

# Nanotecnología Aplicada a Biofilms

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Nicolás Navarro M.  
Químico Farmacéutico

Dra. Erlen Cruz  
Química



# Tabla de Contenidos

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**Generalidades  
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2

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Metálicas**

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**Nanopartículas  
Poliméricas**

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1

# Generalidades Nanotecnología

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*“Nano-technology’ mainly consists of the processing of separation, consolidation, and deformation of materials by one atom or one molecule.”*

—Norio Taniguchi  
International Conference on Production  
Engineering, 1974, Tokyo.

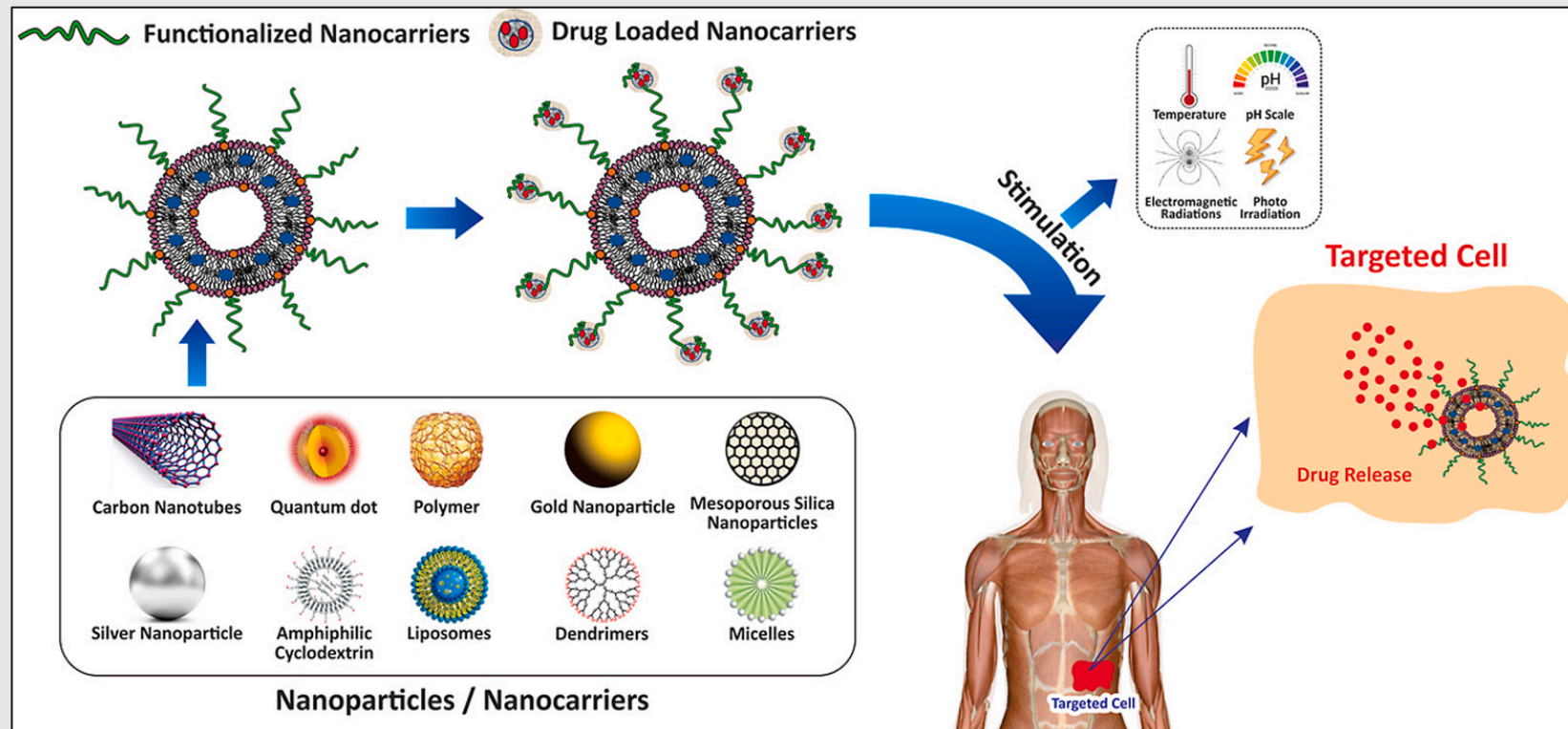
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# INTRODUCCIÓN

“Nanotechnology is the creation of functional materials, devices, and systems through control and manipulation of matter on the nanometer length scale (1-100 nanometers). At this scale, engineers have the ability to exploit novel phenomena and material properties, be they physical, chemical, biological, mechanical, or electrical”

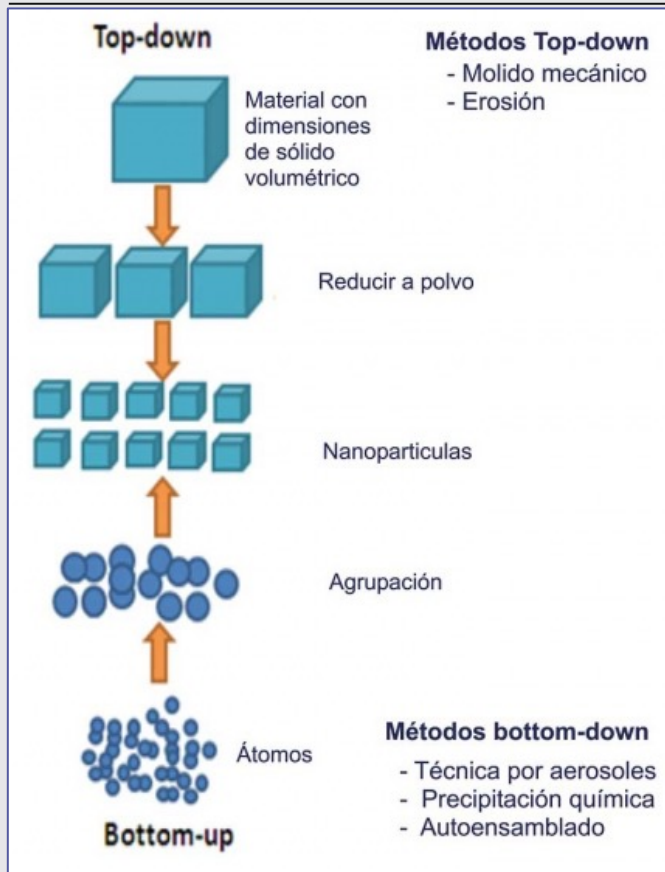


# Nanotecnología aplicada a la medicina



Shah A. et al., J Drug Deliv Sci Technol. 2021;61; 102426.

