



Imaging of Brain Tissue Using CdSe/CdS Core/Shell Quantum Dots for Correlative Fluorescence and Electron Microscopy

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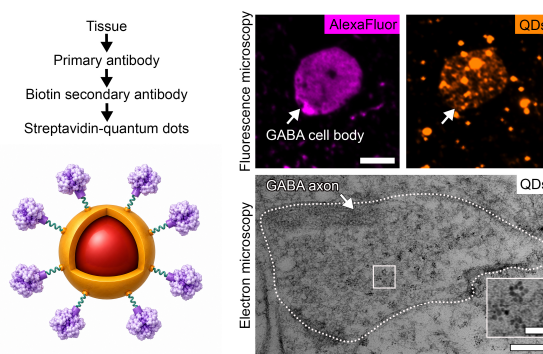
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Abstract: Detecting molecules across different spatial scales remains a major challenge in biological samples, particularly in complex tissues such as brain, where linking molecular identification and nanoscale structural detail is essential for understanding function. Fluorescence microscopy provides selective labeling of specific molecules but cannot fully resolve many cellular and subcellular features, whereas electron microscopy reveals ultrastructure without molecular specificity. Bridging these modalities is difficult because commonly used fluorescent probes such as dyes and proteins cannot provide electron contrast. Quantum dots are particularly useful as they retain fluorescence while providing sufficient electron density for ultrastructural visualization. Here, we show that streptavidin-functionalized CdSe/CdS core/shell quantum dots can function as dual-modal probes for labeling γ -aminobutyric acid (GABA) neurons in brain tissue. The quantum dots produce bright and stable fluorescence signals for optical detection while their inorganic composition generates strong electron contrast in ultrathin sections examined by transmission electron microscopy. This work demonstrates that functionalized CdSe/CdS quantum dots can serve as stable dual-modal probes for fluorescence and electron microscopy in complex tissues, highlighting the potential of semiconductor nanocrystals for multifunctional imaging applications.



Keywords: quantum dots; tissue labeling; fluorescence microscopy; electron microscopy

1. Introduction

Understanding the molecular architecture of complex tissues is challenging due to the high-resolution imaging needed to localize molecules at the subcellular level. Fluorescence microscopy (FM) has been the primary tool to specifically label and identify molecular and structural features of brain cells such as a cell body, dendrites and axons as seen in neurons [1,2]. However, it lacks the spatial resolution needed to resolve subcellular structures. In contrast, electron microscopy (EM) provides ultrastructural detail but does not inherently convey molecular specificity. To integrate molecular information with ultrastructural context, we focused on the use of CdSe/CdS quantum dots (QDs) as correlative probes for FM and EM visualization.

EM approaches to molecular localization come with certain limitations. Normally, one must balance the ultrastructural and molecular preservation of a determined target, followed later by immunoelectron microscopy techniques (immuno-EM) [3]. Immunolabeling on ultrathin EM sections is detected by direct or indirect visualization of antibodies by colloidal gold particles, which are electron dense for EM imaging but cannot be imaged by light microscopy [4,5]. Additionally, the size of gold-antibody complexes provides a challenge since labeling efficiency



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decreases with larger gold particles (5–15 nm) [6,7]. Although ultra-small gold particles (0.8–1.4 nm) can improve labeling and imaging resolution, detection requires silver enhancement which is subject to background and may not reflect individual gold particles. These features therefore increase detection inaccuracies, potentially obscuring ultrastructural details and increasing background due to heterogeneous particle sizes. Accordingly, probes that are reliably visualized and support dual FM and EM imaging are needed for immuno-EM applications [6–9].

