



Quantum-dot-based molecular bioimaging

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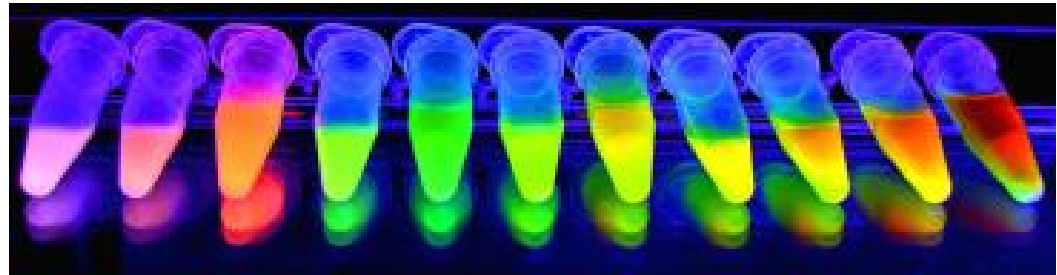
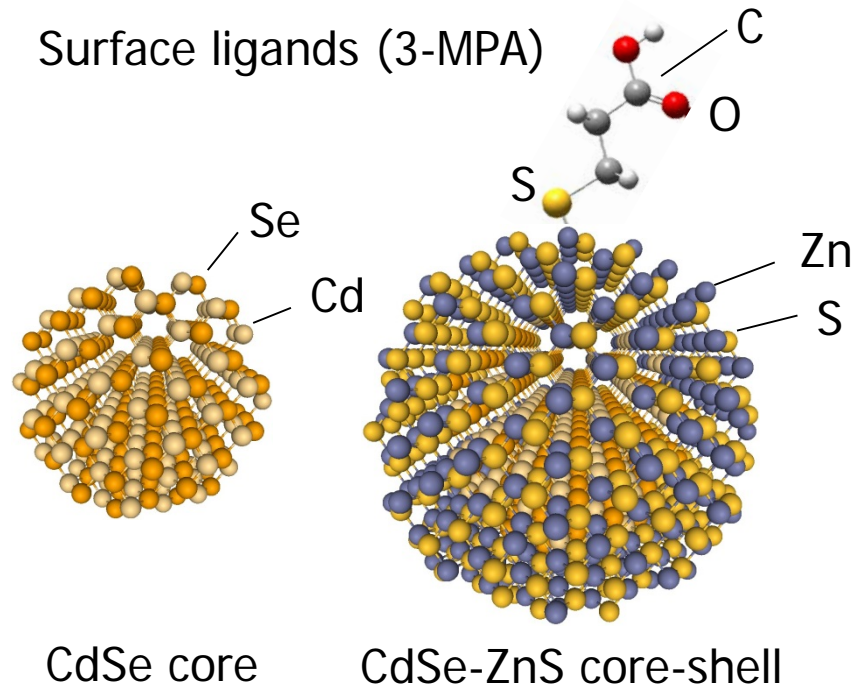
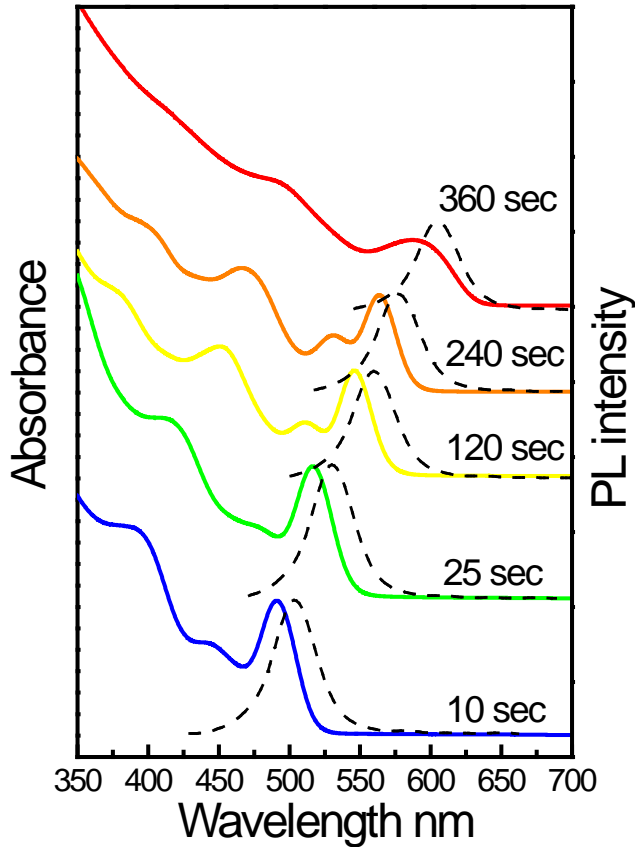
Research organization

The research group focuses on researching and developing bio-conjugated QDs as in vitro and in vivo biomarkers for studying essential molecular and cellular processes. We have an in-house QD laboratory to synthesize, surface-modify and bio-conjugate many different QDs including CdSe-CdS/ZnS, ZnO, 3C-SiC, and graphene. We focus on two major cell types, human vascular endothelial cells HUVEC and liquid-covered/air-interfaced human airway epithelial Calu-3 cells.

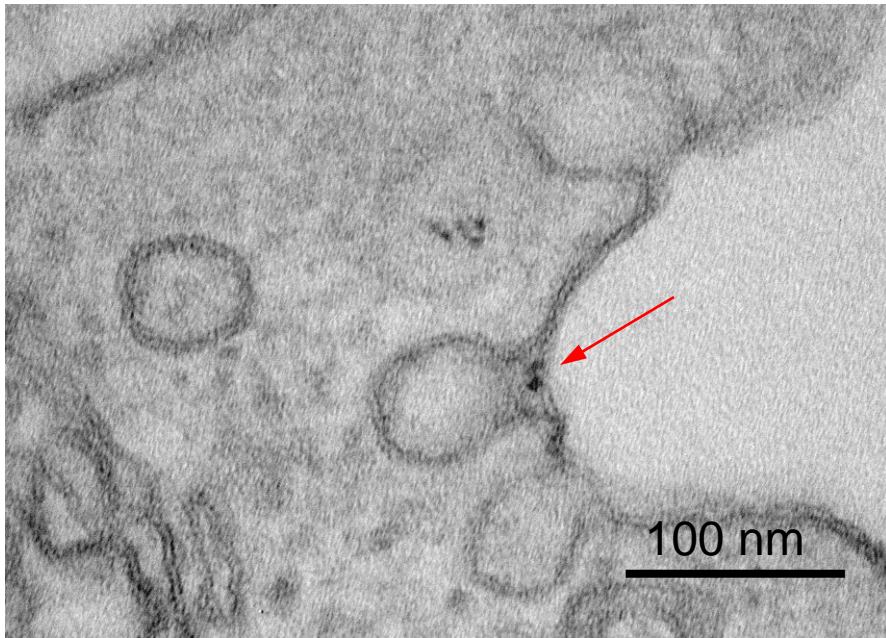
The research group belongs to the Section of Biophysics which is equipped for experimental cellular biophysics and molecular biology with a particular strength in live cell and super-resolution bioimaging. Installed instruments include STED, SIM and PALM/dSTORM super-resolution microscopes, QD-SPT setups, FCS and RICS spectroscopy, as well as several conventional confocal, multiphoton and ratio imaging systems. Important to the capacity of the Biophysics Section is the multi-disciplinary competence of physicists and biologists. The laboratory is located at Science for Life Laboratory (SciLifeLab), which houses experimental facilities and expertise of the highest international level in molecular sciences of life.

