Biobanks and Their Importance in Biomedical Research

Presented by

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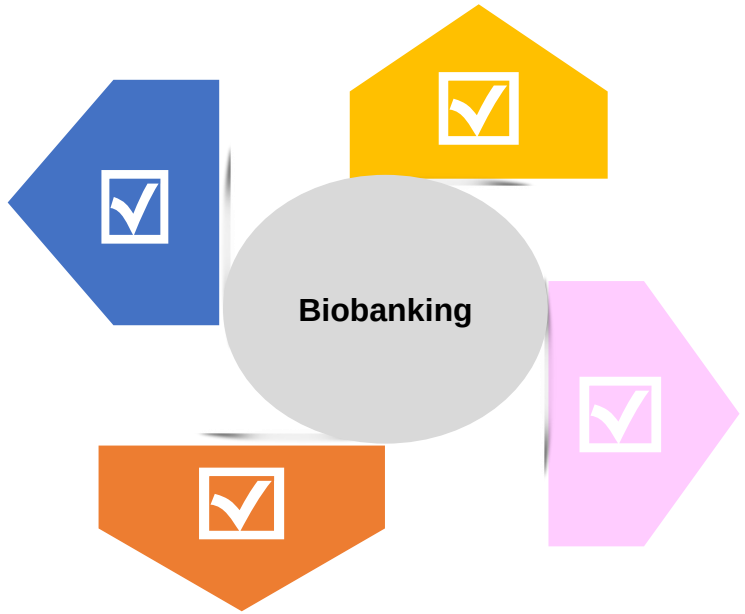
Outlines:

- Biobanking and Biomedical Research
- Biobanks and Fundamental Biology
- Biobanks and Omics
- Biobanks and Time-Series Studies
- Biobanks in Precision Medicine

Why Biobanking Is Essential for Biomedical Research

Building a Standardized Infrastructure for Large-Scale Research

Reducing Sampling Error & Increasing Reproducibility



Supplying Reliable Samples for Molecular Analyses

Enabling Evidence-Based Research

Building a Standardized Infrastructure for Large-Scale Research

- Biobanks provide a **regulated**, **centralized infrastructure** for collecting, storing, and managing biological samples. These infrastructures ensure that biospecimens are handled under consistent, high-quality conditions.

- Such standardization reduces variability arising from pre-analytical handling (collection, transport, storage), which is critical for large-scale molecular studies.

Supplying Reliable Samples for Molecular Analyses

- Biobanks curate high-quality, well-annotated biospecimens (e.g., blood, tissue, DNA/RNA) that are linked with rich clinical and demographic data.

- Quality control is fundamental: by following best practices and international guidelines, biobanks can guarantee that molecular profiles truly reflect the in vivo state.

- Because biobanks are designed for **long-term storage and standardized retrieval**, they support reproducible molecular analyses, as sample degradation and handling bias can be minimized.

Enabling Evidence-Based Research (Design of Studies Based on Real Data)

- Biobanks, especially those linked to electronic health records (EHRs), enable researchers to perform hypothesis-generating studies. Instead of designing studies from scratch, researchers can use existing biobank resources to explore associations in a data-driven way.

- This “evidence-based” approach accelerates discovery: large cohorts permit retrospective and prospective analyses without the full cost and time of de novo sample collection.

- By combining molecular data with longitudinal clinical data, biobanks support precision medicine research — enabling tailored interventions based on real-world evidence.