Semiconductor QDs offer a promising platform to address these limitations. QDs exhibit high brightness, photostability, and size-tunable emission [10–12], making them well suited as fluorescent probes in biological systems [13–16]. In addition, their inorganic composition provides intrinsic electron density, suggesting their potential as contrast agents for EM [17–19]. These properties make QDs attractive candidates for dual-modal imaging. The ability to synthesize and functionalize QDs *de novo* provides flexibility to optimize particle size, emission, and surface properties for specific research needs. Although functionalized QDs have shown efficient correlative labeling in pre-embedding approaches [20–23], their use for post-embedding correlative FM and EM on ultrathin sections has not been developed.

Because commercially available QDs may not always provide optimal surface functionalization, labeling performance, and EM visibility, requiring signal enhancement in some cases [21], we describe in detail the synthesis and functionalization of CdSe/CdS core/shell QDs for use as dual-modal labels in brain tissue post-embedding immuno-EM. By functionalizing the QDs with streptavidin, biotinylated γ -aminobutyric acid (GABA) cells are successfully labeled and visualized in ultrathin brain tissue sections for both FM and EM imaging. Ultrathin sections permit visualization of cells and subcellular structures that can be followed through consecutive series of sections [24]. Immunolabeling using two consecutive serial sections demonstrates that the functionalized streptavidin-QDs enable correlative FM and EM imaging in brain tissue, maintaining functionality across both imaging workflows.

2. Results and Discussion

CdSe/CdS QDs were synthesized using the hot injection method [25]. The QDs exhibit a broad absorption spectrum and a sharp photoluminescence (PL) maximum at 620 nm, as shown in Figure 1A. To further evaluate their optical properties, the photoluminescence quantum yield (PLQY) was measured before and after aqueous transfer. The as-synthesized QDs in hexane exhibited a PLQY of 44.5%, while the MUA-capped QDs after ligand exchange and aqueous dispersion exhibited a PLQY of 16.2%. Although the PLQY decreased after ligand exchange, the QDs retained detectable fluorescence in water (Figure S1), supporting their use as fluorescent probes. Transmission electron microscopy (TEM) revealed that the QDs have a spherical morphology with an average size of 9.0 ± 0.9 nm shown in Figure 1B. To make the QDs water soluble and thus biocompatible, ligand exchange with mercaptoundecanoic acid (MUA) was performed on the as-synthesized QDs. Following ligand exchange, the QDs were functionalized with streptavidin to allow for targeted biological labeling through biotin-streptavidin interactions [26–28]. Details of the functionalization method are available in the Supporting Information, Section 4.

To confirm that streptavidin has been successfully introduced on the QDs, Förster resonance energy transfer (FRET) measurements were conducted using the streptavidin-functionalized QDs as an energy donor and Cy5 biotin as an acceptor fluorophore. The FRET measurement takes advantage of the spectral overlap between QD emission and Cy5 dye absorption (Figure S2) and the strong distance dependence of FRET, which is most effective over donor-acceptor separations of approximately 1–10 nm [29–31]. Therefore, Cy5 dye emission is only detectable when Cy5 biotin binds to streptavidin on the QD surface and brings the acceptor fluorophore into close proximity with the QD donor. For FRET measurements, streptavidin-functionalized QDs dispersed in PBS/BSA were reacted directly with Cy5 biotin in solution and allowed to react for 30 min. Following the addition of Cy5 biotin to the streptavidin-functionalized QDs, the reaction mixture was excited at 400 nm to selectively excite the QDs only and PL emission spectra were collected. Under these conditions, Cy5 emission was observed at 670 nm (Figure 1C), indicating that FRET occurred due to successful binding of Cy5 biotin to streptavidin. Furthermore, PL decay measurements were performed under the same experimental conditions using a 405 nm pulsed laser excitation and the decay curves were fit using a tri-exponential function (Figure S3 and Table S1). A decrease in the QD donor PL lifetime from 17.90 ns to 11.42 ns was observed in the presence of Cy5 biotin (Figure 1D). The faster PL decay observed of the conjugated biotin-streptavidin pair indicates nonradiative energy transfer from QDs to Cy5 which further confirms binding between streptavidin-functionalized QDs and Cy5 biotin [32–34]. These results demonstrate successful streptavidin functionalization at the QD surface.