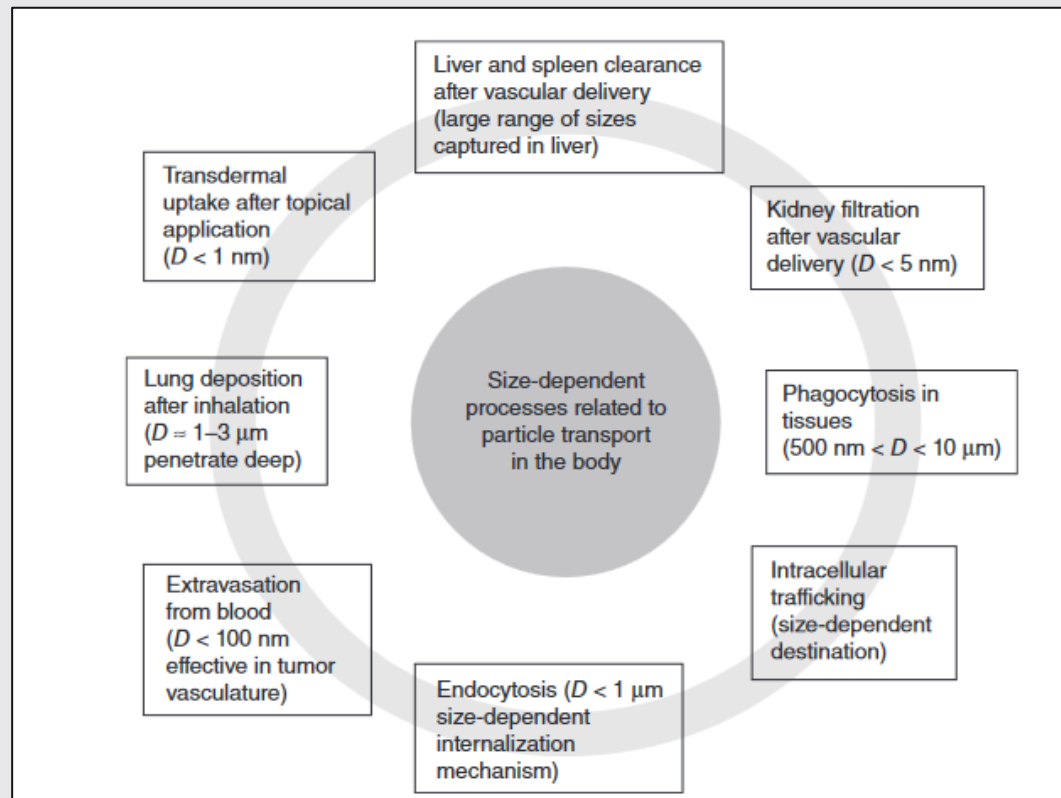
# Nanotransportadores



Son sistemas coloidales en la escala nanométrica (1 - 100 nm), capaces de transportar drogas u otras sustancias de distinta naturaleza.

Din, F. et al. (2017). Effective use of nanocarriers as drug delivery systems for the treatment of selected tumors. *International journal of nanomedicine*, 12, 7291–7309.