Reducing Sampling Error & Increasing Reproducibility

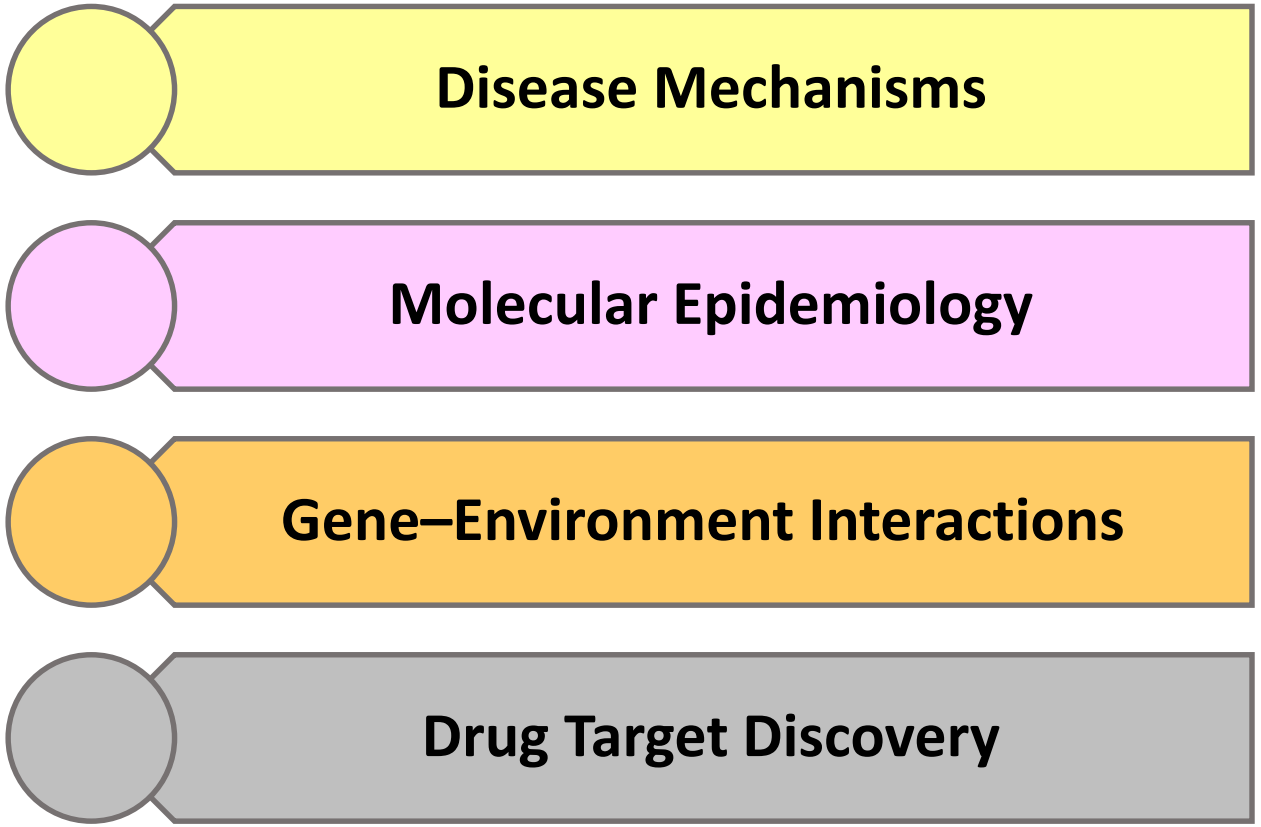
- One major challenge in biomedical research is **variability** and **bias** introduced by small, poorly controlled sample sets. Biobanks mitigate this by providing **large**, **diverse,** and **well-characterized samples**, which **lowers random sampling error.**

- **Standardized biobank protocols** (for collection, storage, retrieval) **enhance reproducibility** across studies because different researchers use samples processed under the same conditions.

- Moreover, biobanks often adhere to **quality management systems and accreditation**, which helps ensure consistent sample integrity and traceability over time.

- large-scale biobank-based studies have **statistical power** to detect subtle effects, **reducing false positives and improving the reliability of scientific findings**.

Biobanks and Fundamental Biology



Disease Mechanisms

- **Biobanks as a window into molecular pathophysiology**
- **Large-scale genetic discoveries**
- **Network medicine approach**

Molecular Epidemiology

- **Biobanks empower epidemiological research**
- **Longitudinal and phenotypic richness**
- **Population-scale statistical power**