- We major in biophysics so focus mostly on the fundamental methodology of the proposed spectroscope.
- We have expert supports from Advanced Light Microscopy (ALM) facility at SciLifeLab about state-of-the-art high speed single photon detection.
- We adopt the well established microfluidics system to incubate QD-antibody stock solution with sample solution and to control fluid flow in the microchannel.

Chemical synthesis



→
Growth time
QD size



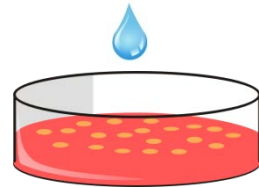
TEM pictures of QDs in endothelial progenitor cells (EPC)



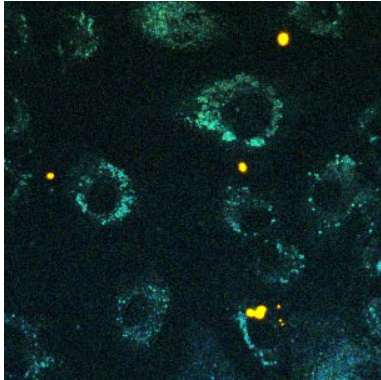
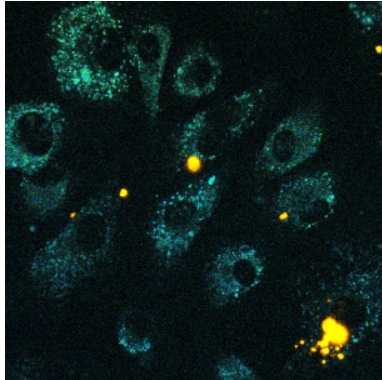
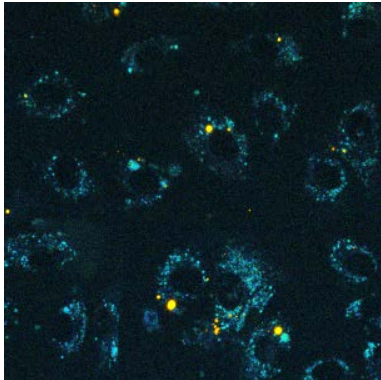
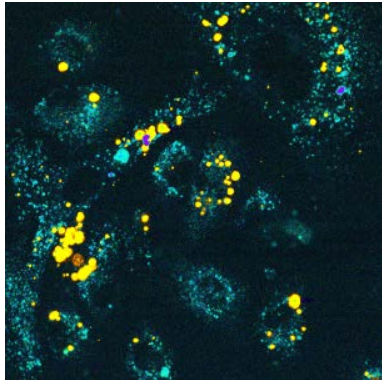
Confocal image of QDs (red) in live EPC

QD target visualize inflammation in live cells

tumor necrosis factor- α (TNF- α) \rightarrow VCAM-1 expression



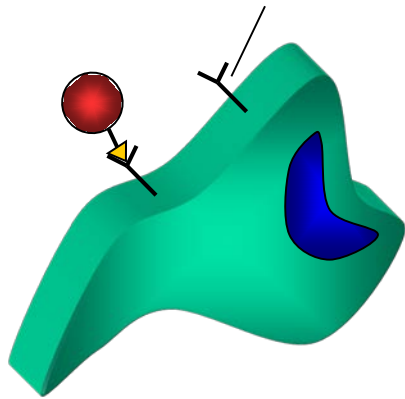
Human Umbilical Vein Endothelial Cells (HUVEC)

