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Fluorescence Microscopy of Single-Walled Carbon Nanotubes in Biological Tissues

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In developing medical applications of single-walled carbon nanotubes (SWNT), it is necessary to detect and visualize the distribution of nanotubes inside biological tissues. It seems unlikely that this task can be achieved by chemical analysis (because nanotubes contain only carbon) or by conventional microscopy (because of the small diameters of SWNT). Radioactively labeled SWNT would be useful but are very difficult to generate. However, the recent discovery of near-infrared band-gap fluorescence from SWNT offers the prospect of powerful fluorescence-based approaches to this problem. We report here the first spectroscopic and imaging studies of SWNT in biological media. Mouse macrophage cultures were incubated in aqueous surfactant suspensions of SWNT and then carefully washed to remove nanotubes external to the cells. Diode laser excitation of these macrophage samples induced near-infrared fluorescence that was clearly characteristic of SWNT. The observed spectrum was somewhat broadened and red-shifted relative to that of SWNT in a surfactant medium. The incubated cells were then imaged using near-infrared fluorescence microscopy with detection limited to wavelengths between 1125 and 1600 nm. Because virtually no endogenous fluorescence was observable in this spectral range, the images revealed only emission from nanotubes. We obtained distinct, high-contrast micrographs showing localization of nanotubes in vesicles within the macrophages. We believe that these images represent first example of biological fluorescence microscopy in this spectral range. In addition, the results indicate that mouse macrophages ingest nanotubes by phagocytosis, and that the nanotubes remain fluorescent inside the phagosomes. Near-infrared fluorescence microscopy should provide a sensitive and selective tool for future studies of nanotubes in biological media.