Gene–Environment Interactions

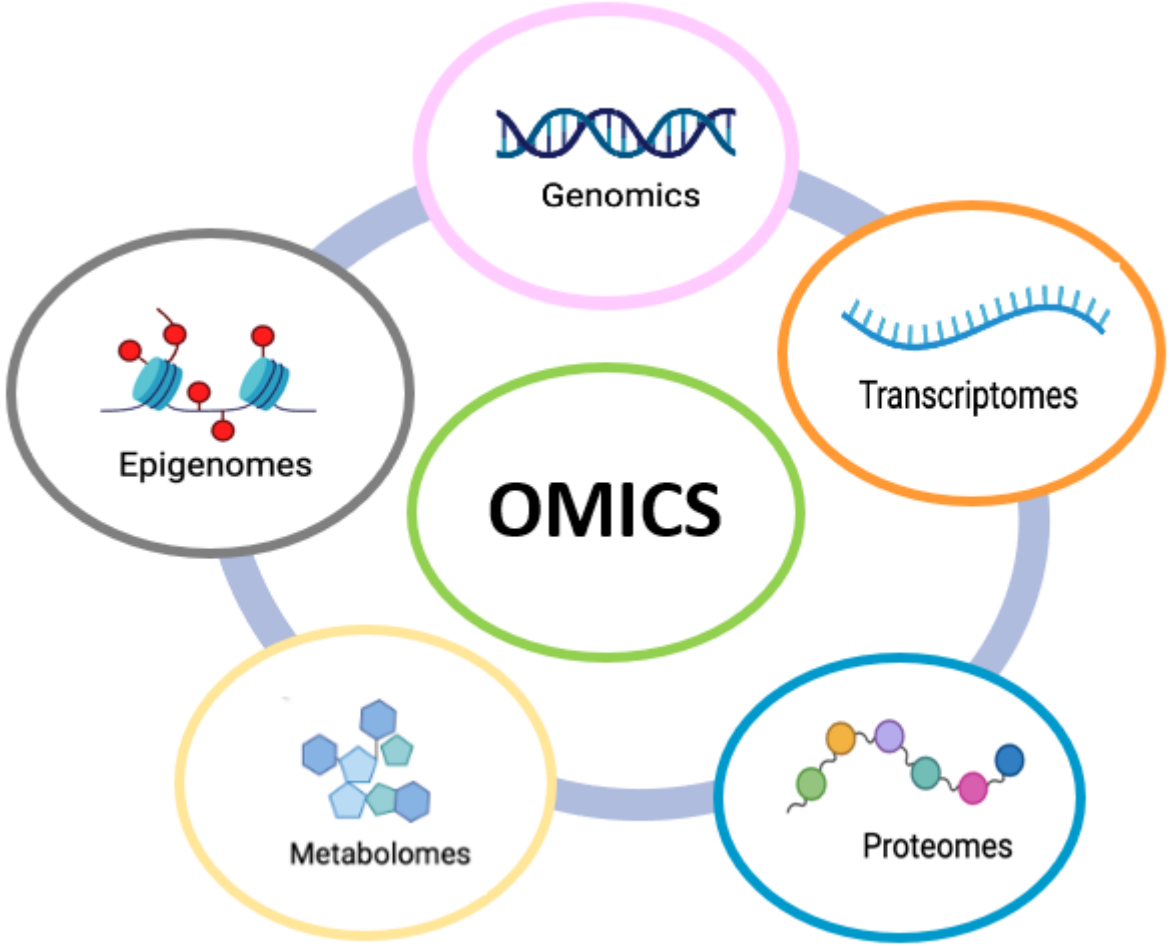
- How the environment modifies genetic effects
- Framework for precision medicine
- Uncovering G×E at a large scale