	VQD in non-TNF- α	VQD in TNF- α
6 hours		
24 hours		

VCAM-1 binding peptide



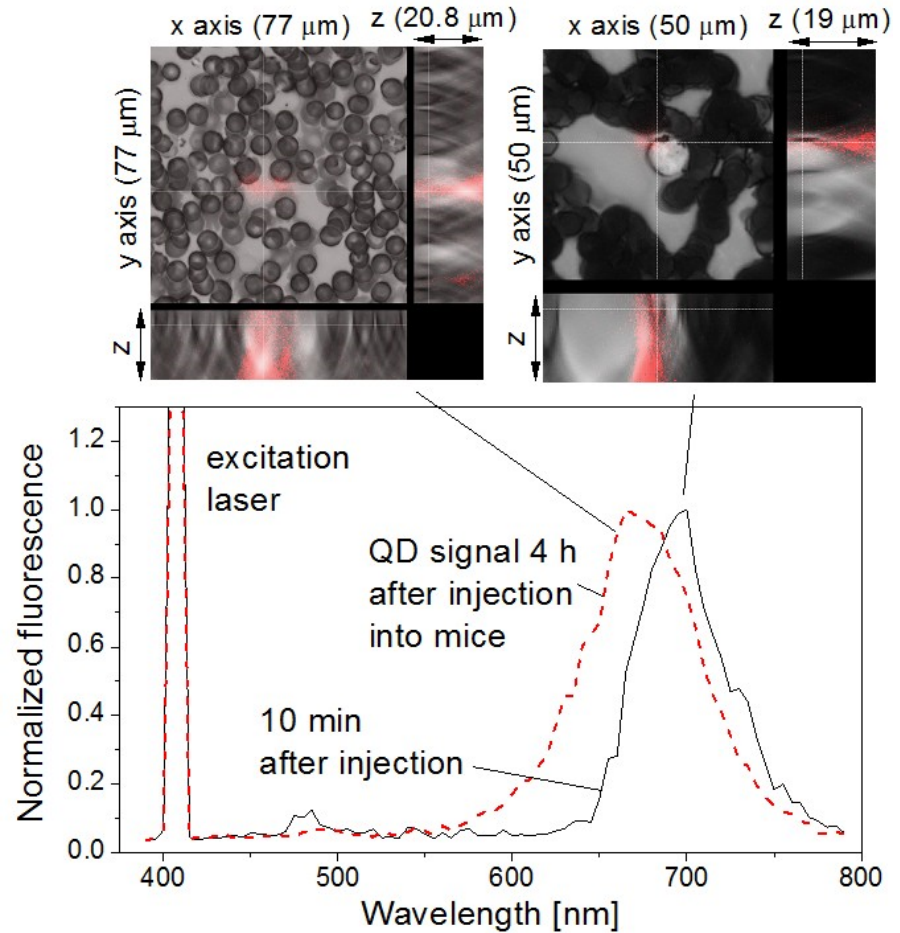
VCAM-1



LPS-treated mouse

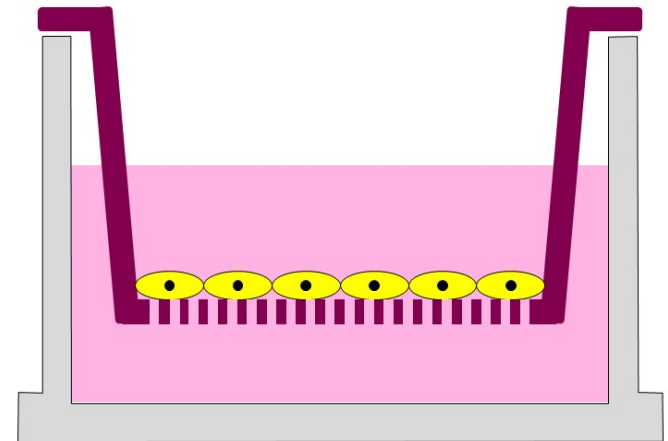
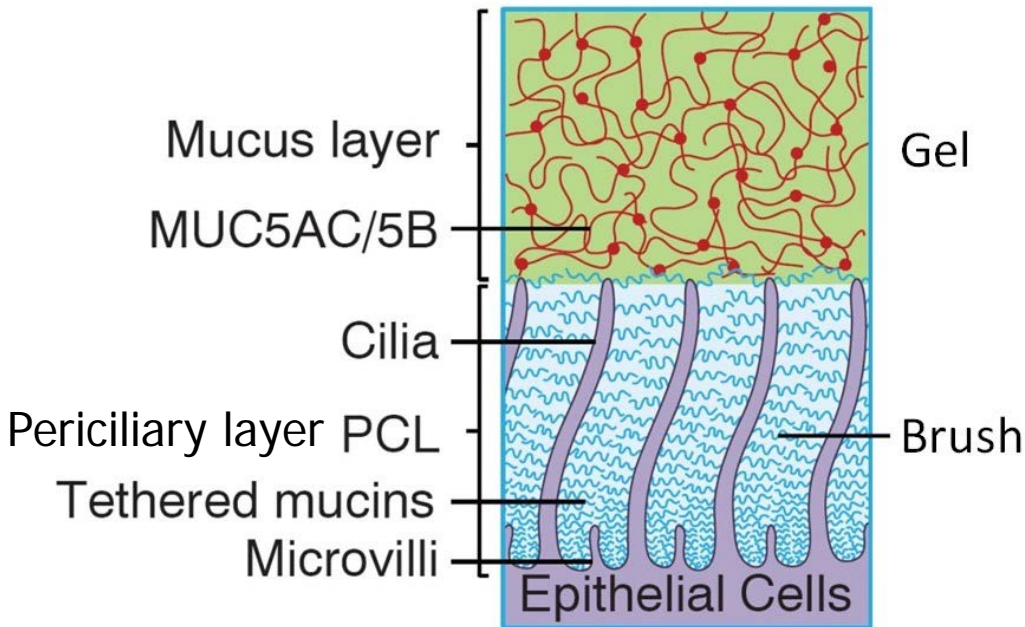
Animal study

- Mice were injected intraperitoneally with LPS to induce inflammation
- VQDs were injected via the tail vein
- aortas were collected from euthanized mice then studied under microscope