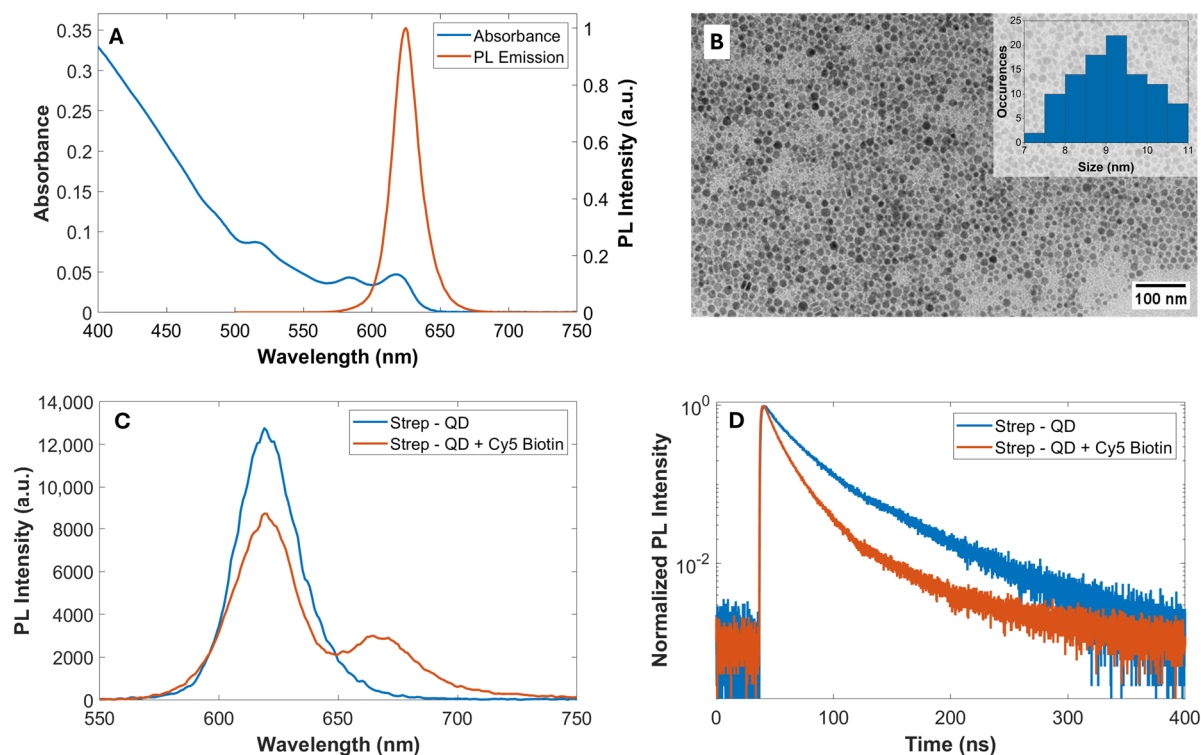


Figure 1. (A) UV-vis absorption spectrum (left axis) and photoluminescence (PL) emission spectrum (right axis) of CdSe/CdS QDs in hexane. (B) Representative TEM image of the QDs. The inset shows a histogram of the QD size distribution. (C) PL spectra of streptavidin-conjugated QDs before and after addition of Cy5 biotin, excited at 400 nm. (D) Time-resolved PL decays of streptavidin-conjugated QDs before and after addition of Cy5 biotin.