Drug Target Discovery

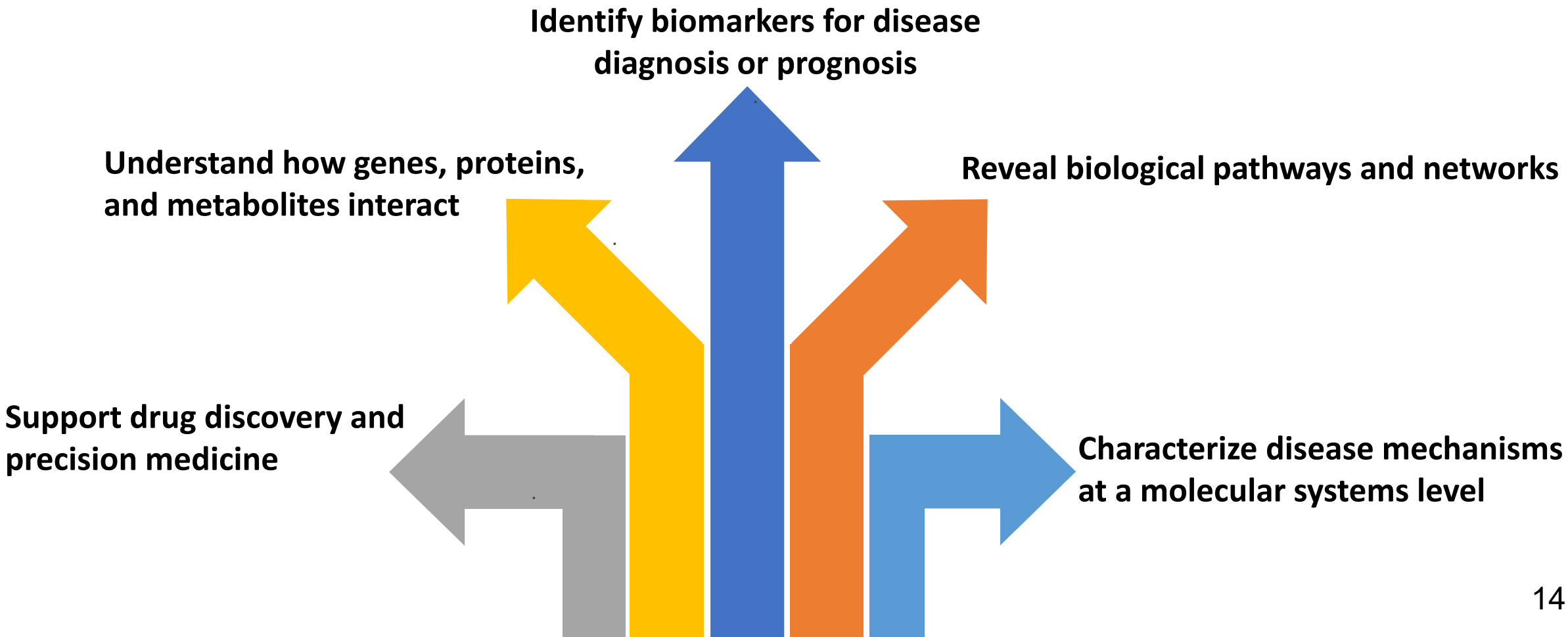
- **Biobanks as a resource for target identification**
- **Pharmacogenetics and drug response**

Biobanking and Omics

Omics refers to a group of large-scale biological research approaches that systematically analyze the complete set of molecules within a cell, tissue, or organism.



What Omics Studies Aim to Do



Why Omics Without Biobanking Is Incomplete

- **Need for a Large Number of Samples for Analyses**
- **Need for High-Quality, Fresh, and Standardized Samples**
- **Capability for Comparisons Across Populations**

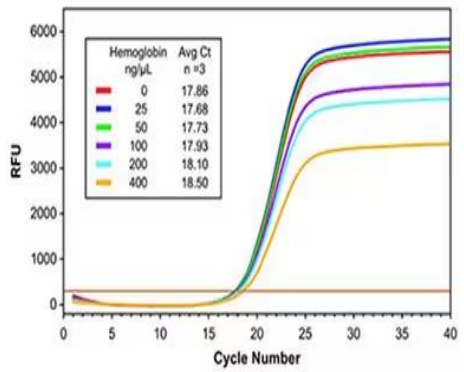
Genomics

Whole Genome Sequencing (WGS)

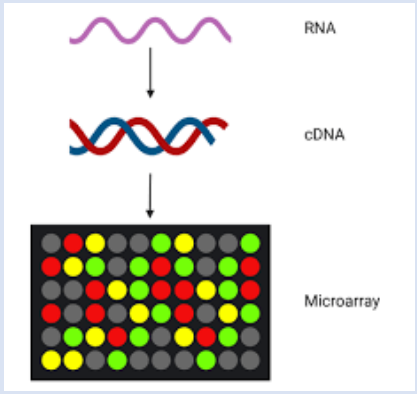
Whole Exome Sequencing (WES)