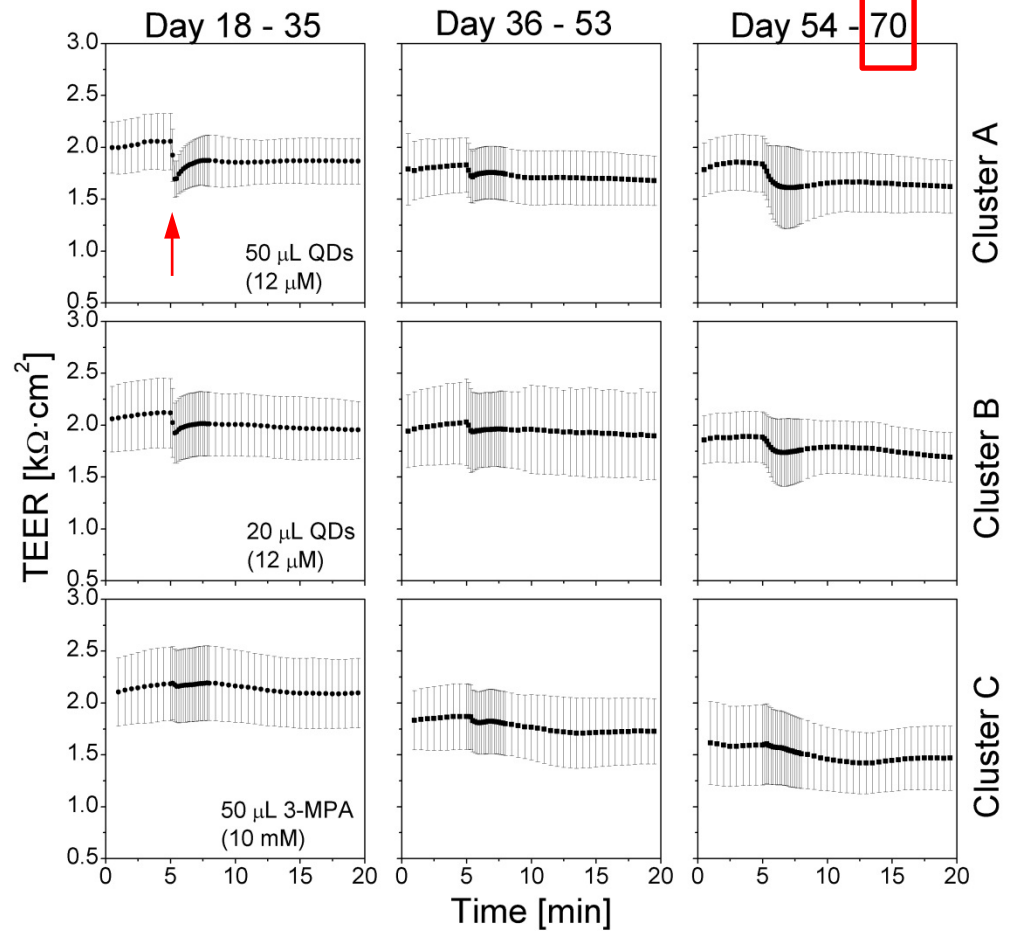
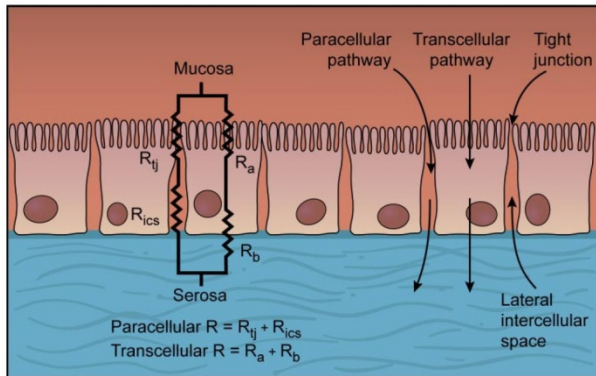
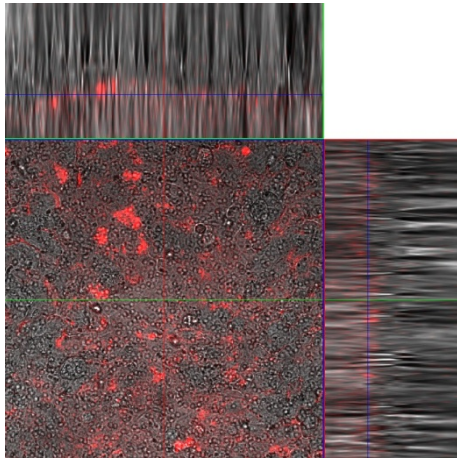
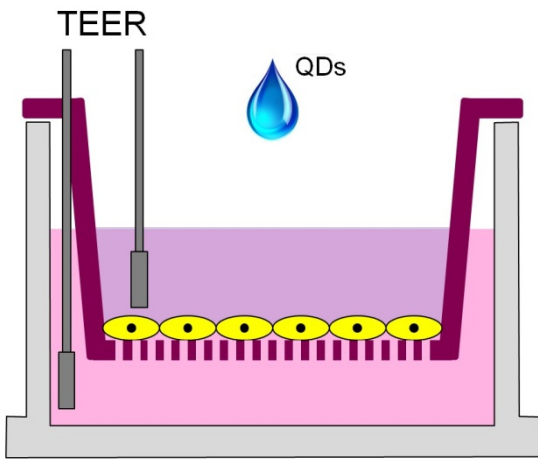


Lung health

Human airway epithelial cells (Calu-3)



B. Button, L.-H. Cai, C. Ehre, M. Kesimer, D. B. Hill, J. K. Sheehan, R. C. Boucher, M. Rubinstein, A Periciliary Brush Promotes the Lung Health by Separating the Mucus Layer from Airway Epithelia, *Science*, v.337, 24 AUGUST 2012, p.937-41

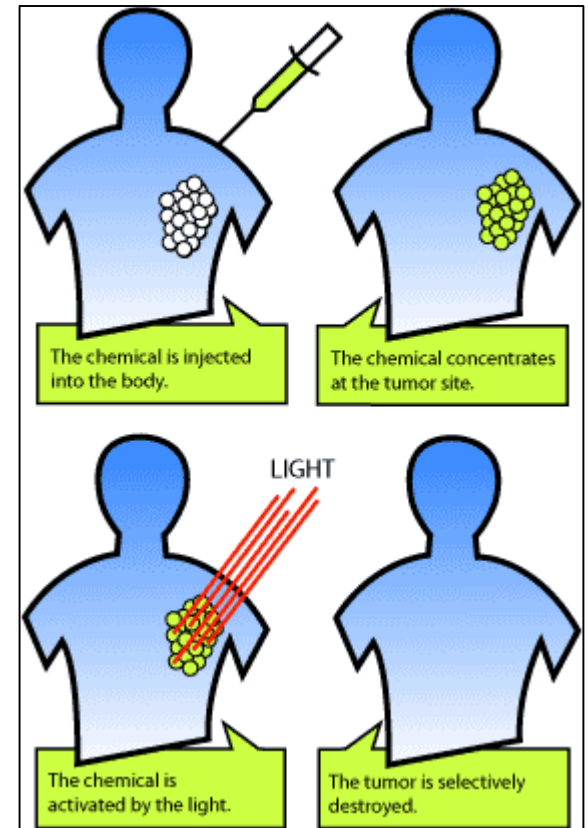
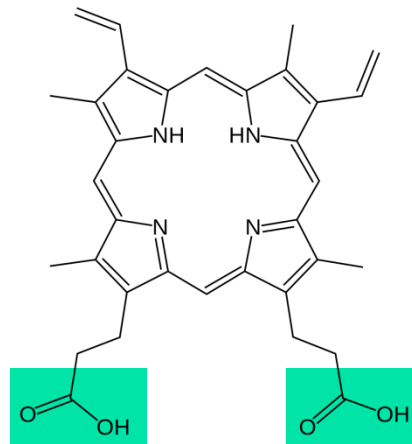


A. Turdalieva, J. Solandt, N. Shambetova, H. Xu, H. Blom, H. Brismar, M. Zelenina, Y. Fu, Plos One 11(2): e0149915, 2016.
 doi:10.1371/journal.pone.0149915

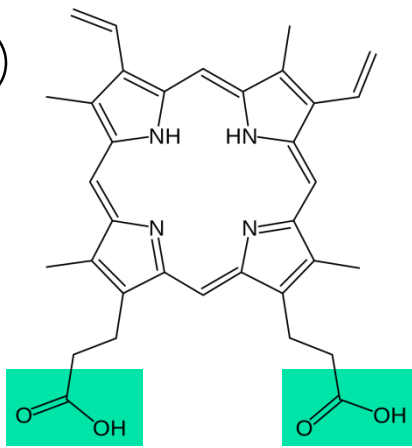
Conclusion: QD deposition causes temporal reduction in cell junctions > chronic exposure to traffic particles – lung health

Target cellular treatment

The sensitivity of protoporphyrin IX against light is used as a therapy against different forms of cancer (photodynamic therapy, PDT)

