

Nanotechnology

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Nanotechnology in Medicine

Nanoparticles for medical diagnostics, sensors

Nanoparticles for therapeutic delivery

Theranostic nanoparticles, nanorobots

Advantages of Nanomedicine

- Targeted therapeutic delivery
- Response to pathophysiological conditions
- Altered pharmacokinetic profile
 - Prolonged plasma half-life
 - Controlled drug release

Nanomedicine

How big is a nanoparticle?

Nanomedicine

How big is a nanoparticle?

1-1000 nm

Typical size for drug delivery application is approximately 100 nm

Nanomedicine

How big is a nanoparticle?



Length 4.1 m

Nanomedicine

How big is a nanoparticle?



Length 4.1 m



Nanomedicine

4.1 km = 2.5 miles

The screenshot shows the Google Maps interface for Washington D.C., DC. The search bar contains "Washington D.C., DC". The "Get Directions" panel on the left shows a route from "U.S. Capitol" (Point A) to "Lincoln Memorial Cir" (Point B). The map displays a blue walking route starting from the U.S. Capitol and heading west towards the Lincoln Memorial. The route is approximately 2.5 miles long. The map also shows various landmarks, streets, and highways in the area.

Walking directions are in beta.
Use caution – This route may be missing sidewalks or pedestrian paths.

Walking directions to Lincoln Memorial Cir

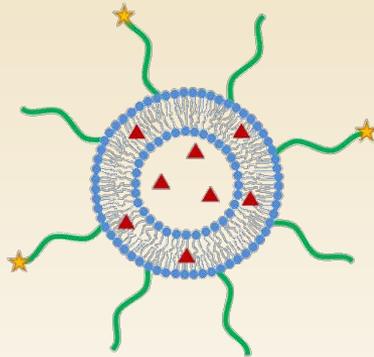
Suggested route	Distance	Time
Maryland Ave SW	2.5 mi	48 mins
Independence Ave SW	2.5 mi	49 mins
Maryland Ave SW and Independence Ave SW	2.5 mi	49 mins

Nanomedicine

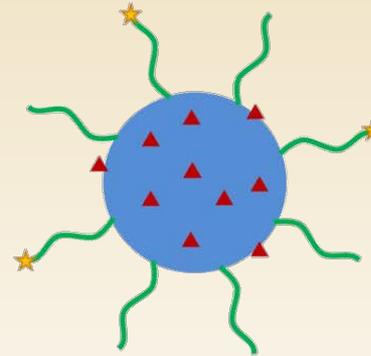
How big is a nanoparticle?

One thousand 100-nm particles “bumper-to-bumper” would span the width of a single human hair.