# Nanotransportadores

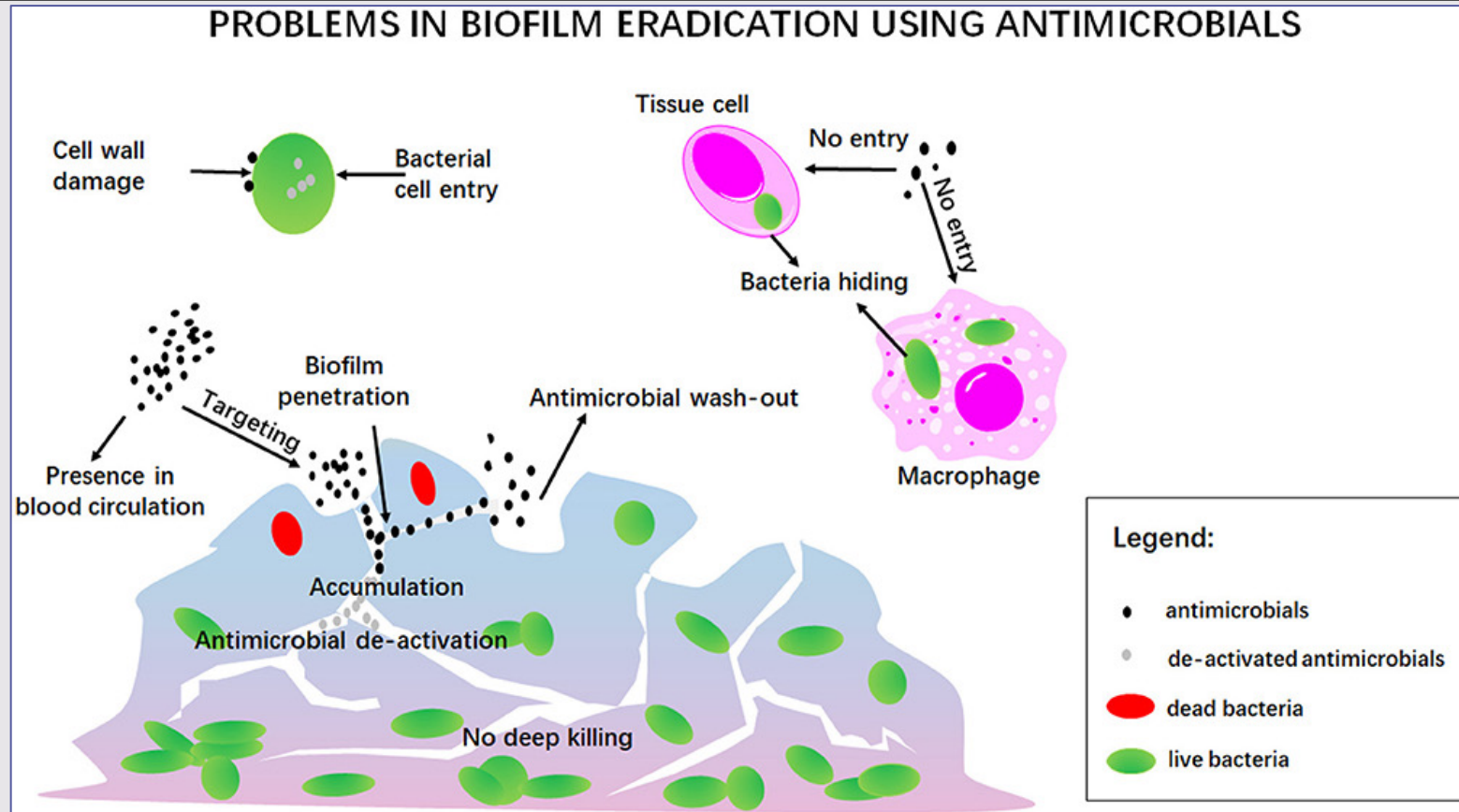


Particle Size Relative to Clearance and Applications	
Particle Size (Based on Rigid Sphere)	Nanomedicine Applications
$< 10 \text{ nm}$	Rapidly cleared through extravasation or renal clearance
$10\text{--}20 \text{ nm}$	Detection, imaging, potential to cross blood-brain barrier (BBB)
$20\text{--}100 \text{ nm}$	Drug/gene delivery, cancer therapy, sites of inflammation (optimal range to escape physiological barriers; high circulation potential, reduced filtration by liver and spleen)
$100\text{--}200 \text{ nm}$	Drug/gene delivery (high potential for prolonged circulation)
$200 \text{ nm}\text{--}1 \text{ }\mu\text{m}$	Generally cleared by the spleen
$> 1 \text{ }\mu\text{m}$	Usually opsonized and accumulate in liver and spleen, cleared from circulation almost immediately

Mitragotri S, Lahann J. Physical approaches to biomaterial design. Nat Mater 2009, 8:15–23. doi:10.1038/nmat2344

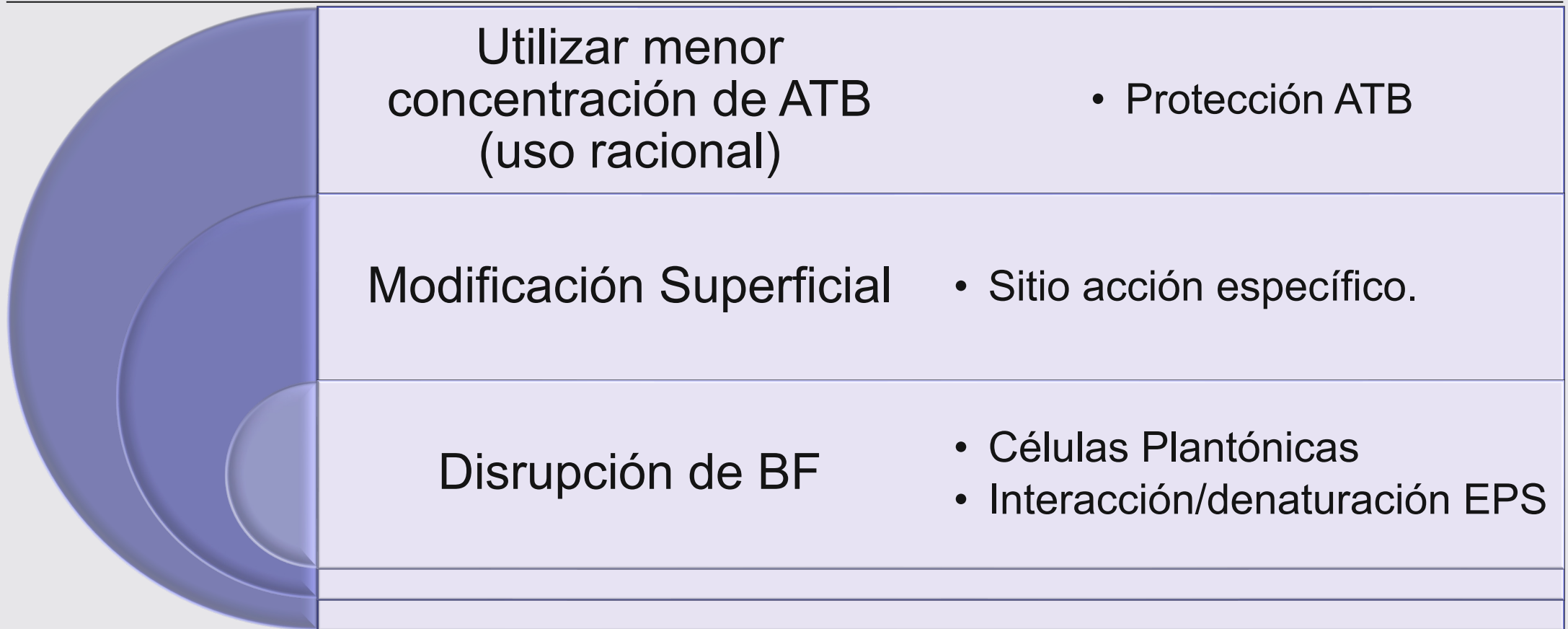


# Nanotransportadores de ATB



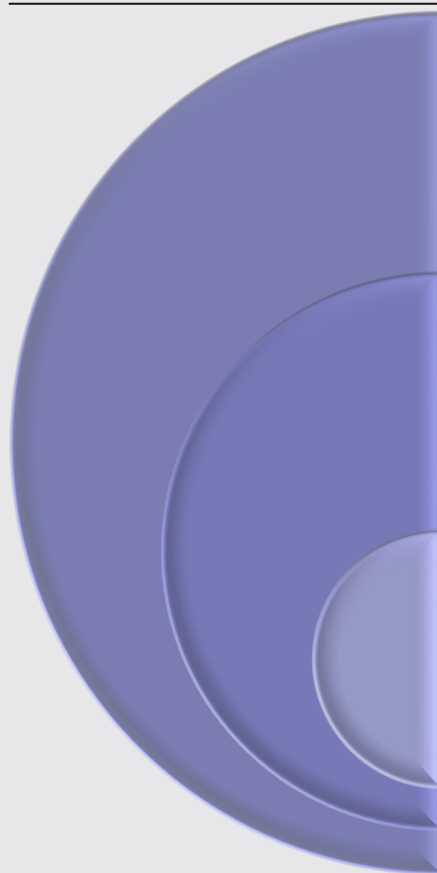
Wang DY, van der Mei HC, Ren Y, Busscher HJ, Shi L. Lipid-Based Antimicrobial Delivery-Systems for the Treatment of Bacterial Infections. Front Chem. 2020

# Nanotransportadores de ATB



Din, F. et al. (2017). Effective use of nanocarriers as drug delivery systems for the treatment of selected tumors. *International journal of nanomedicine*, 12, 7291–7309.