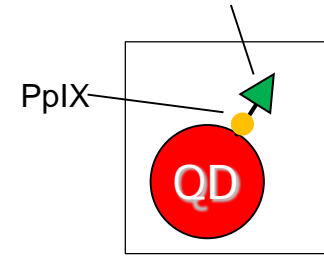


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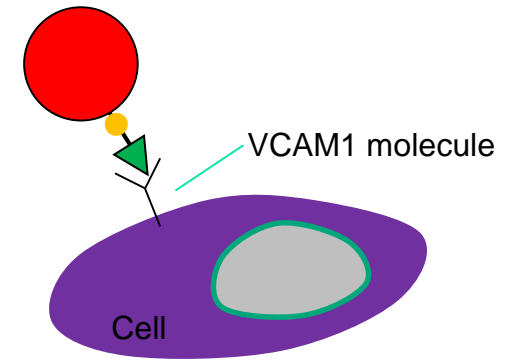
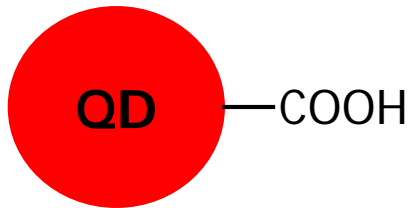


Protoporphyrin IX (PpIX)

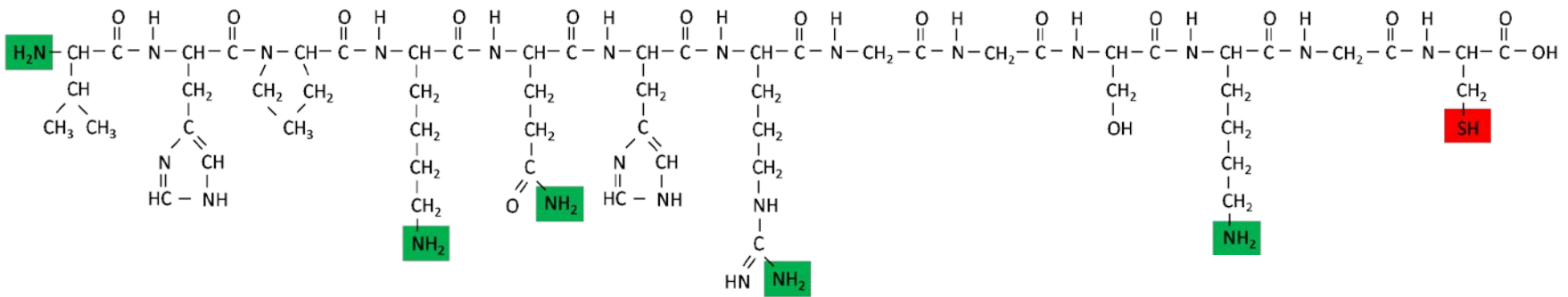
VCAM-1 binding peptide



2

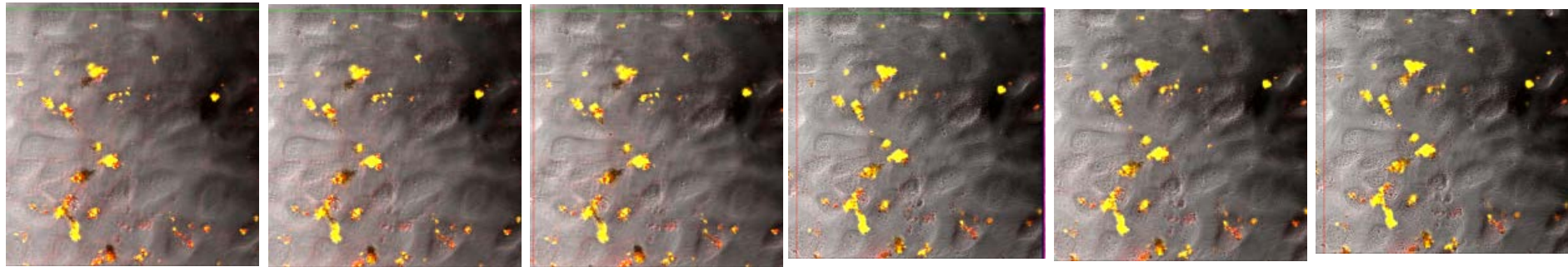


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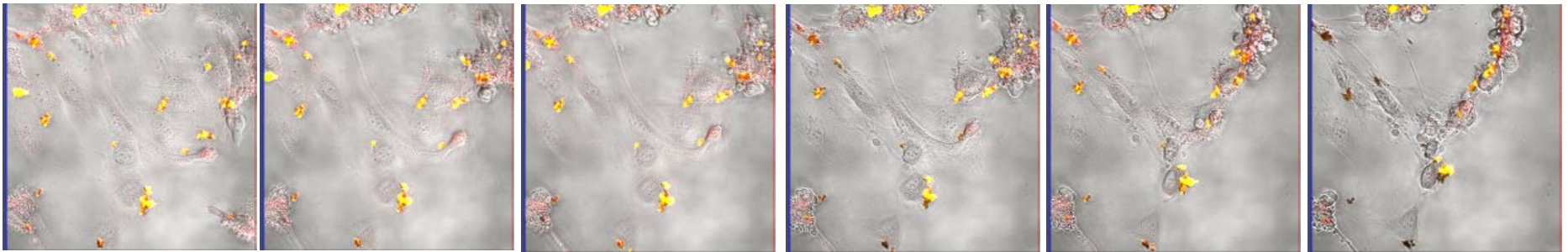