While successful conjugation of streptavidin was confirmed *in vitro*, removal of unbound streptavidin is critical to ensure effective labeling of the targets in the tissue sections by QDs rather than free streptavidin. A 100 kDa molecular weight cut off filter was applied to purify the streptavidin-functionalized QDs to remove unbound streptavidin. The QDs were evaluated for specific labeling in ultrathin brain tissue sections using an antibody-based approach as illustrated in Figure 2A. The QDs were then used to visualize GABA, one of the main neurotransmitters to identify inhibitory cell types in the brain, on ultrathin (70 nm) sections of rat brain [35,36]. Perfusion-fixed rat brains were sectioned on a vibratome and the amygdala region was dissected out and embedded in resin following the procedure in Section 6 in the Supporting Information. Embedded tissue blocks were sectioned at 70 nm using an ultramicrotome and sections placed on coverslips or gold pioloform grids were used for immuno-EM labeling. The tissue sections were then treated with the primary antibody to GABA followed by a biotinylated secondary antibody. Lastly, the tissue sections were incubated with streptavidin-QDs or AlexaFluor 647 as a control, as detailed in Section 7 in the Supporting Information. The tissues were examined under fluorescence or transmission electron microscopes. Ultrathin tissue sections ensure that adjacent sections contain nearly identical structural information, allowing reliable comparison across sections.

In the brain, GABA is found in the neuron cell body, as well as in dendrites and axons [36,37]. Labeling of GABA cells using streptavidin-AlexaFluor 647 is seen with a strong labeled cell body (arrow in Figure 2B). A consecutive section labeled with streptavidin-QDs show the same pattern of staining of the same cell (arrow in Figure 2C), although some non-specific puncta were observed in the tissue (arrowheads in Figure 2C). Fluorescence microscopy images of QDs were excited at 385 nm and emission was collected with an ET605/52 nm filter. Fluorescence imaging indicates that streptavidin-functionalized QDs preferentially bind in the presence of biotin in tissue, with minimal QD signal observed in the absence of the primary antibody (Figure 2D). GABA is widely distributed in the brain making it difficult to confirm non-specific QDs puncta in neuropil (the dense space between neuronal cell bodies primarily composed of axons, dendrites and glial cells), so EM is needed to confirm the specificity of the QD labels. Axons and dendrites can be followed through series of consecutive ultrathin sections [24]. To test streptavidin-QDs labeling at EM resolution, two consecutive ultrathin 70 nm sections were labeled with GABA, using one section with streptavidin AlexaFluor 647 as a validation of the labeled structures (magenta signal in Figure 2E), and the following one with QDs directly to tissue on EM gold pioloform grids (Figure 2F,G). Imaging at high resolution showed individual QDs on tissue structures (arrows in Figure 2G). GABA positive puncta was aligned to specific neuronal processes using the AlexaFluor 647 signal (Figure 2E),

and QDs were distributed within these processes (white arrows in Figure 2F,G). However, non-specific binding of QDs was also present in some GABA-negative processes (arrowheads in Figure 2F), and not all GABA-positive processes exhibited QD labeling (black arrow in Figure 2F). The presence of streptavidin-functionalized QDs on some GABA-positive processes supports target-associated labeling; however, nonspecific binding in GABA-negative structures and incomplete labeling of GABA-positive processes indicate that labeling efficiency and specificity remain limited. These observations may reflect inefficient binding of the QD probes to the secondary antibody due to incomplete removal of unbound streptavidin, as excess free streptavidin could occupy the biotinylated secondary antibody sites. Although size exclusion filters have previously been used for QD purification [38–40], as well as to remove excess free streptavidin [41], more precise purification methods, such as high-performance size exclusion chromatography (HPSEC) may further reduce unbound streptavidin and QD aggregates [42] potentially improving labeling specificity. Together, these factors highlight the importance of optimizing purification and surface functionalization to improve labeling specificity in tissue sections.