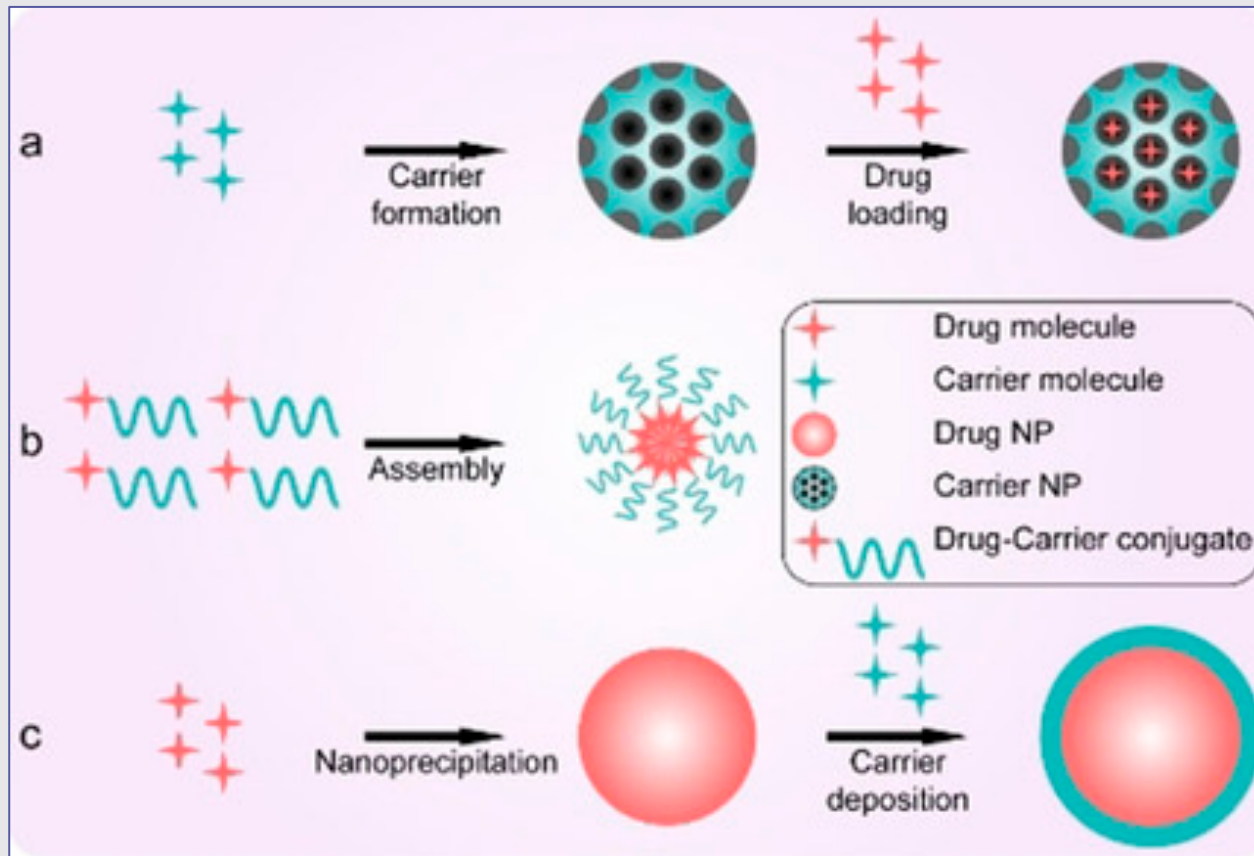
# Nanotransportadores de ATB



Strain	MIC against free antibiotics (mg/L)	MIC against liposomal encapsulated antibiotics (mg/L)	References
<b>Vancomycin</b>			
<i>E. coli</i>	512	6–25	Nicolosi et al., 2010
	512	10.5	
<i>Klebsiella</i>	512	25–50	
<i>P. aeruginosa</i>	512	50	
	512	83.7	
<i>Acinetobacter baumannii</i>	512	6–125	
<i>S. aureus</i> (MRSA)	1	0.5	Bhise et al., 2018
<b>Amikacin</b>			
<i>P. aeruginosa</i>	8	4	Mugabe et al., 2006

Wang DY, van der Mei HC, Ren Y, Busscher HJ, Shi L. Lipid-Based Antimicrobial Delivery-Systems for the Treatment of Bacterial Infections. Front Chem. 2020

# Nanotransportadores de ATB



Y. Liu, G. Yang, S. Jin, L. Xu, C.-X. Zhao, *ChemPlusChem* **2020**, *85*, 2143.

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¿De qué manera podemos utilizar la NT para el control de BF?

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¿De qué manera podemos utilizar la NT para el control de BF?



