling of membrane lipid composition, which influences receptor clustering and signal initiation. These findings demonstrate how complex lipids contribute to the regulation of innate and adaptive immune responses.

In the nervous system, complex lipids are particularly abundant and perform specialized biological functions. Sphingolipids and glycolipids are major components of myelin sheaths and synaptic membranes, where they support nerve impulse transmission and synaptic plasticity. Integrated omics technologies have enabled detailed analysis of lipid composition in neural tissues and have

**Correspondence to:** Irina Petrova, Laboratory of Functional Omics and Metabolic Networks, Northern Biomedical Research Center, Novosibirsk, Russia, E-mail: irina.petrova@nbr.ru

**Received:** 01-Sep-2025, Manuscript No JGL-25-40769; **Editor assigned:** 03-Sep-2025, PreQC No. JGL-25-40769 (PQ); **Reviewed:** 17-Sep-2025, QC No. JGL-25-40769; **Revised:** 24-Sep-2025, Manuscript No. JGL-25-40769 (R); **Published:** 01-Oct-2025, DOI: 10.35248/2153-0637.24.14.417

**Citation:** Petrova I (2025) Functional Roles of Glycomics and Lipidomics in Cellular Signaling Pathways, J Glycomics Lipidomics 14:417

**Copyright:** © Petrova I 2025. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

identified lipid alterations associated with neurological disorders. Genomic and lipidomic studies have linked defects in complex lipid metabolism to neurodegenerative diseases, emphasizing the importance of lipid balance for neuronal survival and function.

Integrated omics approaches have also advanced the understanding of complex lipid involvement in disease development and progression. By combining data from multiple omics layers, researchers can identify lipid based biomarkers and therapeutic targets with greater accuracy. For instance, cancer studies using integrated omics have revealed that tumor cells often exhibit distinct lipid profiles that support rapid growth, resistance to cell death and metastatic potential. These discoveries highlight the potential of complex lipids as diagnostic indicators and as targets for novel therapeutic strategies.

## CONCLUSION

In conclusion, integrated omics technologies have transformed the study of complex lipids by providing a comprehensive and systems level understanding of their biological functions. Through the integration of genomic, transcriptomic, proteomic, glycomic and lipidomic data, scientists have uncovered the critical roles of complex lipids in membrane organization, signaling, metabolism, immunity, neural function and disease. This holistic perspective emphasizes that complex lipids are dynamic and multifunctional molecules essential for cellular homeostasis. Continued advancements in integrated omics methodologies will further deepen insight into lipid biology and support the development of innovative approaches for disease diagnosis and treatment.