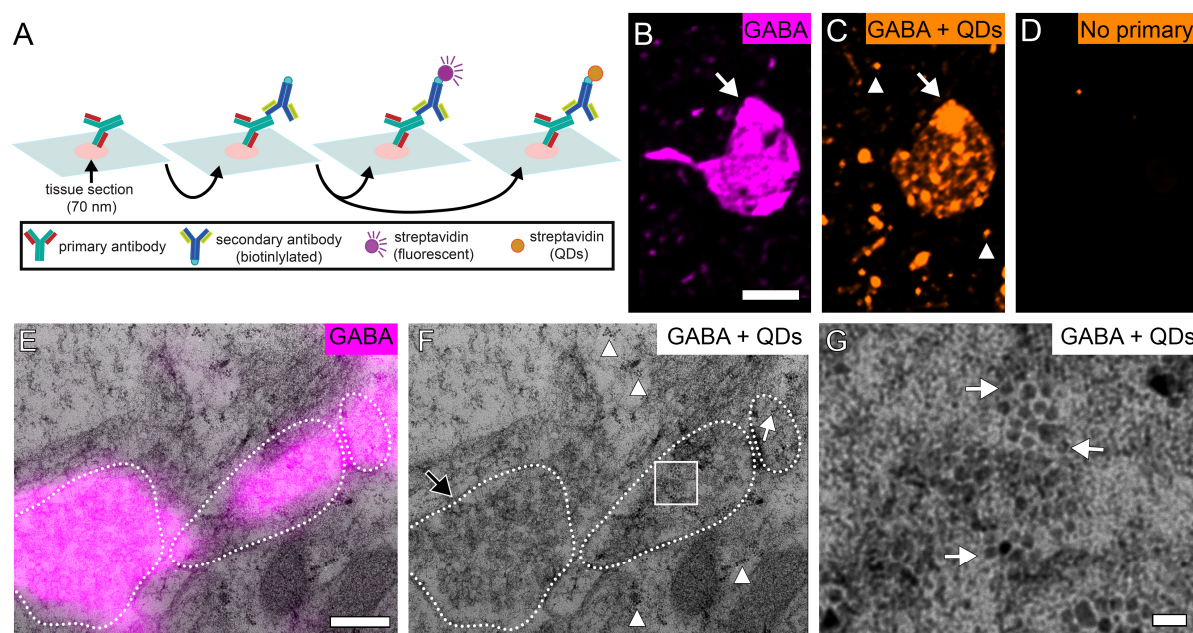


Figure 2. (A) Schematic of immunolabeling on 70 nm ultrathin sections. Signal from primary antibody is detected by biotin and streptavidin interaction. Streptavidin is either fluorescent or functionalized with QDs. A GABA positive cell is detected by fluorescent streptavidin (arrow in **B**) and streptavidin-QDs (arrow in **C**) after immunolabeling is performed on ultrathin sections. A no primary antibody control shows less or no signal of streptavidin-QDs (**D**). GABA positive processes are visualized at EM level after immunolabeling is performed on EM gold pioloform grids. Fluorescence microscopy in a consecutive 70 nm section validates labeled structures (magenta signal in **E**). Streptavidin-QDs are seen in positive (white arrows in **F** and **G**) and non-positive (arrowheads in **F**) GABA processes. A positive GABA axon (black arrow in **F**) is shown with no QDs. (**G**) is an inset magnification of the boxed region in (**F**). Scale bars: 10 μ m in (**B**), 200 nm in (**E**), and 10 nm in (**G**).

In conclusion, streptavidin functionalized CdSe/CdS QDs function as dual-modal probes that retain fluorescence and electron contrast, enabling correlative imaging in ultrathin brain tissue sections. While specific labeling of GABA neuronal processes was achieved, nonspecific binding and incomplete labeling indicates that further optimization of purification and surface functionalization is needed. These results demonstrate the feasibility of using semiconductor QDs for integrated fluorescence and electron microscopy and support their continued development as multifunctional imaging probes.

Supplementary Materials: The following supporting information can be downloaded at: <https://media.sciltp.com/articles/others/2608141007326916/MI-26050111-SI.pdf>, Chemicals, instrumentation, QD synthesis and surface functionalization procedures, tissue embedding, sectioning and labeling procedures, and additional experimental data.