Transcriptomics

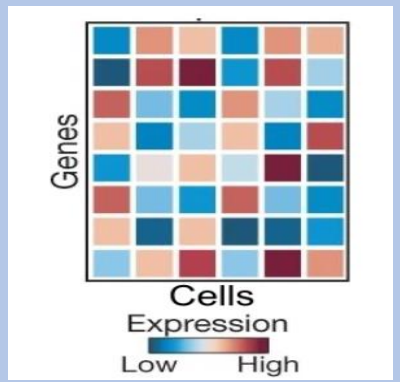
q-RT PCR



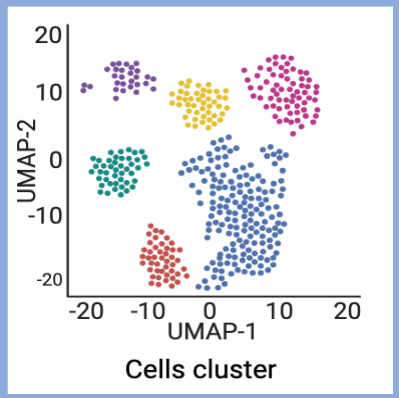
Microarray



Bulk RNA-seq



Single cell RNA-seq

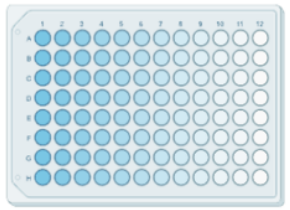


Proteomics

1 Purification

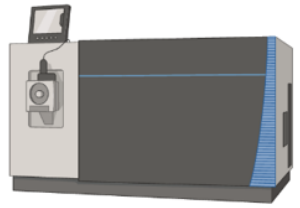
- Chromatography-based techniques

2 Detection



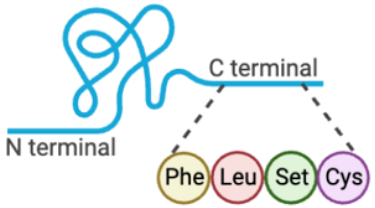
- ELISA
- Western blotting
- Protein microarray

3 Characterization



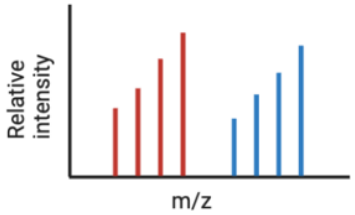
- Gel-based approaches
- Mass spectrometry