**Modificación  
Superficial**



**Nanocarriers  
ATB/ATM**

# ¿De qué manera podemos utilizar la NT para el control de BF?



## Modificación Superficial

Catéteres centrales de acceso venoso

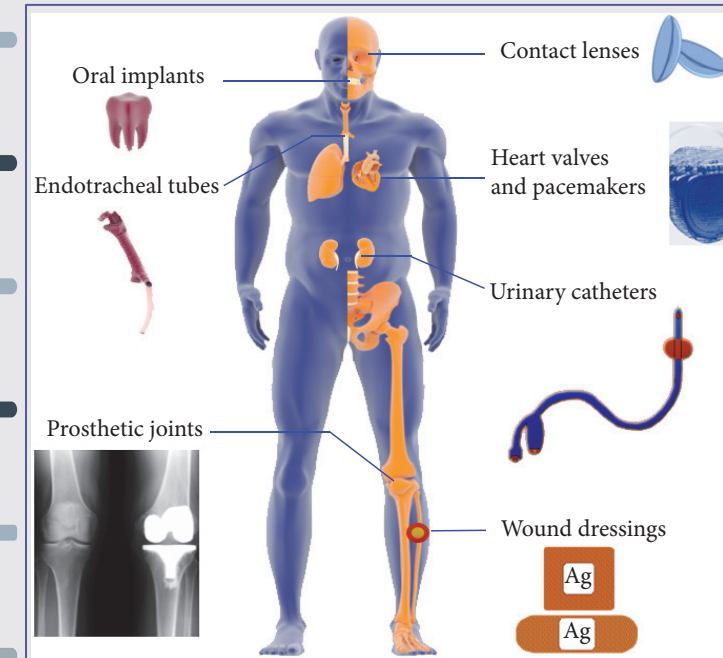
Catéteres urinarios

Tubos endotraqueales

Implantes dentales

Implantes articulares

Marcapasos y Válvulas cardiacas

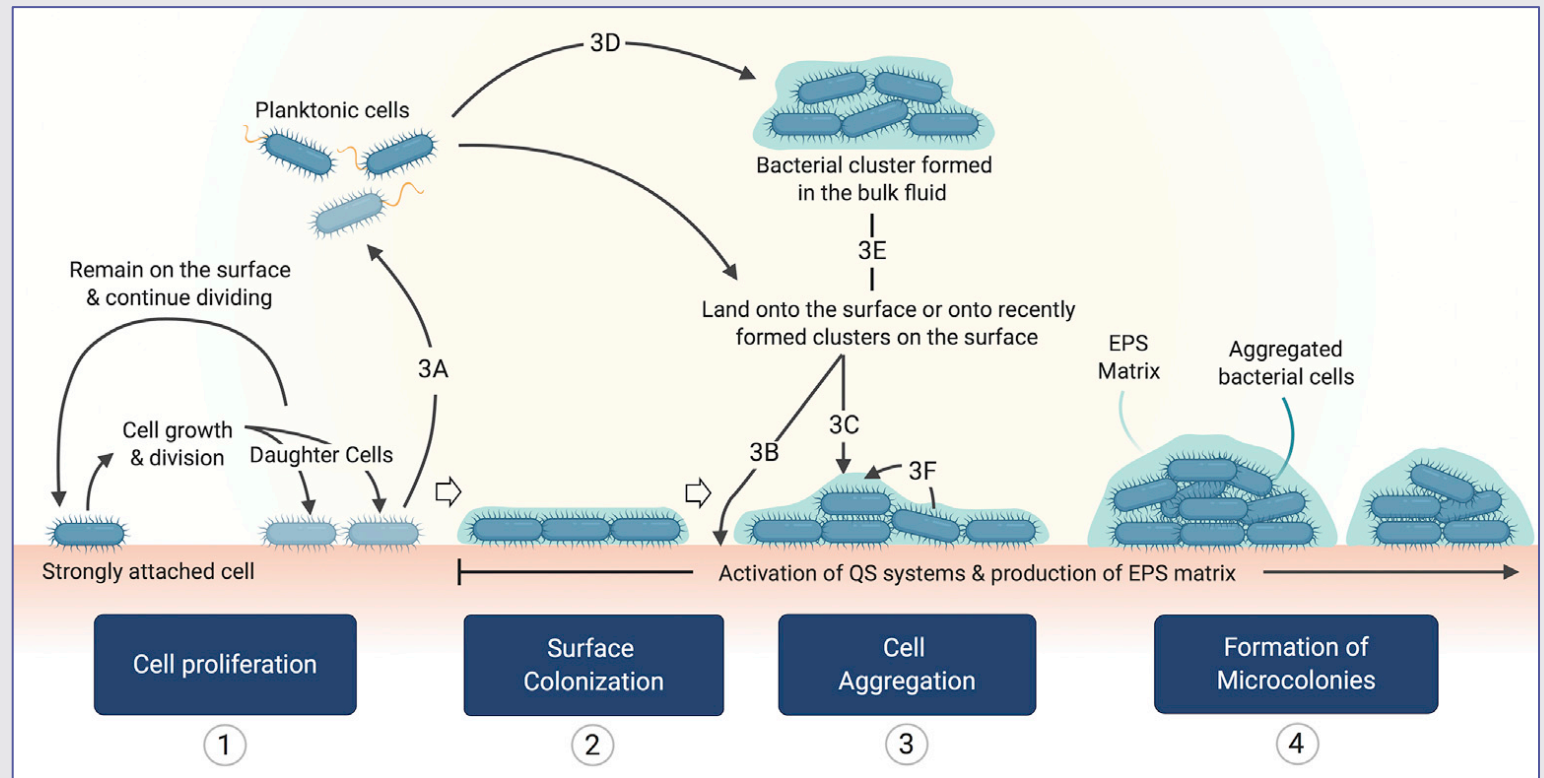


Ramasamy M, Lee J. Recent Nanotechnology Approaches for Prevention and Treatment of Biofilm-Associated Infections on Medical Devices. Biomed Res Int. 2016.