VCAM-1 binding peptide

Non-TNF- α treated cells with 20 μ L PVQs under irradiation of 405nm laser



TNF- α treated cells with 20 μ L PVQs under irradiation of 405nm laser



5 min

10 min

15 min

20 min

25 min

30 min

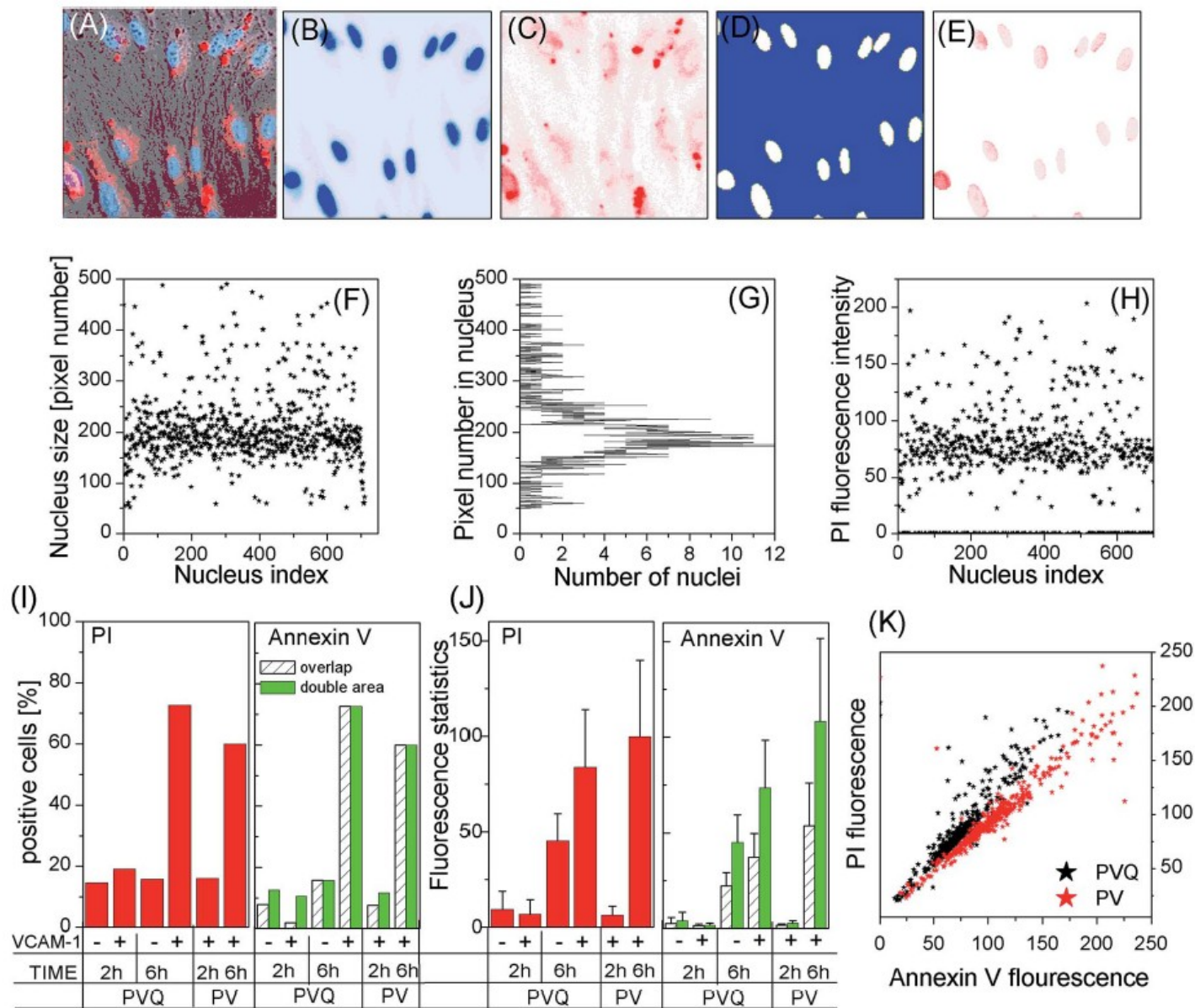
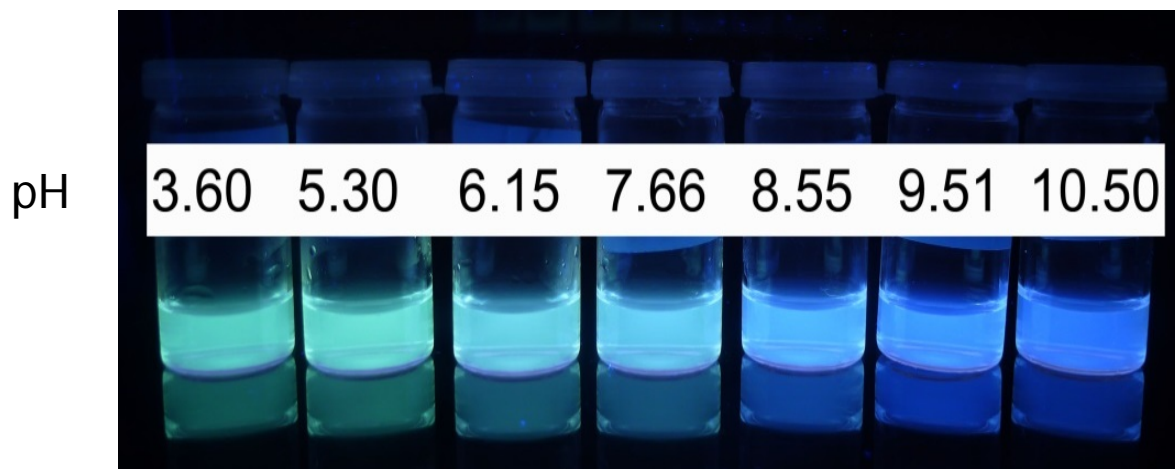
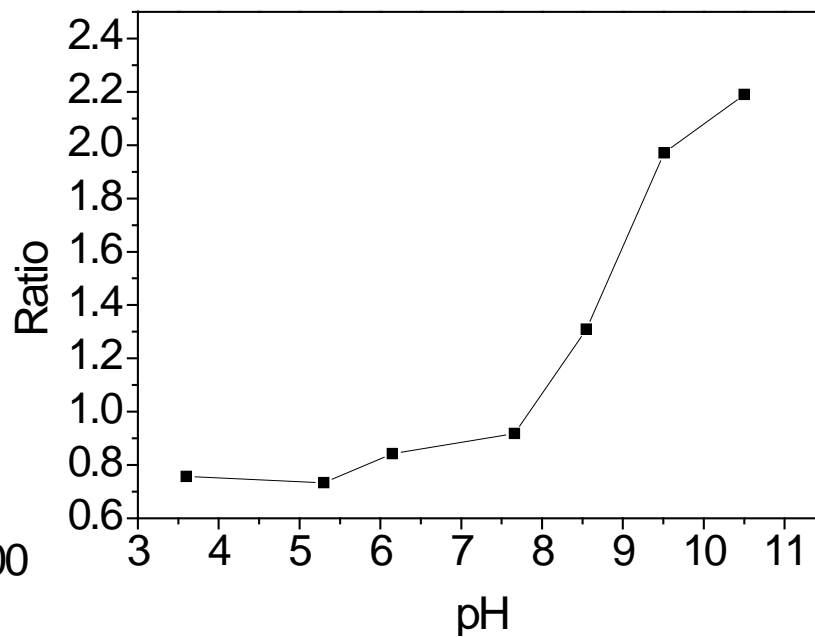
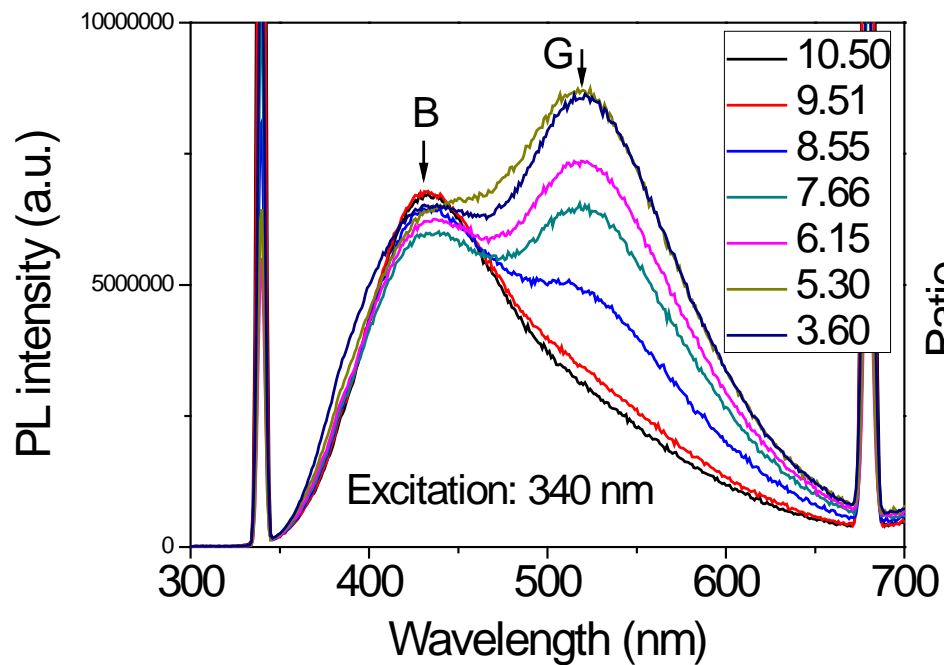


