Inorganic Physiology: Distribution and Speciation of Metal Ions in Biological Systems

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Metal ions play a critical role in virtually all biological processes, including catalysis, electron transport, structural stability, and cellular signaling. In the absence of sufficient metal, critical cellular functions fail, frequently leading to pathological conditions. However, most metals are both bio-essential and, at sufficiently high concentrations, toxic, with the details being dependent on the metal, concentration, and organism; others are exclusively toxic. Consequently, metal ion levels within cells are tightly regulated, and a complex set of machinery has evolved to control the uptake, storage, and efflux of metals. A critical piece of information for understanding the control of this "inorganic physiology" is direct measurement of the concentration and speciation of metal ions, both in tissue and also on the sub-cellular length scale. Modern x-ray fluorescence microprobe and nanoprobe beamlines make it possible to determine absolute metal concentrations with a spatial resolution as good as ~100 nm and ~μM detection limits. In favorable circumstances, spatially resolved metal speciation can be determined using x-ray absorption spectroscopy. We have used these methods together with conventional x-ray absorption spectroscopy to investigate metal ions in a variety of biological environments, providing new insights into the basis of Cd toxicity and the mechanisms of metal homeostasis.

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