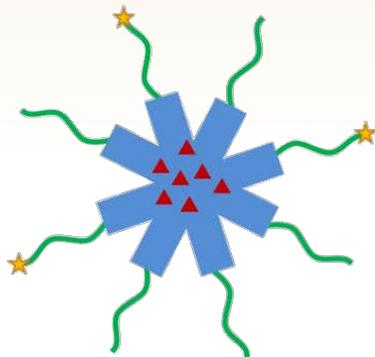
Nanoparticles for Drug Delivery



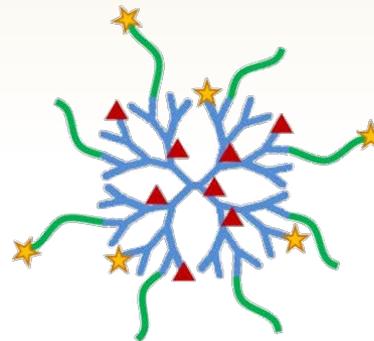
Liposomes



Polymeric Nanoparticles



Polymeric Micelles



Dendrimers

▲ Drug

★ Targeting Moiety

~ Steric Inhibitor

Nanoparticles for Medical Diagnostics

MRI contrast agents with targeting ligands

Fluorescent biosensors

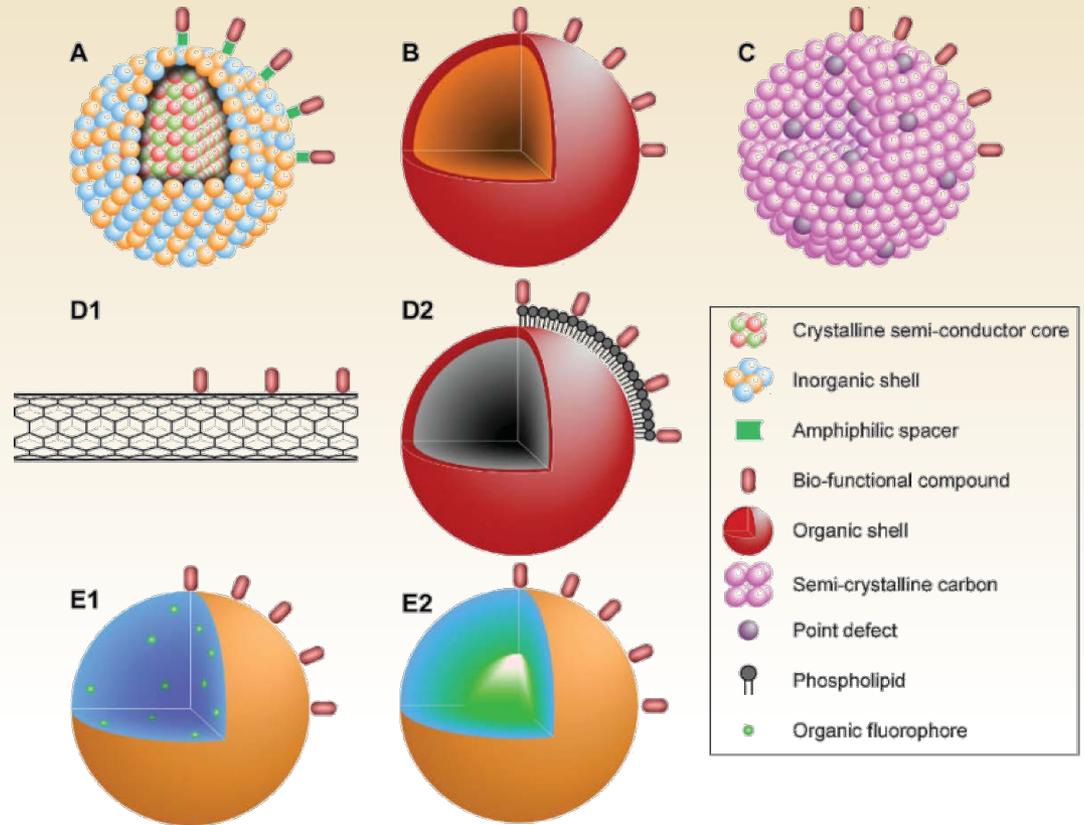


Figure 1. Schematic overview of the composition of A) a QD, B) an AuNP, C) a DNP, D1) a CNT, D2) a C-Dot, E1) a SNP with encapsulated organic fluorophores, and E2) a SNP with a fluorescent core. Several chemical methods for surface binding of bioactive compounds are mentioned in the text. See Table 2 for spatial dimensions.

