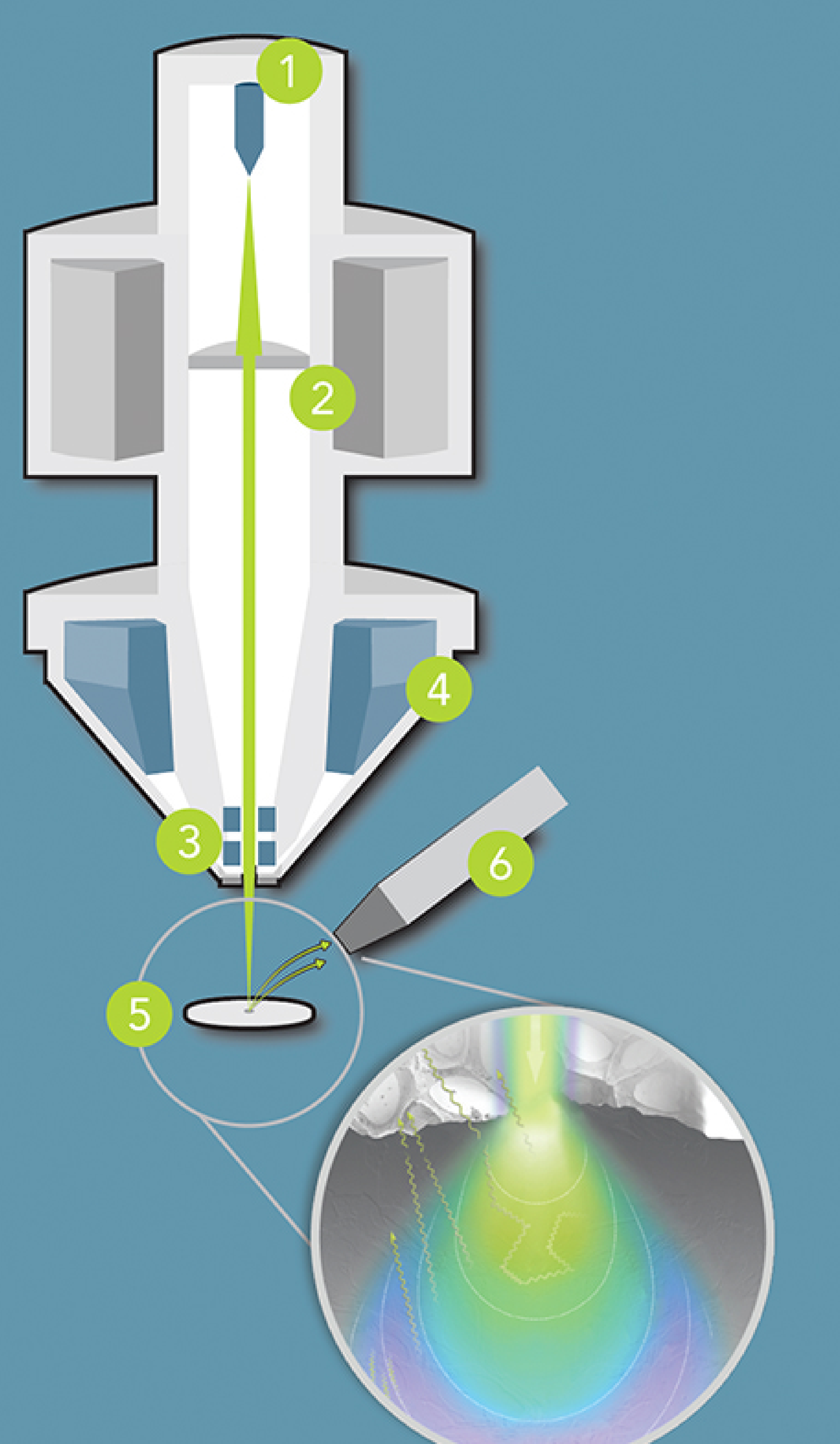
Diagram of SEM



1

Electron source

Electrons are extracted from a sharp tip by means of thermal activation and/or a strong electric field. Three common types of electron sources exist: thermionic, cold field, and Schottky emitters.

All microscopes require a light source. In a light microscope that might be a laser or halogen lamp; in electron microscopes, it's an electron source, of which three types are common (see table below).

Thermionic emitters use a heated tungsten filament with a sharpened tip as an electron source, or alternatively, a brighter and longer-lasting lanthanum hexaboride (LaB_6) crystal. The operating temperature used is higher than the onset electron emission temperature of the tip material.

Cold field-emission sources operate on a different principle: A thin, sharpened tungsten wire is positioned near a positively charged extraction electrode. The electrical potential difference between the two creates a very high electric field at the apex of the tungsten wire and causes electron emission via quantum tunneling. In contrast to cold field-emitters, in a thermally assisted or Schottky-type field-emission source, the emitting filament is heated, yielding a more stable electron beam.

Though all these designs are functional, thermionic emitters generally have a shorter lifetime and lower resolution than field emitters. But field emitters require lower (and thus more expensive and delicate) vacuum pressures, plus higher acquisition and maintenance costs.

Type	Thermionic		Cold field	Schottky
Material	W	LaB_6	W	ZrO/W
Operating temperature (K)	2800	1900	Room Temperature	1800
Vacuum (Pa)	$\leq 10^{-2}$	$\leq 10^{-3}$	$\leq 10^{-7}$	$\leq 10^{-5}$
Brightness (A/cm^2 sr kV)	10^4	10^5	2×10^7	10^7
Maximum probe current (nA)	1000	1000	<20	100-500
Best achievable resolution (nm)	<3	<2	<1	<1

Typical characteristics of different electron source types. W, tungsten; LaB_6, lanthanum hexaboride; ZrO/W, zirconiated tungsten; K, kelvin; Pa, pascals; A/cm^2, current density (amperes per square centimeter); sr, square radian; kV, kilovolt; nA, nanoamperes; nm, nanometers.

2

Beam limiting aperture

Filters out those electrons with trajectories that are not near the optical axis. This reduces the impact of spherical aberrations.

3

Scan coils

Used to deflect the electron beam to allow raster scanning of the sample.

4

Objective lens

Focuses the electron beam to the smallest possible spot. The final beam spot size depends on parameters such as beam current, electron landing energy, and working distance. The beam spot size and the nature of the beam-sample interaction determine the achievable imaging resolution.

5

Sample

Virtually any sample can be studied in an SEM. Imaging of non-conducting, outgassing, or wet samples usually involves either sample preparation steps or requires special imaging conditions in the SEM (e.g., low electron beam energies or low vacuum).

Because SEM images with an electron beam, the sample must be either electrically conductive or some sort of charge neutralization mechanism must be provided. For some samples, such as metals and semiconductors that isn't a problem, but many non-conductive samples ("insulators") need to be sputter-coated with a fine metal coating such as gold and palladium to make them conductive.

Preparation of biological samples can be particularly challenging since, in addition to being insulating, these samples are often not compatible with the high vacuum levels in the SEM chamber. Wet samples, such as cells, are therefore fixed with glutaraldehyde and osmium tetraoxide, then dried using ethanol and liquid carbon dioxide. Finally, the samples are sputter-coated and imaged.

An alternative approach is environmental scanning electron microscopy (ESEM). ESEMs enable the direct imaging of wet biological materials by incorporating design elements to bridge the substantial pressure divide between the electron optics (at high vacuum) and the sample chamber (low vacuum).

6

Detector

Used to detect different signals resulting from the interaction of electron beam and sample. The detector signals are recorded point by point during the scan and collated to create an image.