4 Sequence analysis



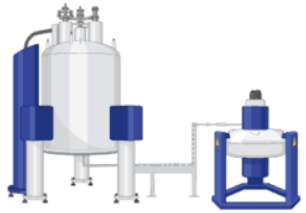
- Edman sequencing

5 Quantification



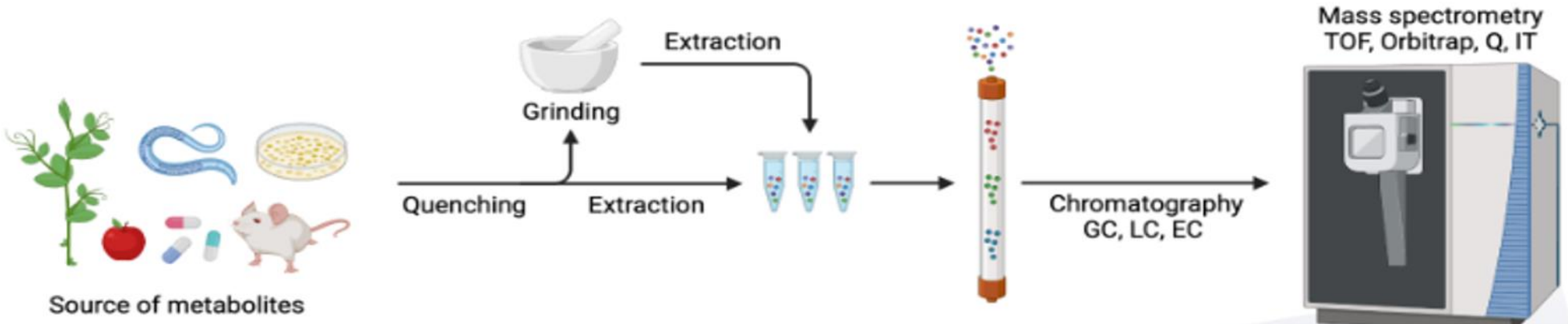
- ICAT
- SILAC
- iTRAQ

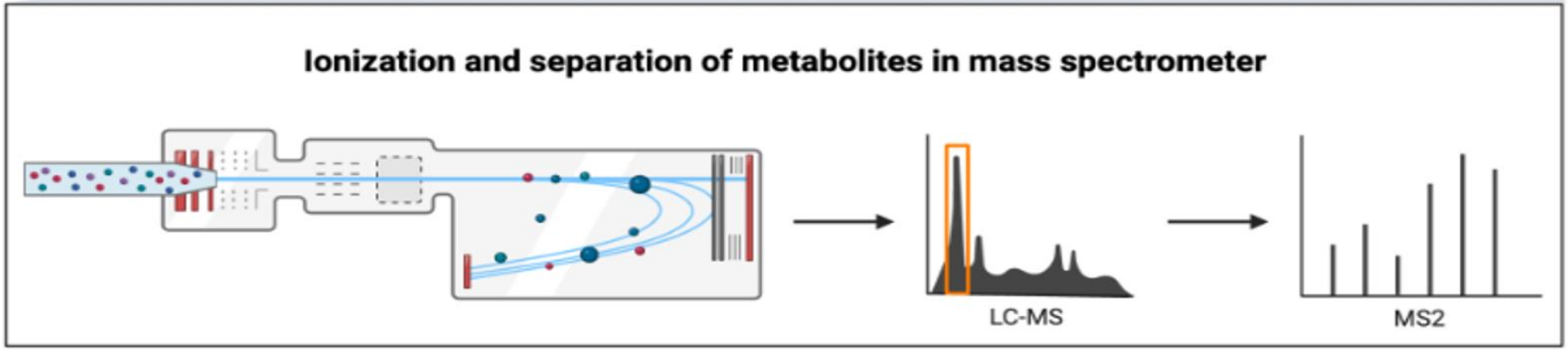
6 Structural analysis



- X-ray crystallography
- NMR spectroscopy

Metabolomics





Biobanks and Time-Series Studies

Time-series omics refers to **longitudinal sampling** and **multi-omics profiling** across **different time points** to monitor dynamic biological processes.

Such studies provide insights into disease evolution, treatment responses, and temporal biomarker discovery. **Biobanks** are essential for generating high-quality longitudinal datasets by standardizing the collection, processing, and storage of serial samples.

- **Longitudinal Time-Series Studies**
- **Interrupted Time-Series (ITS) Studies**
- **Multi-Omics Time-Series Studies**
- **Single-Subject (N-of-1) Time-Series Studies**
- **Epidemiological Time-Series Studies**
- **Clinical Monitoring Time-Series Studies**

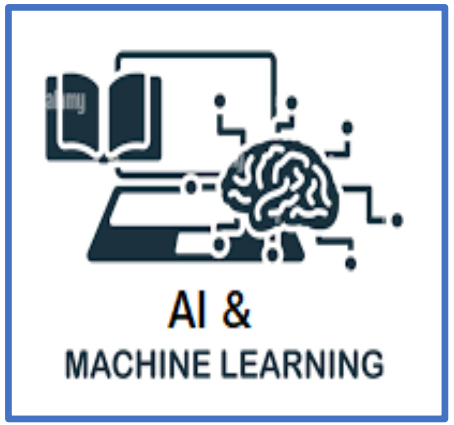
Time-Series Omics Studies

Dynamic disease analysis	**Provides serial, high-quality biospecimens for temporal molecular profiling**
Treatment response analysis	**Ensures technical consistency for detecting therapy-induced molecular changes**
Disease progression modelling	**Offers longitudinal cohorts with standardized sampling for robust computational modelling**
Time-dependent biomarker discovery	**Enables accurate temporal annotation and preservation of sensitive biomolecules**

Multi-omics Integration

Each distinct omics method provides information about a different but incomplete aspect of the internal state of the cell. Joint analysis of two or more omics methods provides more comprehensive insight into key factors that can be used for classification or prediction and or serve as potential biomarkers or drug targets.