Nanoparticles for Medical Diagnostics

Ratiometric tumor hypoxia imaging agents

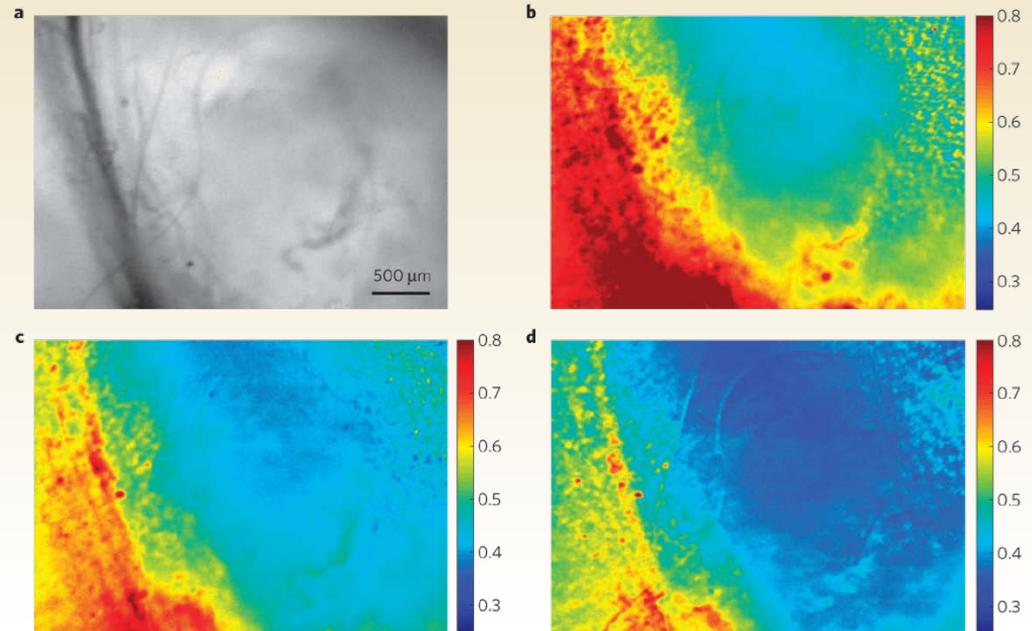
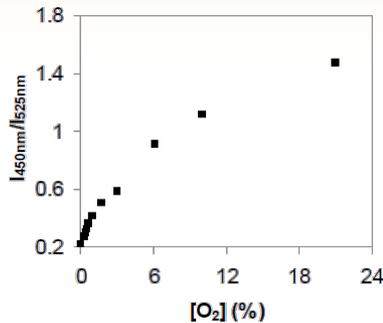
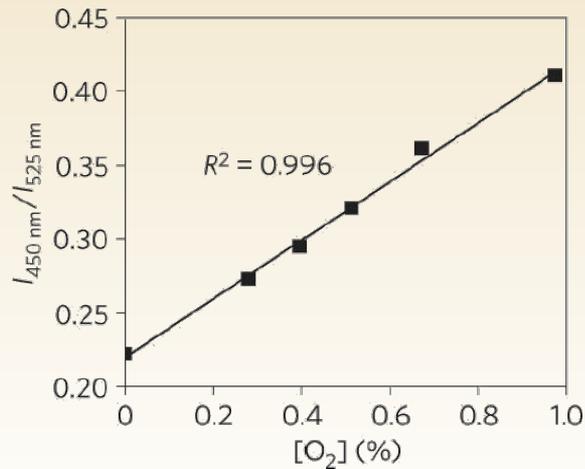


Figure 3. Tumour hypoxia imaging with P2 BF₂dbm(I)PLA nanoparticles
a-c, *In vivo* imaging of the breast cancer 4 T1 mammary carcinoma tumour region in a mouse window chamber model showing the bright-field (a) and BNP fluorescence/phosphorescence ratio while breathing carbogen—95% O₂ (b), room air—21% O₂ (c) and nitrogen—0% O₂ (d). Emission intensity was averaged from 430 to 480 nm (fluorescence) and 530 to 600 nm (phosphorescence). Several blood vessels run vertically on the left side of the images (dark lines in the bright-field image; more oxygenated yellow-red regions in the fluorescence/phosphorescence images), with the tumour comprising the region to the right of the vessels (less-oxygenated blue regions in the fluorescence/phosphorescence images).

Proposed Intravascular Sensors

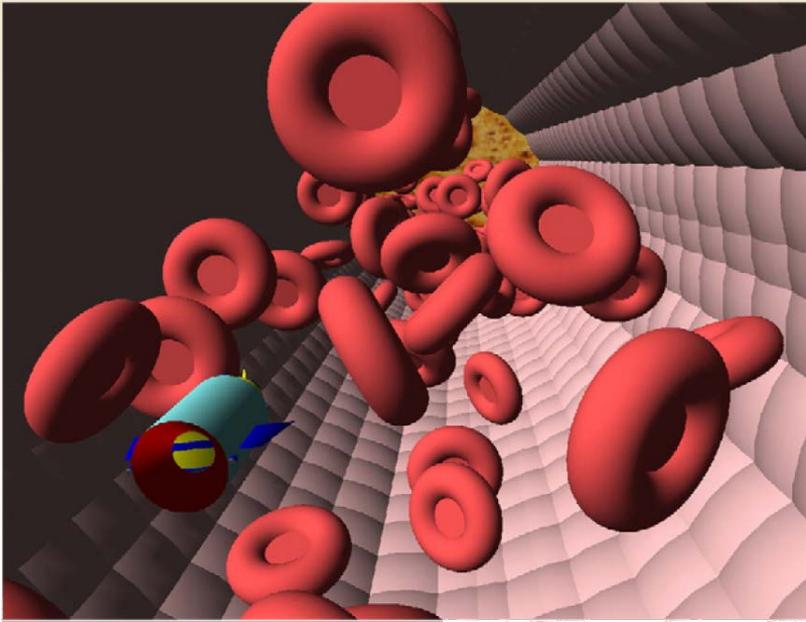


Figure 1. Pervasive monitoring for a patient with diabetes. Embedded nanobiosensors are used to detect glucose levels in bloodstream. The collected information can be transferred to a cell phone as a practical way to interface and communicate with nanorobots.

