NETWORK PHARMACOLOGY:

Mapping the Future of Multi-Target Drug Discovery

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Drug discovery has rapidly evolved beyond the traditional paradigm. This has shifted researchers' perspectives from a single "magic bullet" towards a "multi-target bullet", as a single-target approach may no longer be sufficient for complex diseases such as cancer, diabetes, cardiovascular disorders, neurodegenerative diseases and chronic inflammatory conditions. These diseases involve interconnected molecular networks, signalling pathways and regulatory mechanisms and are rarely driven by a single gene or protein alone. Through network pharmacology, researchers can discover and map the potential of compounds to interact with multiple molecular targets and disease-related signalling pathways. This systems-based approach reflects the complex and wide-ranging nature of the human biological system.

In brief: Network pharmacology uses big data, graph theory and computational models to help researchers understand how bioactive compounds interact with multiple targets and pathways, thereby informing drug discovery and elucidating therapeutic mechanisms.

WHAT IS NETWORK PHARMACOLOGY?

Network pharmacology is an interdisciplinary approach that combines pharmacology, systems biology, bioinformatics and computational modelling. It examines interactions among compounds, molecular targets, signalling pathways and disease mechanisms, rather than focusing on a one-to-one relationship between compounds and targets.

In contemporary pharmacy research, this approach is valuable, as therapeutic effects often involve complex interactions across biological systems. To maintain normal physiology, proteins interact with one another, genes regulate cellular responses and signalling pathways communicate with one another. However, these networks may be disrupted when disease occurs. Therefore, a compound that influences multiple relevant targets or pathways may offer broader pharmacological potential than one acting on a single target.

APPLICATIONS IN NATURAL PRODUCT AND MEDICINAL PLANT RESEARCH

Secondary metabolites of plants, such as flavonoids, alkaloids, phenolic acids, terpenoids and tannins, can influence molecular targets in various ways, either individually or collectively. Using network pharmacology, medicinal plants such as *Acalypha indica* (kucing galak) and *Persicaria minor* (kesum) (Figure 1), which contain diverse phytochemicals, can be investigated for potential associations with multiple molecular targets and biological pathways.

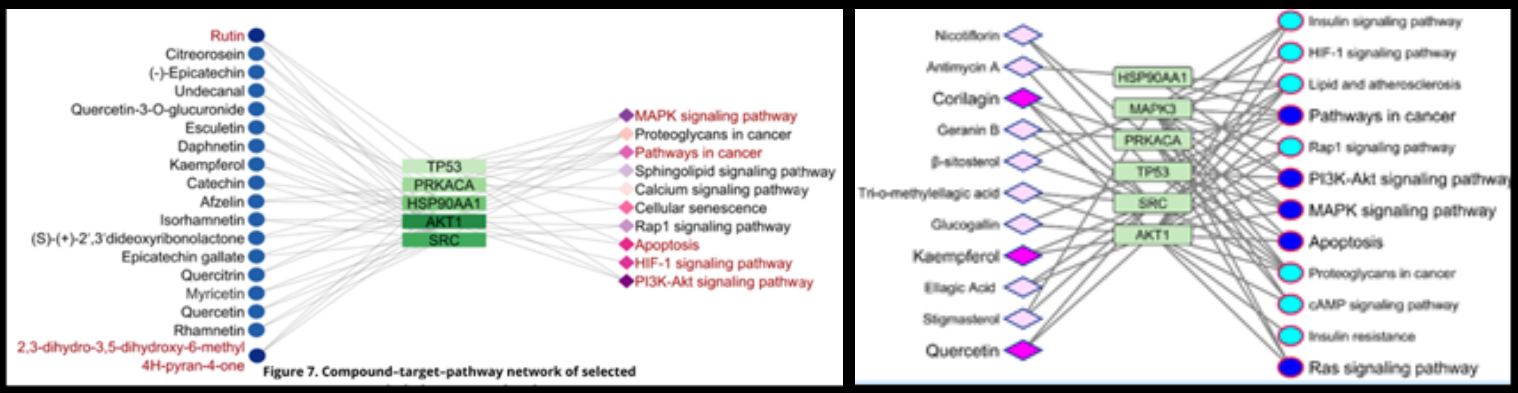

Figure 1. Examples of medicinal plants used in network pharmacology-based natural product research: (a) *Acalypha indica* and (b) *Persicaria minor.*

GENERAL NETWORK PHARMACOLOGY WORKFLOW

The overall workflow of network pharmacology is illustrated in Figure 2. The workflow begins with the identification of bioactive compounds from phytochemical databases, published literature, or analytical platforms such as liquid chromatography- mass spectrometry. Potential molecular targets are then predicted using computational tools, while disease-associated genes or proteins are identified from established biological databases. Overlapping targets between compounds and diseases may indicate potential points of pharmacological relevance.