# ¿De qué manera podemos utilizar la NT para el control de BF?



## Modificación Superficial



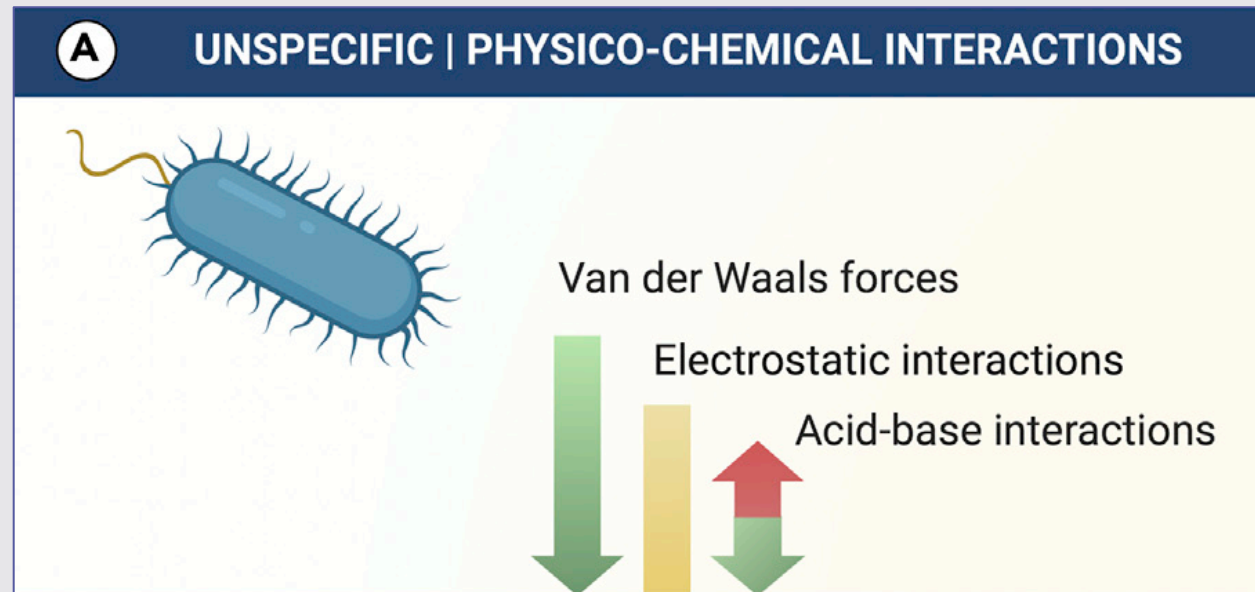
Guzmán-Soto I. et al. Mimicking biofilm formation and development: Recent progress in *in vitro* and *in vivo* biofilm models. *iScience*. 2021



# ¿De qué manera podemos utilizar la NT para el control de BF?



## Modificación Superficial



Guzmán-Soto I. et al. Mimicking biofilm formation and development: Recent progress in *in vitro* and *in vivo* biofilm models. *iScience*. 2021

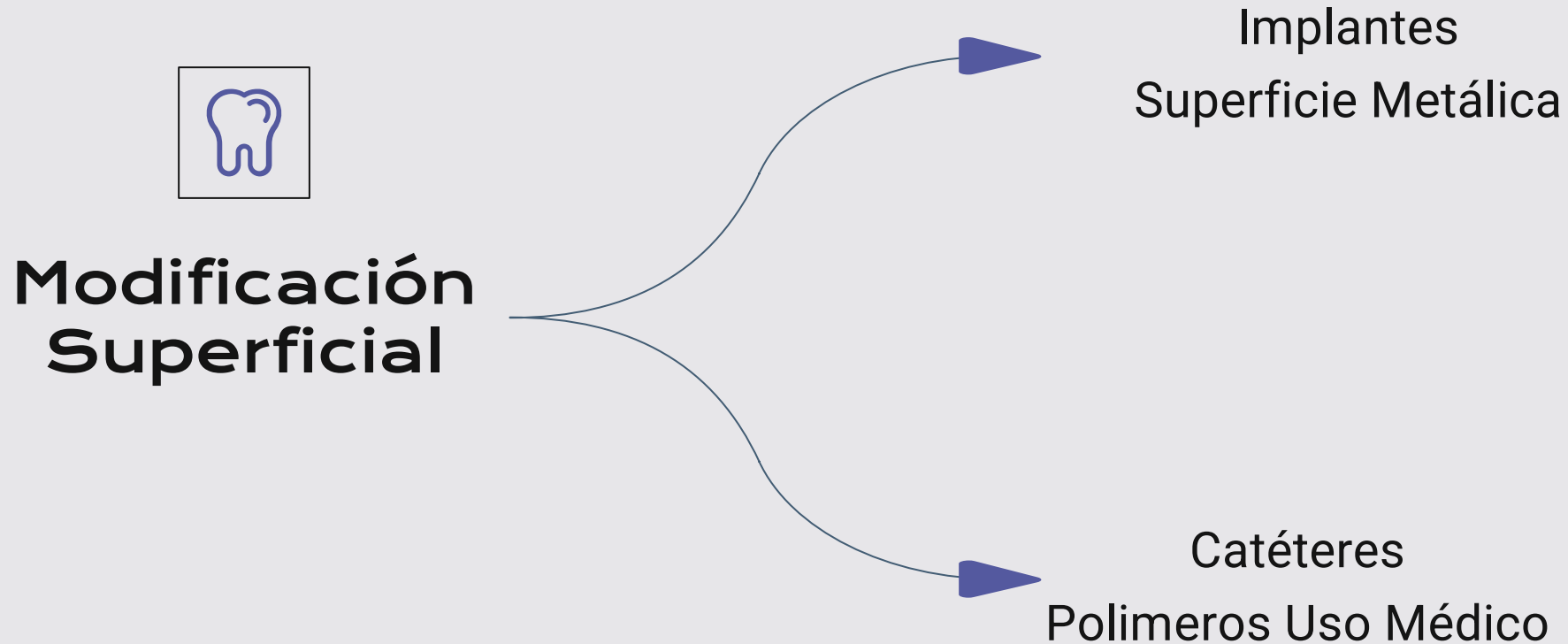
# ¿De qué manera podemos utilizar la NT para el control de BF?



## Modificación Superficial

- 1) *Antifouling coatings* (Dureza, carga, hidrofobicidad)
- 2) Modificaciones antiadhesivas (polímeros)
- 3) Adición de antimicrobianos.
- 4) Modificación química.
- 5) Adición de moléculas bioactivas (QSi).

# ¿De qué manera podemos utilizar la NT para el control de BF?



# Modificación Superficies Metálicas

**Table 2** Summary of Implant Coatings

Implant coating	Example	Studies	Outcome
Carbon coating <sup>15-18</sup>	Currently not on the market; still being investigated	In vitro, in vivo studies, and clinical studies	Improved biologic properties and histocompatibility but studies are still under way
Bisphosphonates <sup>19-22</sup>	Currently not on the market; still being investigated	No long-term studies available	No long-term studies available
Bone stimulating Factors <sup>23-27</sup>	Currently not on the market; still being investigated	Pilot animal studies and clinical studies	Studies are still under way
Bioactive glasses and ceramics <sup>28-30</sup>	Currently not on the market; still being investigated	Chemical, in vivo, and in vitro studies	Studies are still under way
Fluoride coatings <sup>31</sup>	OsseoSpeed	In vitro studies	Selective osteoblast differentiation results
Hydroxyapatite (HA) <sup>32-36</sup>	Restore Implant system	In vivo, in vitro, and retrieval studies	Most commonly used type of implant coating; other implant coating studies mainly use HA as a control
Titanium/titanium nitride <sup>37-41</sup>	IonFusion	In vitro, in vivo, and clinical studies	Titanium mechanical properties are considered in relation to the degree of osseointegration

Xuereb M, et al. Int J Prosthodont. 2015 Jan-Feb;28(1):51-9.