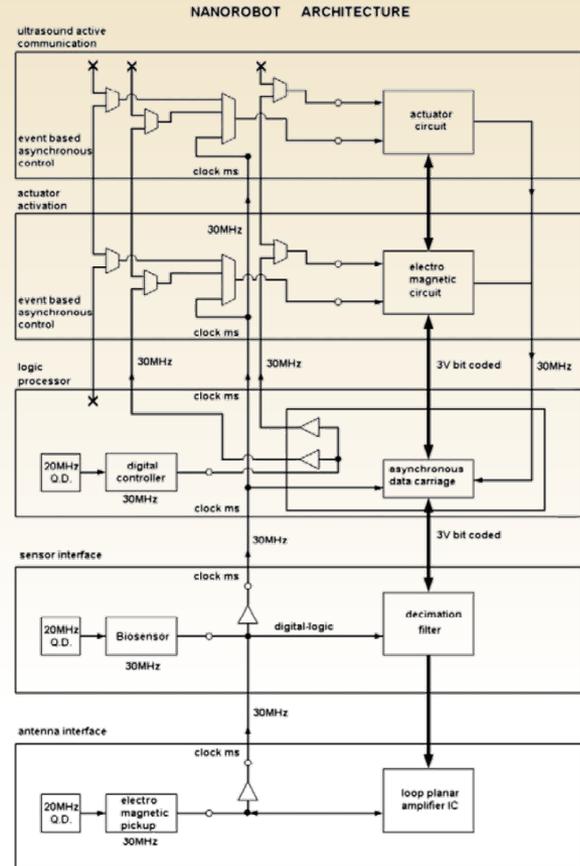


Figure 5. Integrated circuit block diagram.