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Data Availability Statement: All data generated in this study, such as the raw and processed data from spectral characterizations and microscopy images will be shared upon request. The data will be deposited in the open-access repository Figshare and made available after the publication of this work.

Conflicts of Interest: The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies: No AI tools were utilized for this paper.

References

1. Rah, J.C.; Choi, J.H. Finding Needles in a Haystack with Light: Resolving the Microcircuitry of the Brain with Fluorescence Microscopy. *Mol. Cells* **2022**, *45*, 84–92.
2. Yin, C.; Li, J.; Meng, K.; Zhang, J.; Chen, M.; Chen, R.; Hu, Y.; Wang, S.; Xie, S. Fluorescent Labeling Methods for Brain Structure Research. *Molecules* **2026**, *31*, 817.
3. Luján, R.; Rubio, M.E. Editorial: Immunoelectron Microscopy: Placing Molecular Functions within a Neuronal Context. *Front. Neuroanat.* **2022**, *16*, 1043371.
4. Jones, J.C.R. Pre- and Post-Embedding Immunogold Labeling of Tissue Sections. *Methods Mol. Bio.* **2016**, *1474*, 291–307.
5. Lucocq, J. Particulate Markers for Immunoelectron Microscopy. In *Fine Structure Immunocytochemistry*; Griffiths, G., Ed.; Springer: Berlin/Heidelberg, Germany, 1993; pp. 279–306.
6. Humbel, B.M.; Sibon, O.C.; Stierhof, Y.D.; Schwarz, H. Ultra-Small Gold Particles and Silver Enhancement as a Detection System in Immunolabeling and in Situ Hybridization Experiments. *J. Histochem. Cytochem.* **1995**, *43*, 735–737.
7. Stierhof, Y.-D.; Humbel, B.M.; Hermann, R.; Otten, M.T.; Schwarz, H. Direct Visualization and Silver Enhancement of Ultra-Small Antibody-Bound Gold Particles on Immunolabeled Ultrathin Resin Sections. *Scanning Microsc.* **1992**, *6*, 12.
8. Petralia, R.S.; Wang, Y.X. Review of Post-Embedding Immunogold Methods for the Study of Neuronal Structures. *Front. Neuroanat.* **2021**, *15*, 763427.
9. Mayer, G.; Leone, R.D.; Hainfeld, J.F.; Bendayan, M. Introduction of a Novel HRP Substrate-Nanogold Probe for Signal Amplification in Immunocytochemistry. *J. Histochem. Cytochem.* **2000**, *48*, 461–469.
10. Greytak, A.B.; Allen, P.M.; Liu, W.; Zhao, J.; Young, E.R.; Popović, Z.; Walker, B.J.; Nocera, D.G.; Bawendi, M.G. Alternating Layer Addition Approach to CdSe/CdS Core/Shell Quantum Dots with near-Unity Quantum Yield and High on-Time Fractions. *Chem. Sci.* **2012**, *3*, 2028–2034.