Using AI for Integrating Multi-Layer Omics Data



Biobanks in Generating Large Datasets for Machine Learning

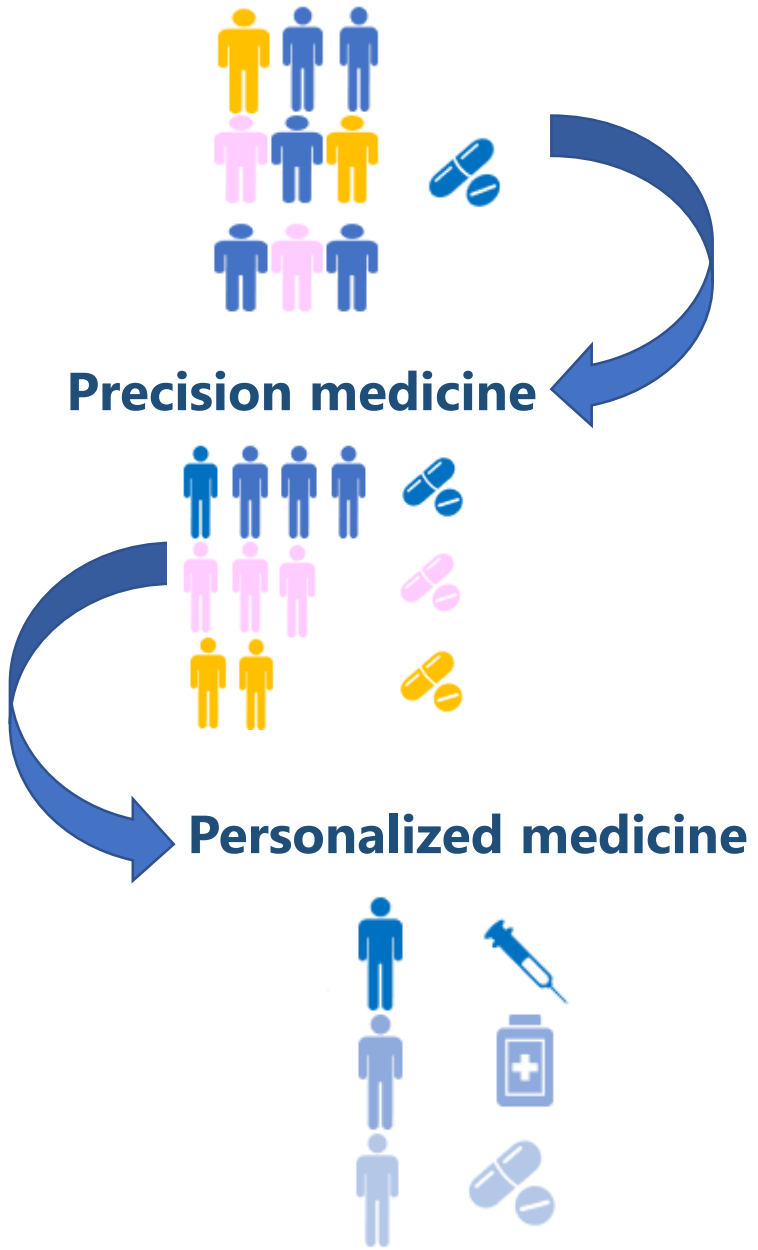
Biobanks in Generating Large Datasets for Machine Learning

- Biobanks (especially large population biobanks) are a critical source of **high-quality**, **deeply phenotyped samples**, enabling the creation of **massive multi-omics datasets** that are necessary for training robust AI models.
- These biobank-derived datasets enhance ML model performance in disease prediction, patient stratification, and biomarker discovery.
- From a methodological perspective, as the volume and complexity of multi-omics data increase, biobanks provide the **“fuel”** needed for AI frameworks to scale, generalize, and find clinically meaningful patterns.

Biobanks in Precision Medicine

Precision medicine

Personalized medicine



Precision Medicine

Predict the risk of developing diseases based on molecular data

Predict which patients will respond to which treatments

Diagnose the disease at a very early stage

Prevent wrong or ineffective drugs

Genomics

Transcriptomes

Proteomes

Epigenomes

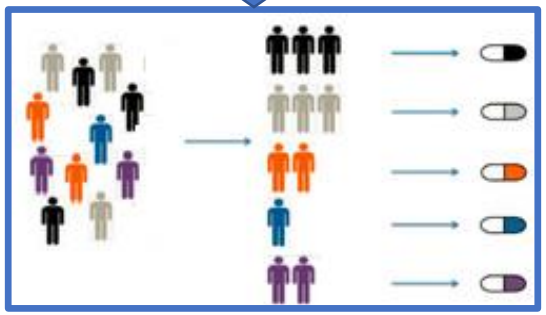
Metabolomes

Clinical information

AI &
MACHINE LEARNING

Identification of:

- **Diagnostic or prognostic biomarkers**
- **Signatures**
- **Networks**
- **New potential targets**




THANK YOU
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ATTENTION