Nanorobot Movement

Magnetic Resonance Navigation

- Steering provided by a clinical MRI scanner

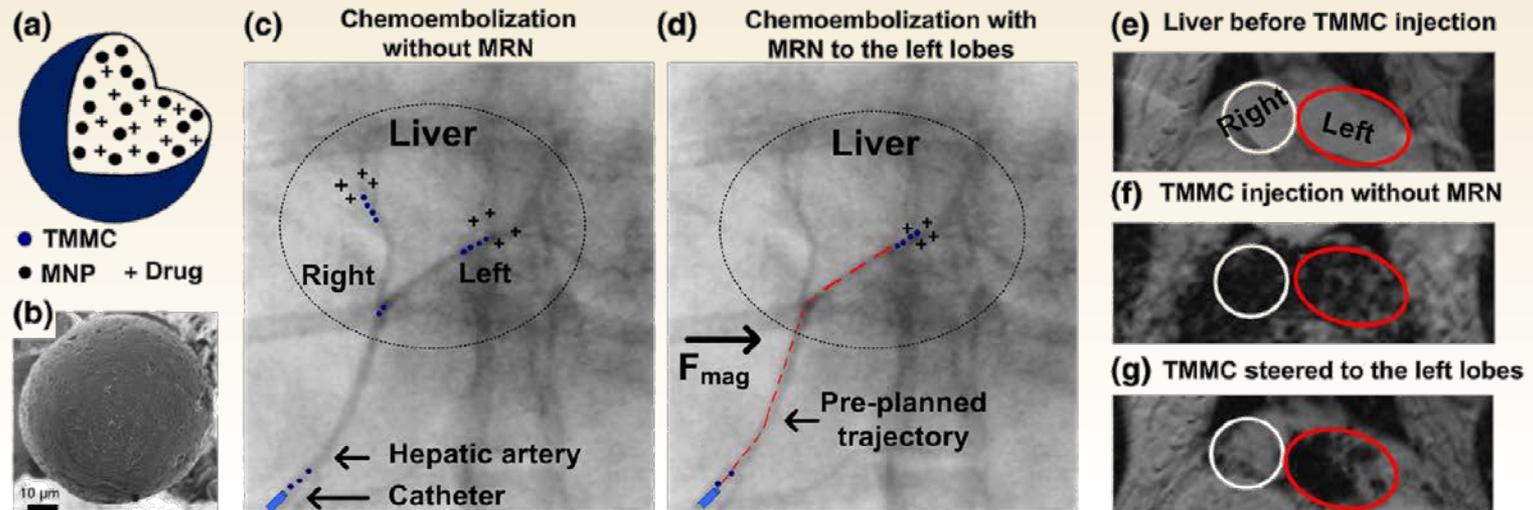


FIGURE 2. Targeted rabbit liver chemoembolization with TMMC. Image (a) corresponds to a schematic representation of TMMC loaded with MNP and an antitumor drug. Image (b) is a scanning electron microscopy image of TMMC. Images (c, d) are fluorescence images of the rabbit hepatic artery with superposed images of the TMMC distribution without (c) and with (d) MRN. On image (c), the microcarriers are released from the catheter in the artery and deliver to both lobes. Image (d) displays the targeting of the left bifurcation by MRN according to a pre-planned trajectory. Images (e–g) correspond to *in vivo* liver T2*-weighted gradient-echo MR images before (e) and after TMMC injection without (f) and with MRN (g). Without MRN, the right and left lobes are darkening, indicating the presence of TMMC in the whole liver. With steering to the left lobes, the right lobe appears mainly free of TMMC (Adapted from Pouponneau *et al.*,³⁹ NanoRobotics Laboratory, Ecole Polytechnique de Montréal).

Nanorobot Movement

Propulsion by Pt-catalyzed decomposition of H_2O_2
or by flagella with ATP fuel source

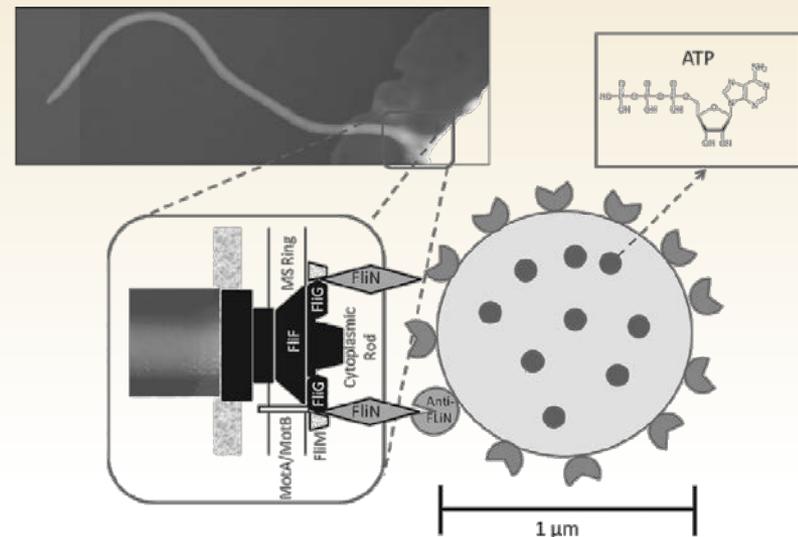
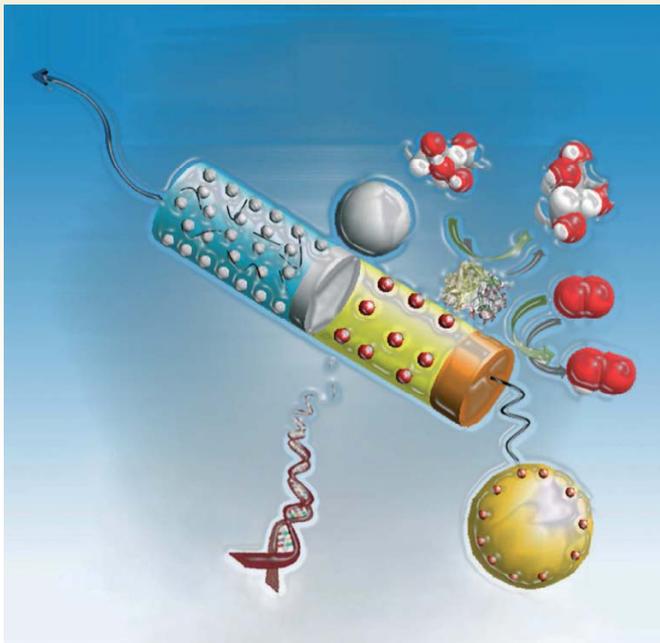


Fig. 1. Schematic of the envisioned nanorobot. The core of the robot is a polysaccharide-based nanoparticle, where modular components can be attached using known chemistry. The propulsive system is a fully functional flagella isolated from *E. coli*, attached to the core by means of the FLiN protein on the flagella and anti-FLiN receptors on the core. To power the propulsive system, ATP will be encapsulated into the nanoparticle core.

