Table S1. Molecular Markers and Enabling Technologies

Marker Class	Specific Marker Types	Biological Level	What They Capture	Key Technologies	Typical Applications
DNA (Genetic)	SNPs, STRs, InDels, CNVs, SVs	Genome	Inherited sequence variation	PCR, SNP arrays, WGS/WES, Long-read sequencing	GWAS, population genetics, forensics, disease risk
Epigenetic	DNA methylation, histone modifications	Chromatin	Gene regulation & environment effects	Bisulfite-seq, ChIP-seq, ATAC-seq, Nanopore epigenomics	Cancer diagnostics, aging clocks, exposure studies
RNA (Transcriptomic)	mRNA, miRNA, lncRNA, circRNA	Transcriptome	Gene expression & regulation	RNA-seq, scRNA-seq, spatial transcriptomics	Disease subtyping, biomarker discovery, drug response
Protein (Proteomic)	Enzymes, receptors, cytokines	Proteome	Functional cellular machinery	LC-MS/MS, DIA-MS, ELISA, CyTOF	Clinical diagnostics, pathway analysis, therapeutics
Metabolite	Lipids, sugars, amino acids	Metabolome	Real-time cellular physiology	GC-MS, LC-MS, NMR spectroscopy	Disease phenotyping, nutrition, toxicology
Cellular Phenotype	Cell surface markers, morphology	Cell	Cell identity & state	Flow cytometry, imaging cytometry, AI microscopy	Immunophenotyping, cancer heterogeneity
Spatial Markers	RNA/protein localization	Tissue	Molecular context & architecture	Spatial transcriptomics, MERFISH, IMC	Tumor microenvironment, brain mapping
Functional Markers	Gene perturbation effects	System	Causality & gene function	CRISPR screens, RNAi, base editing	Target discovery, functional validation
Circulating Markers	ctDNA, cfRNA, exosomes	Biofluids	Disease signals in circulation	Liquid biopsy, digital PCR, NGS	Early detection, minimal residual disease

https://doi.org/10.3390/d18040208