# Modificación Superficies Metálicas

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Plasma Spraying

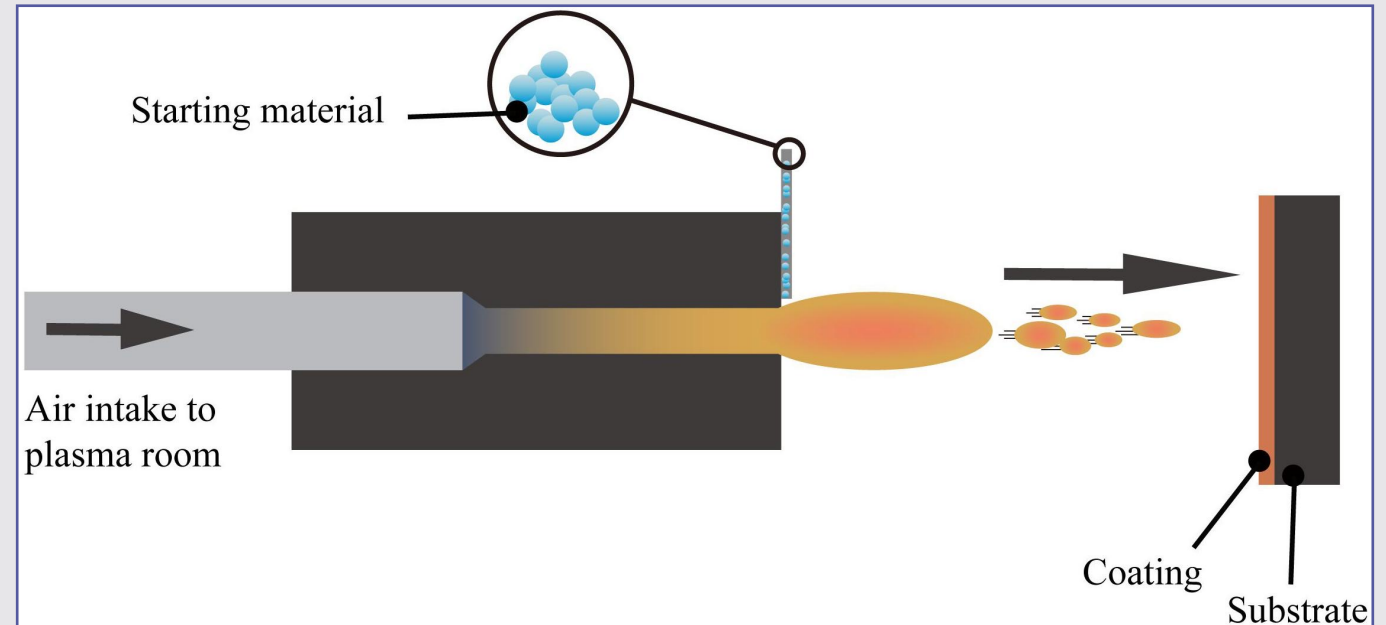
Electrochemical  
Anodization

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Xuereb M, et al. Int J Prosthodont. 2015 Jan-Feb;28(1):51-9.

# Plasma Spraying

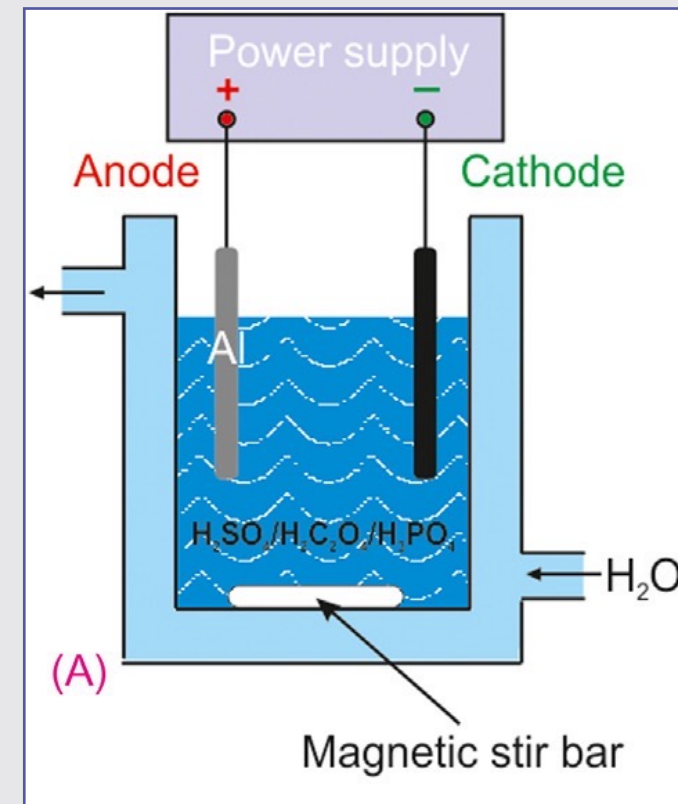
- Gold Estándar.
- Cerámicas (HA) y Metales.
- Recubrimiento Nanométrico.
- Gran estabilidad y control.
- Alta eficiencia de deposición y baja porosidad.



Liu Jianqiao, et al. *Frontiers in Bioengineering and Biotechnology*, (8), 1314, 2020.

# Electrochemical Anodization

- Películas de óxido anódicas.
- Morfología compacta, nanoporosa o nanotubular.
- Dopaje metales (Zn, Ag, Au, Cu, etc).
- Modificación estructural.
- Bajo costo.
- Escalabilidad técnica.



Grzegorz D. Sulka, Chapter one - Introduction to anodization of metals, In Micro and Nano Technologies, Nanostructured Anodic Metal Oxides, Elsevier, 2020, Pages 1-34.

# Electrochemical Anodization

Formación de nanotubos en superficie de implantes de titanio.