11. Chen, O.; Zhao, J.; Chauhan, V.P.; Cui, J.; Wong, C.; Harris, D.K.; Wei, H.; Han, H.S.; Fukumura, D.; Jain, R.K.; et al. Compact High-Quality CdSe-CdS Core-Shell Nanocrystals with Narrow Emission Linewidths and Suppressed Blinking. *Nat. Mater.* **2013**, *12*, 445–451.
12. Murray, C.B.; Norris, D.J.; Bawendi, M.G. Synthesis and Characterization of Nearly Monodisperse CdE (E = S, Se, Te) Semiconductor Nanocrystallites. *J. Am. Chem. Soc.* **1993**, *115*, 8706–8715.
13. Nisman, R.; Dellaire, G.; Ren, Y.; Li, R.; Bazett-Jones, D.P. Application of Quantum Dots as Probes for Correlative Fluorescence, Conventional, and Energy-Filtered Transmission Electron Microscopy. *J. Histochem. Cytochem.* **2004**, *52*, 13–18.
14. Smith, A.M.; Nie, S. Chemical Analysis and Cellular Imaging with Quantum Dots. *Analyst* **2004**, *129*, 672–677.
15. Cotta, M.A. Quantum Dots and Their Applications: What Lies Ahead? *Appl. Nano Mater.* **2020**, *3*, 4920–4924.
16. Susumu, K.; Uyeda, H.T.; Medintz, I.L.; Pons, T.; Delehanty, J.B.; Mattoussi, H. Enhancing the Stability and Biological Functionalities of Quantum Dots via Compact Multifunctional Ligands. *J. Am. Chem. Soc.* **2007**, *129*, 13987–13996.
17. Walther, T. Electron Microscopy of Quantum Dots. *J. Microsc.* **2015**, *257*, 171–178.
18. Ogunkoya, Y.; Nickel, B.M.; Gay, V.L.; Murray, S.A. Using Quantum Dots to Visualize Clathrin Associations. *Biotech. Histochem.* **2009**, *84*, 109–115.
19. Bera, D.; Qian, L.; Tseng, T.K.; Holloway, P.H. Quantum Dots and Their Multimodal Applications: A Review. *Materials* **2010**, *3*, 2260–2345.
20. Killingsworth, M.C.; Bobryshev, Y.V. Correlative Light- and Electron Microscopy Using Quantum Dot Nanoparticles. *J. Vis. Exp.* **2016**, *114*, e54307.
21. Uematsu, M.; Mikami, K.; Nakamura, A.; Takahashi, R.; Yokota, T.; Hirokawa, K.; Uchihara, T. Parallel Gold Enhancement of Quantum Dots 565/655 for Double-Labeling Correlative Light and Electron Microscopy on Human Autopsied Samples. *Sci. Rep.* **2022**, *12*, 6113.
22. Deerinck, T.J. The Application of Fluorescent Quantum Dots to Confocal, Multiphoton, and Electron Microscopic Imaging. *Toxicol. Pathol.* **2008**, *36*, 112–116.
23. Giepmans, B.N.G.; Adams, S.R.; Ellisman, M.H.; Tsien, R.Y. The Fluorescent Toolbox for Assessing Protein Location and Function. *Science* **2006**, *312*, 217–224.

