Electron Microscopy – Question Bank with Answer Key

Short Answer Questions (2–3 marks each)

1. Define the principle of electron microscopy. (Remembering)

   Answer: Electron microscopy works by using a beam of high-energy electrons, which have much shorter wavelengths than visible light, to achieve higher resolution imaging of specimens.

2. Differentiate between photons and electrons as illumination sources in microscopy. (Understanding)

   Answer: Photons are particles of light with wavelengths of 400–700 nm, limiting resolution to ~200 nm. Electrons behave as waves with sub-nanometer wavelengths, enabling nanometer to atomic resolution.

3. State the typical resolution limit of a light microscope. (Remembering)

   Answer: Approximately 0.2 µm (200 nm).

4. Mention two applications of transmission electron microscopy (TEM) in biology. (Understanding)

   Answer: Studying virus morphology and visualizing cell organelles such as mitochondria or Golgi apparatus.

5. Why is a vacuum environment necessary in electron microscopy? (Understanding)

   Answer: To prevent electrons from scattering in air, ensuring a coherent and focused electron beam.

6. List two advantages of cryo-electron microscopy. (Applying)

   Answer: Preserves native structure without chemical fixation; allows near-atomic resolution of proteins and macromolecular complexes.

7. What is the function of an electron gun in EM? (Remembering)

   Answer: It generates and accelerates electrons to high velocities for imaging.

8. Give one example of how SEM is applied in material science. (Applying)

   Answer: Imaging the surface morphology of nanomaterials, polymers, or semiconductors.

9. Name two heavy metals used for staining in TEM. (Remembering)

   Answer: Uranyl acetate and lead citrate.

10. Distinguish between 2D and 3D imaging in TEM and SEM. (Analyzing)

    Answer: TEM provides 2D internal structural images, while SEM provides 3D surface images of specimens.

Short Essay Questions (5–7 marks each)

1. Explain how the wavelength of electrons improves resolution in EM compared to light microscopy. (Understanding)

Answer: Electrons accelerated at high voltages have sub-nanometer wavelengths, much shorter than visible light (400–700 nm). According to the resolution limit principle, shorter wavelengths allow resolving much finer details than light microscopy.

2. Describe the role of electromagnetic lenses in electron microscopy. (Understanding)

Answer: Electromagnetic lenses, created by magnetic fields, focus and control the electron beam. Condenser lenses control beam intensity, while objective lenses sharpen the final image.

3. Compare and contrast TEM and SEM in terms of principles, image characteristics, and applications. (Analyzing)

Answer: TEM transmits electrons through thin specimens, producing 2D images of internal structures at high resolution. SEM scans the surface with electrons, producing 3D topographic images with lower resolution but excellent surface detail.

4. Outline the main steps of specimen preparation for TEM. (Remembering/Understanding)

Answer: Fixation → Dehydration → Embedding → Sectioning (ultrathin slices) → Heavy metal staining.

5. Discuss the limitations of electron microscopy in studying living cells. (Evaluating)

Answer: Cells must be fixed, dehydrated, and placed in a vacuum, which kills them. Thus, EM cannot directly image live processes under natural conditions (except in special environmental EM).

6. Explain the significance of cryo-EM in structural biology. (Applying/Analyzing)

Answer: Cryo-EM allows imaging of biomolecules in near-native states, avoiding artifacts from fixation. It has enabled near-atomic resolution of proteins and complexes like ribosomes and viral spike proteins.

7. Illustrate how EM contributed to the structural understanding of SARS-CoV-2. (Applying)

Answer: EM, particularly cryo-EM, revealed the 3D structure of the spike protein, aiding vaccine and drug development.

8. Analyze the impact of EM in differentiating bacterial morphotypes in clinical samples. (Analyzing)

Answer: EM distinguishes fine structural differences between cocci, bacilli, and other morphotypes, helping in bacterial identification and clinical diagnosis.

9. Evaluate the role of in-situ EM in modern research. (Evaluating)

Answer: In-situ EM allows real-time observation of dynamic processes, such as nanoparticle formation, crystal growth, and biological changes under controlled environments.

10. Discuss how artificial intelligence is transforming image analysis in EM. (Evaluating/Creating)

Answer: AI enhances EM by automating segmentation, denoising, and 3D reconstruction, enabling faster and more accurate interpretation of complex datasets.

Long Essay Questions (10–15 marks each)

1. Describe in detail the principles, types, specimen preparation techniques, and applications of electron microscopy in biology. (Understanding/Analyzing)

Answer: Electron microscopy uses electron beams with sub-nanometer wavelengths for high-resolution imaging. Types include TEM, SEM, STEM, and cryo-EM. Specimen prep involves fixation, dehydration, embedding, sectioning, and staining. Applications include cell biology, virology, pathology, and nanotechnology.

2. Critically evaluate the advantages and limitations of TEM, SEM, and cryo-EM, giving examples from biology and materials science. (Evaluating)

Answer: TEM: Very high resolution of internal structures, but requires thin sectioning and complex prep. SEM: Excellent 3D surface imaging, but lower internal resolution. Cryo-EM: Near-native imaging at atomic resolution, but expensive and technically demanding.

3. Discuss the role of electron microscopy in virology, with reference to HIV and SARS-CoV-2 research. (Analyzing/Evaluating)

Answer: TEM revealed morphology of HIV particles; cryo-EM resolved the spike protein structure of SARS-CoV-2, aiding in vaccine design and drug targeting.

4. Explain how advances in cryo-EM and AI-based reconstruction are shaping the future of structural biology and nanotechnology. (Evaluating/Creating)

Answer: Cryo-EM allows high-resolution imaging of macromolecules, while AI automates image processing, enhancing speed and accuracy. Together, they accelerate drug discovery and nanomaterial design.

5. Propose a research study using electron microscopy to investigate a novel biological or nanomaterial system. Justify your choice of EM type and specimen preparation method. (Creating)

Answer: Example: Studying nanoparticle–cell interactions using SEM for surface morphology and TEM for internalization. Prep involves fixation, dehydration, embedding, and staining. Justification: Provides complementary 3D and 2D insights into nanoparticle uptake.