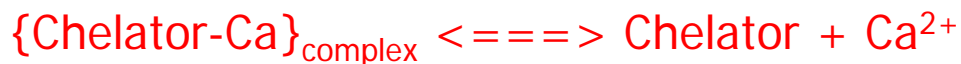
Fig. 6 Apoptosis induced by PDT from the conjugates. (A–H) method to quantify PI signal; (I) the percentage of PI and Annexin-positive cells in different cell groups; (J) PI/Annexin signal intensities in PI/Annexin-positive cells; (K) the correlation of PI and Annexin V in PVQ and PV-induced PDT.



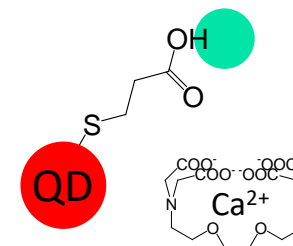
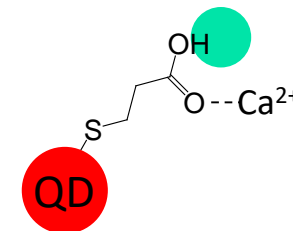
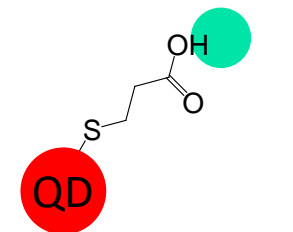
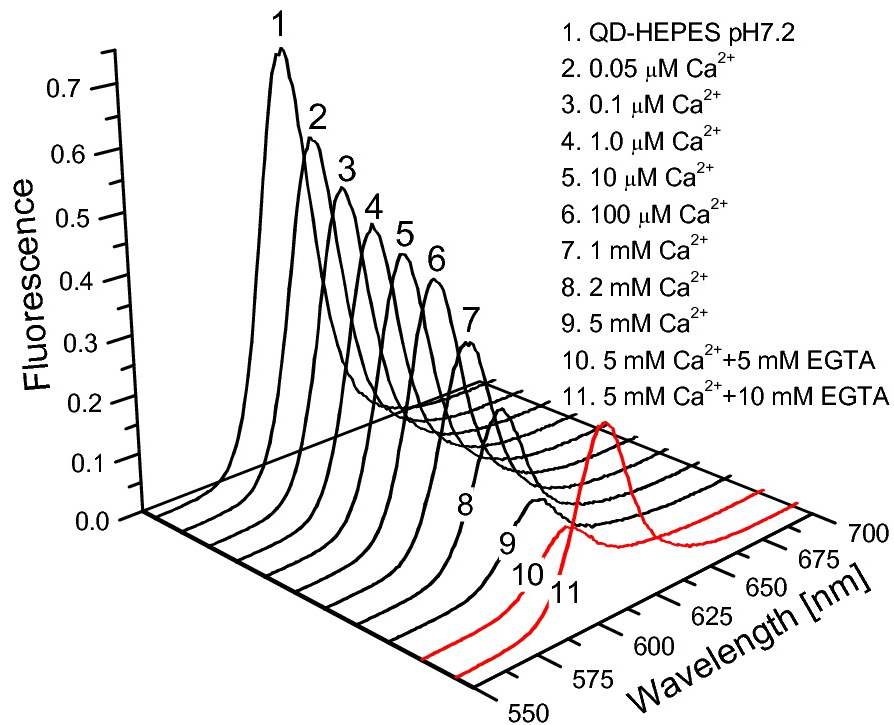
Nitrogen doped **graphene** QDs