24. Pérez-Garza, J.; Orea, J.; Deane, Z.; Raimondi, G.; Tripp, R.; Charles, I.; Ostroff, L. Ultraplex Microscopy: Versatile Highly-Multiplexed Molecular Labeling and Imaging across Scale and Resolution. *bioRxiv* **2024**. <https://doi.org/10.1101/2024.08.17.605585>.
25. Wang, X.; Chen, S.; Thota, S.; Wang, Y.; Tan, H.; Tang, M.; Quan, Z.; Zhao, J. Anisotropic Arm Growth in Unconventional Semiconductor CdSe/CdS Nanotetrapod Synthesis Using Core/Shell CdSe/CdS as Seeds. *J. Phys. Chem. C* **2019**, *123*, 19238–19245.
26. Bayer, E.A.; Wilchek, M. Application of Avidin—Biotin Technology to Affinity-Based Separations. *J. Chromatogr. A* **1990**, *510*, 3–11.
27. Michael Green, N. Avidin and Streptavidin. *Methods Enzymol.* **1990**, *184*, 51–67.
28. Chen, Y.; Ren, H.L.; Liu, N.; Sai, N.; Liu, X.; Liu, Z.; Gao, Z.; Ning, A.N. A Fluoroimmunoassay Based on Quantum Dot–Streptavidin Conjugate for the Detection of Chlorpyrifos. *J. Agric. Food Chem.* **2010**, *58*, 8895–8903.
29. Cardoso Dos Santos, M.; Algar, W.R.; Medintz, I.L.; Hildebrandt, N. Quantum Dots for Förster Resonance Energy Transfer (FRET). *Trends Anal. Chem.* **2020**, *125*, 115819.
30. Clegg, R.M. Fluorescence Resonance Energy Transfer. *Curr. Opin. Biotechnol.* **1995**, *6*, 103–110.
31. Medintz, I.L.; Clapp, A.R.; Mattoussi, H.; Goldman, E.R.; Fisher, B.; Mauro, J.M. Self-Assembled Nanoscale Biosensors Based on Quantum Dot FRET Donors. *Nat. Mater.* **2003**, *2*, 630–638.
32. Lu, X.; Hou, X.; Tang, H.; Yi, X.; Wang, J. A High-Quality CdSe/CdS/ZnS Quantum-Dot-Based FRET Aptasensor for the Simultaneous Detection of Two Different Alzheimer’s Disease Core Biomarkers. *Nanomaterials* **2022**, *12*, 4031.
33. Medintz, I.L.; Mattoussi, H. Quantum Dot-Based Resonance Energy Transfer and Its Growing Application in Biology. *Phys. Chem. Chem. Phys.* **2008**, *11*, 17–45.
34. Clapp, A.R.; Medintz, I.L.; Mauro, J.M.; Fisher, B.R.; Bawendi, M.G.; Mattoussi, H. Fluorescence Resonance Energy Transfer Between Quantum Dot Donors and Dye-Labeled Protein Acceptors. *J. Am. Chem. Soc.* **2003**, *126*, 301–310.
35. McDonald, A.J. Functional Neuroanatomy of the Basolateral Amygdala: Neurons, Neurotransmitters, and Circuits. In *Handbook of Behavioral Neuroscience*; Elsevier: Amsterdam, The Netherlands, 2020; Volume 26, pp. 1–38.
36. McDonald, A.J. Immunohistochemical Identification of γ -Aminobutyric Acid-Containing Neurons in the Rat Basolateral Amygdala. *Neurosci. Lett.* **1985**, *53*, 203–207.
37. Jiang, C.; Chen, Y.; Sun, T. From the Gut to the Brain, Mechanisms and Clinical Applications of γ -Aminobutyric Acid (GABA) on the Treatment of Anxiety and Insomnia. *Front. Neurosci.* **2025**, *19*, 1570173.
38. Shamirian, A.; Samareh Afsari, H.; Hassan, A.; Miller, L.W.; Snee, P.T. In Vitro Detection of Hypoxia Using a Ratiometric Quantum Dot-Based Oxygen Sensor. *ACS Sens.* **2016**, *1*, 1244–1250.
39. Tosat-Bitrián, C.; Avis-Bodas, A.; Porras, G.; Borrego-Hernández, D.; García-Redondo, A.; Martín-Requero, A.; Palomo, V. CdSe Quantum Dots in Human Models Derived from ALS Patients: Characterization, Nuclear Penetration Studies and Multiplexing. *Nanomaterials* **2021**, *11*, 671.
40. Le, P.; Lim, S.J.; Baculis, B.C.; Chung, H.J.; Kilian, K.A.; Smith, A.M. Counting Growth Factors in Single Cells with Infrared Quantum Dots to Measure Discrete Stimulation Distributions. *Nat. Commun.* **2019**, *10*, 909.
41. Zrazhevskiy, P.; Gao, X. Quantum Dot Imaging Platform for Single-Cell Molecular Profiling. *Nat. Commun.* **2013**, *4*, 1619.
42. Wu, J.K.; Tian, Z.Q.; Zhang, Z.L.; Liu, A.A.; Tang, B.; Zhang, L.J.; Chen, Z.L.; Pang, D.W. Purification of Quantum Dot-Based Bioprobes via High-Performance Size Exclusion Chromatography. *Talanta* **2016**, *159*, 64–73.