Electron Microscopy: Quick Reference Guide

Why Electron Microscopy Matters

Light microscopes are limited to ~0.2 µm resolution, leaving viruses (20–300 nm) and ribosomes (~25 nm) invisible. Electron microscopy (EM) uses high-energy electrons to achieve sub-nanometer resolution, transforming biology, medicine, and materials science.

Key Principles

• Electron Gun: Generates high-energy electrons. • Electromagnetic Lenses: Focus the beam using magnetic fields. • Vacuum System: Prevents electron scattering. • Detectors: Capture signals to form images.

Types of EM

• TEM: Transmits electrons through thin specimens; <1 nm resolution; reveals organelles, viruses, chromatin. • SEM: Scans surfaces; 3D topography; useful for pollen, insect exoskeletons, nanomaterials. • Cryo-EM: Freezes specimens to preserve native structures; enabled near-atomic resolution of proteins and viral structures.

Specimen Preparation

Fixation (glutaraldehyde, osmium tetroxide), dehydration, embedding, ultrathin sectioning (for TEM), heavy metal staining, and sputter-coating (for SEM). Preparation is time-intensive but critical for clarity.

Advantages

• Unmatched resolution (sub-nanometer). • Reveals ultrastructural and surface detail. • Versatile across biology, medicine, and nanotechnology.

Limitations

• Expensive equipment and maintenance. • Complex specimen prep; generally cannot image live cells. • Requires expertise and careful handling.

Applications

• Biology: Organelles, cytoskeleton, chromatin. • Virology: Virus morphology (HIV, SARS-CoV-2). • Medicine: Kidney ultrastructure, tumors, pathology. • Nanotechnology: Nanoparticles, polymers, semiconductors.

Future Directions

Advances include cryo-EM, in-situ EM for dynamic imaging, and AI-assisted image reconstruction, making EM increasingly powerful and indispensable.