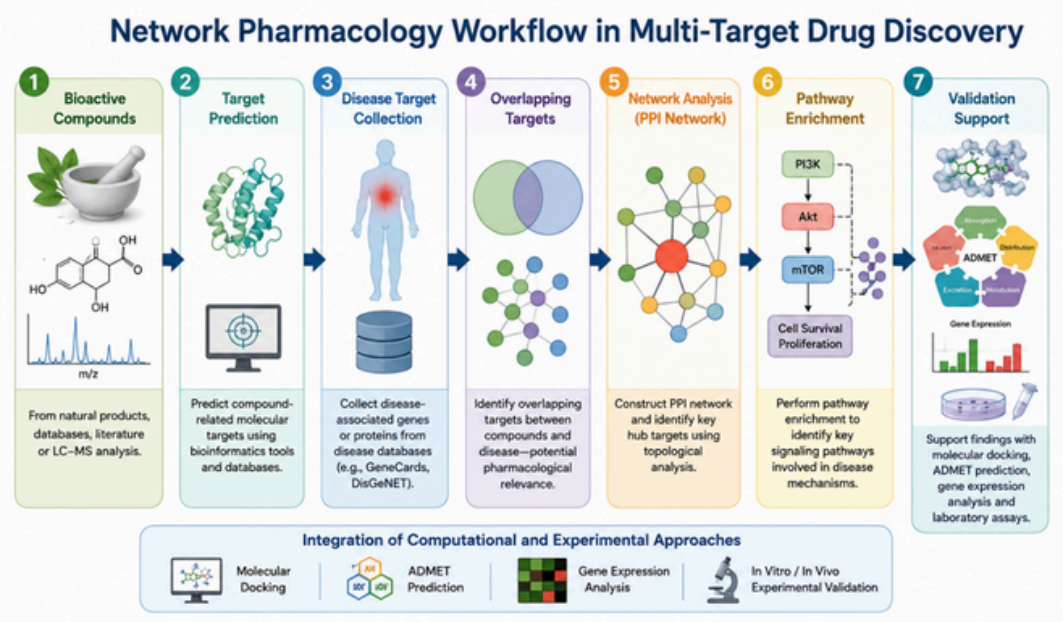

Figure 2. Conceptual workflow of network pharmacology in multi-target drug discovery.

Subsequently, network analysis prioritises key hub proteins, whereas pathway enrichment analysis identifies the biological pathways most strongly associated with the predicted targets. In cancer research, hallmark pathways may include PI3K–Akt signalling, MAPK signalling, apoptosis, p53 signalling, oestrogen signalling and cell-cycle regulation. Molecular docking, absorption, distribution, metabolism, excretion and toxicity (ADMET) prediction, gene expression analysis and laboratory validation provide further support for the proposed mechanisms.

Despite its value, network pharmacology should be viewed as a hypothesis-generating approach rather than definitive experimental proof because its findings rely on database quality, predictive models and input data. It focuses on prioritising compounds, targets and pathways for further study. With validation, researchers can narrow down from large datasets into targeted, evidence-driven experiments.

STRENGTHENING RESEARCH TRAINING IN THE FACULTY

For the Faculty of Pharmacy, network pharmacology is highly relevant to areas such as drug discovery, natural product research, computational biology, precision medicine and translational pharmaceutical sciences. It provides a useful platform for undergraduate and internship students to connect bioactive compounds, molecular targets and disease pathways using publicly accessible databases and computational tools. Additionally, postgraduate students could expand their studies by incorporating programming and engaging in experimental research.

Such exposure supports interdisciplinary learning and gives students the opportunity to understand how complex biological data can be translated into testable scientific explanations.

CONCLUSION

Network pharmacology provides an effective approach to understanding complex disease mechanisms and multiple therapeutic targets. Connecting compounds, targets, pathways and diseases offers a comprehensive perspective on pharmacological actions. As pharmaceutical research advances through data-driven techniques, network pharmacology remains an important approach for identifying and exploring new treatment options.

FURTHER READING

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