Ca²⁺ ion affects QD fluorescence

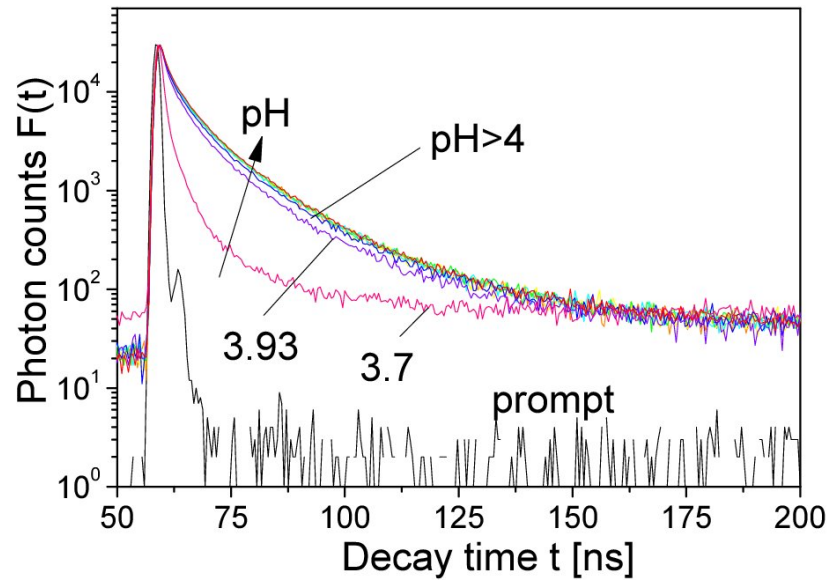
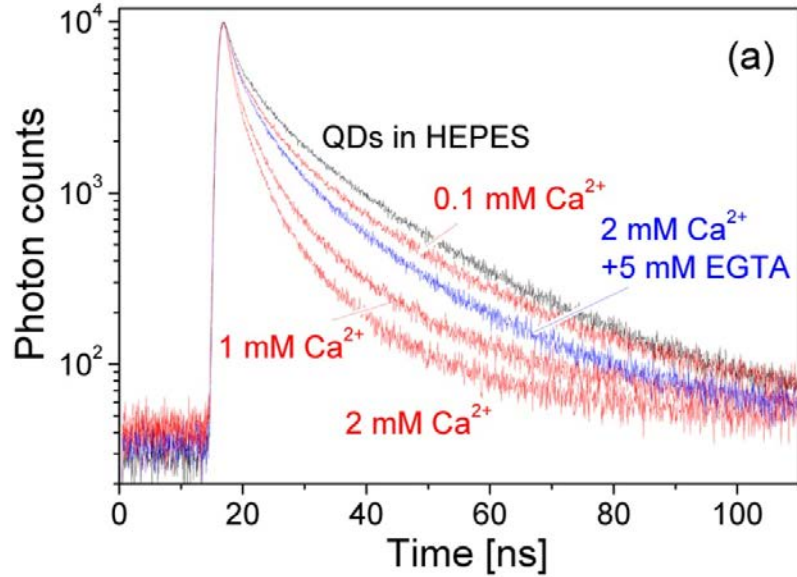
- (1) Ca²⁺ (CaCl₂) with different concentrations into QD solution
- (2) Ca²⁺ chelator, EGTA (Ethylene glycol-bis(2-aminoethylether)-*N,N,N',N'*-tetraacetic acid) to clear free Ca²⁺ in the solution



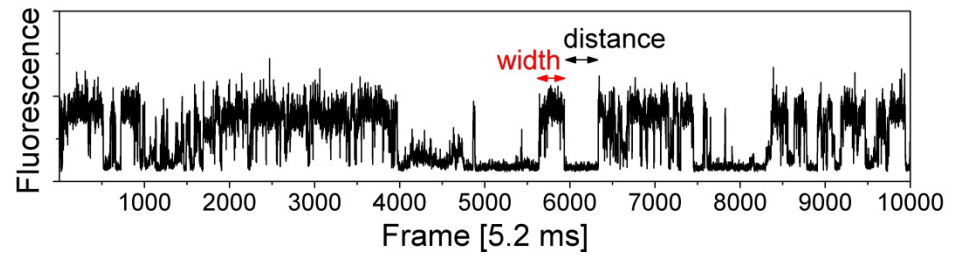
Acid dissociated
De-protonated



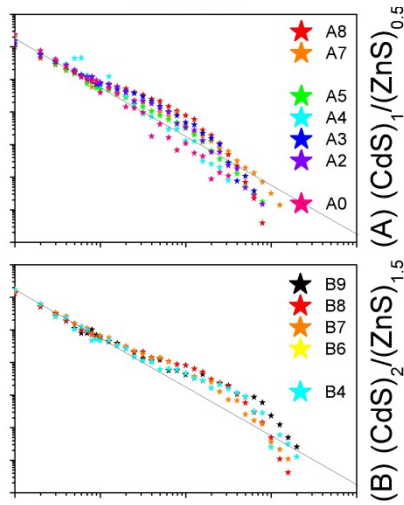
Ca²⁺ , pH affect QD fluorescence lifetime



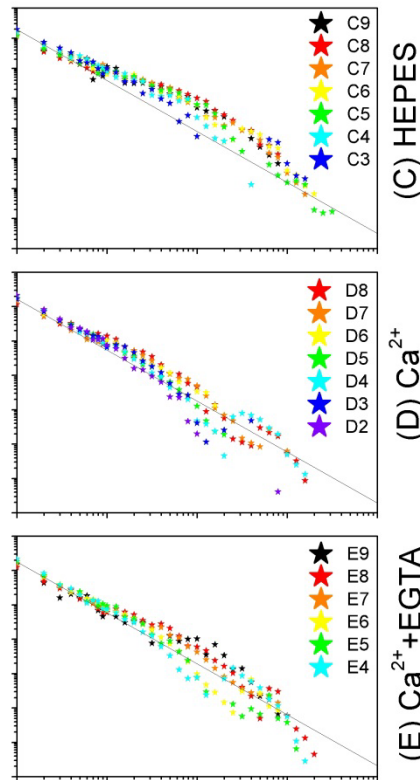
Single QD blinks under CW excitation



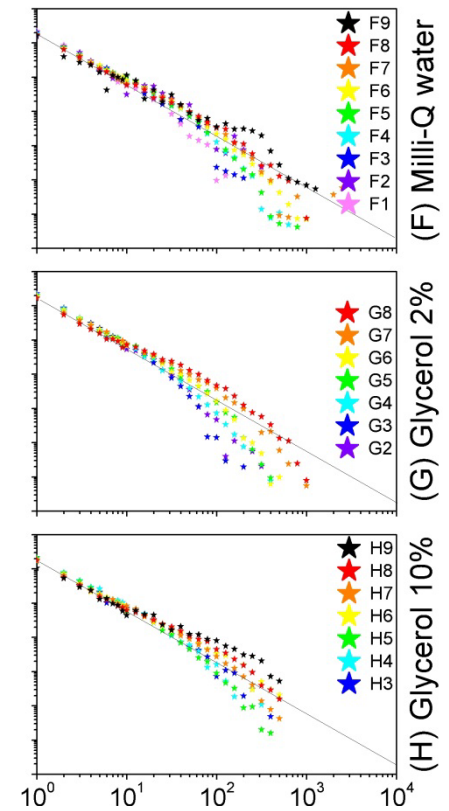
* Different QD structure shows different blinking statistics



* Attaching Ca^{2+} modifies blinking



* Attaching glycerol modifies blinking



- Attaching antibody to form QD-Ab modifies blinking
- Binding target molecule with QD-Ab modifies blinking > trace molecule quantification