Actuation

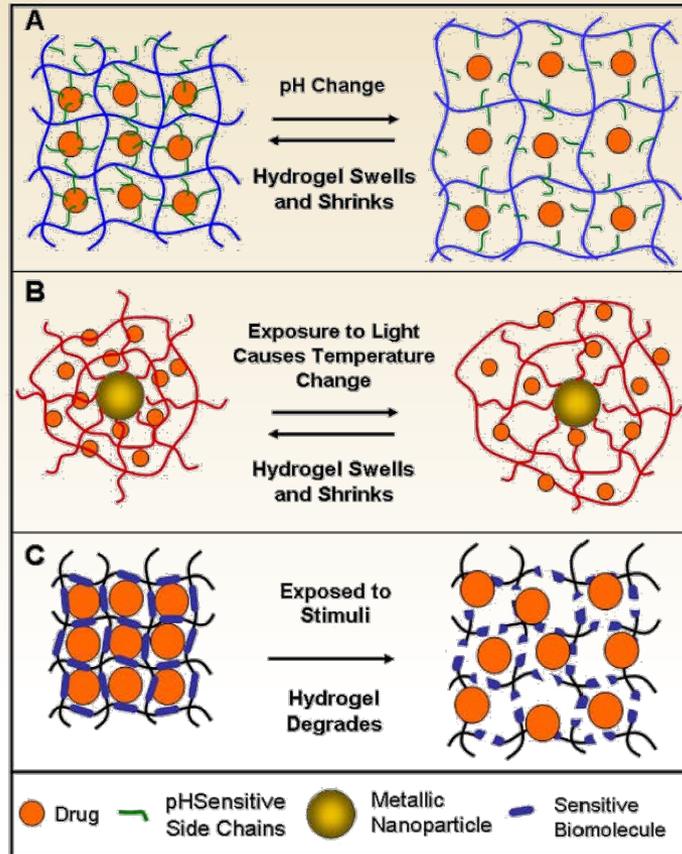


Fig. 1. Versatility of hydrogel networks: (A) pH-sensitive hydrogels: When the hydrogel is in a low pH environment, the polymer network entraps the loaded agents within the network but once the network is exposed to a higher pH environment, the polymer network swells and releases the drug. (B) Temperature sensitive hydrogels: When the hydrogel is exposed to a temperature change, the hydrogel network will either swell and release encapsulated agents or shrink to encapsulate agents. (C) Biomolecule sensitive hydrogels: These gels have a stimuli responsive biomolecule incorporated directly into their polymer hydrogel network. When these molecules are exposed to the particular agent they are sensitive to, the biomolecule will breakdown and in turn the hydrogel network will degrade and release the drug that was encapsulated within the gel.

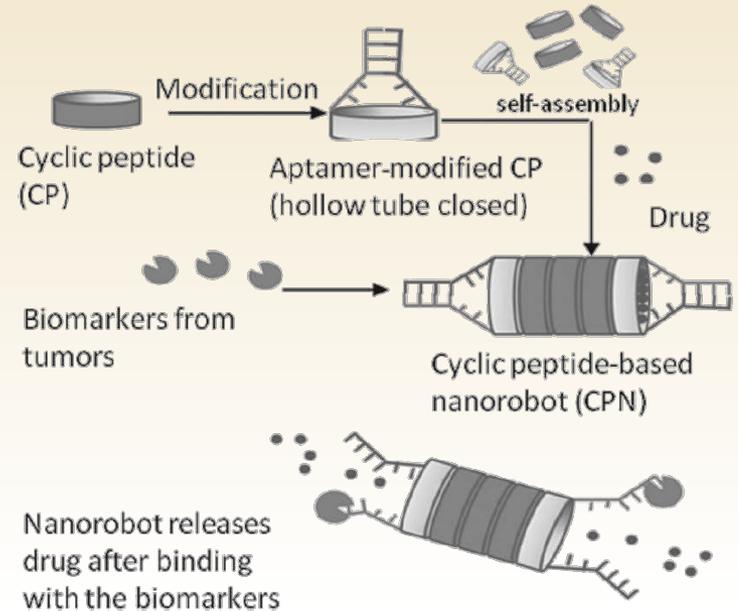


Fig. 2. Schematic of the CP nanorobot core with the aptamers designed for closing and locking the nanotube.

Current Challenges

- Biocompatibility
 - Immunogenicity
 - In vivo fate of nanomaterials
- Power supply
 - Lack of miniaturized batteries, circuit boards, inductive coupling
- Wireless communication and actuation
- Computation, decision-making abilities