- Bajo costo
- Control de características superficiales
  - El diámetro del nanotubo se puede controlar mediante el voltaje de oxidación.
  - La longitud del nanotubo se controla mediante la combinación del tiempo de oxidación, la temperatura de oxidación y el valor de pH del electrolito.

Liu Jianqiao, et al. *Frontiers in Bioengineering and Biotechnology*, (8), 1314, 2020.



# Electrochemical Anodization

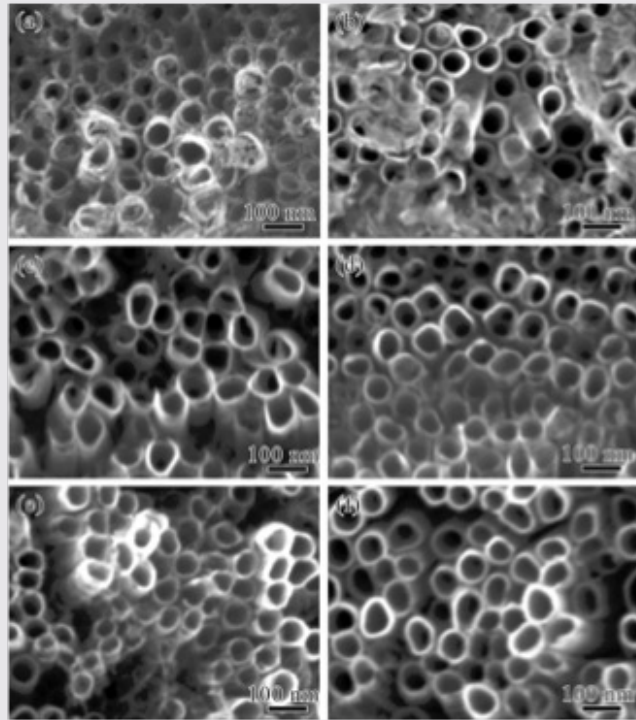


Figure 4. FE-SEM images representing the top view of ZnO-TNTs. (a) Undoped TNTs (spray-gold), (b)  $1 \text{ mM} \cdot \text{L}^{-1}$  ZnO-TNTs, (c)  $2 \text{ mM} \cdot \text{L}^{-1}$  ZnO-TNTs, (d)  $3 \text{ mM} \cdot \text{L}^{-1}$  ZnO-TNTs, (e)  $4 \text{ mM} \cdot \text{L}^{-1}$  ZnO-TNTs, (f)  $5 \text{ mM} \cdot \text{L}^{-1}$  ZnO-TNTs.

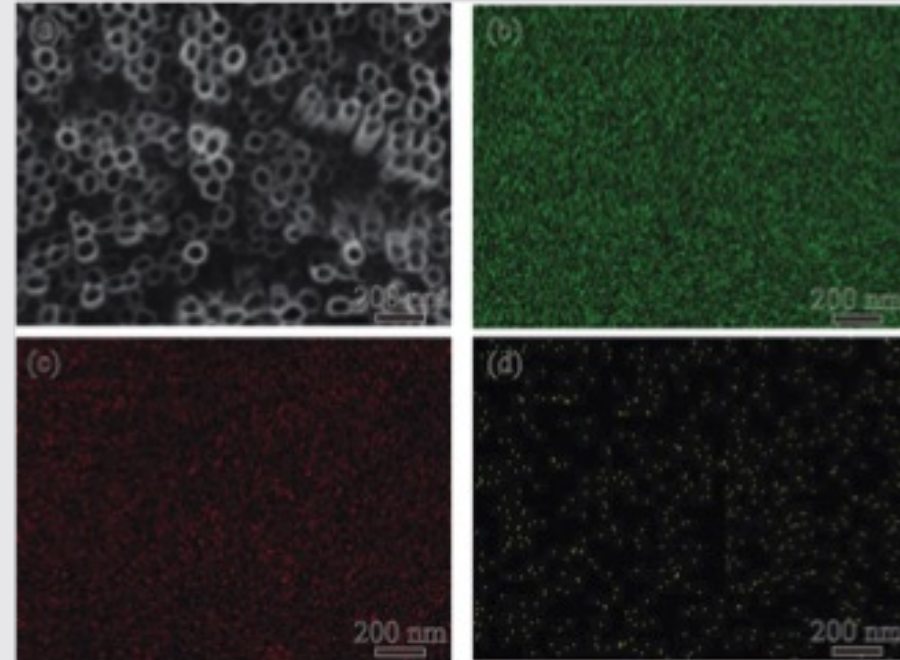


Figure 8. EDS analysis of ZnO-TNTs. (a) The selected area, (b) the distribution of Ti, (c) the distribution of O, (d) the distribution of Zn.

Chang F, et al. J Nanosci Nanotechnol. 2019 Apr 1;19(4):2070-2077.

# Electrochemical Anodization

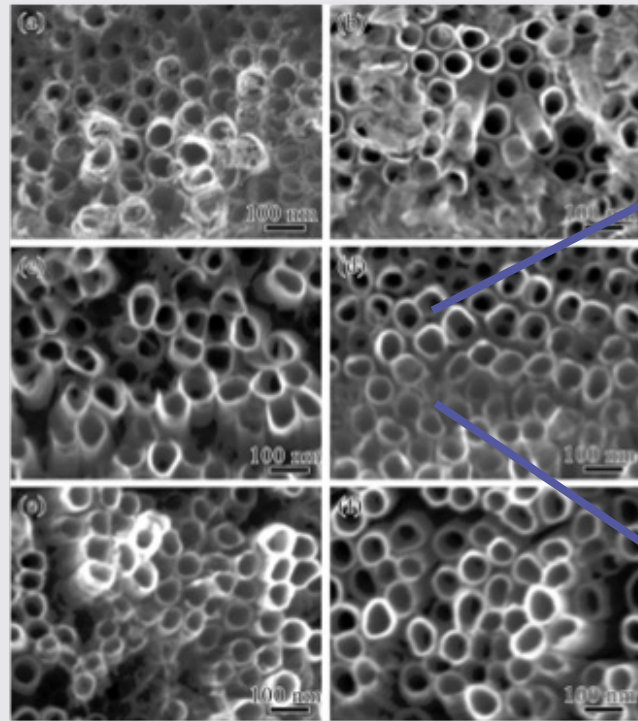


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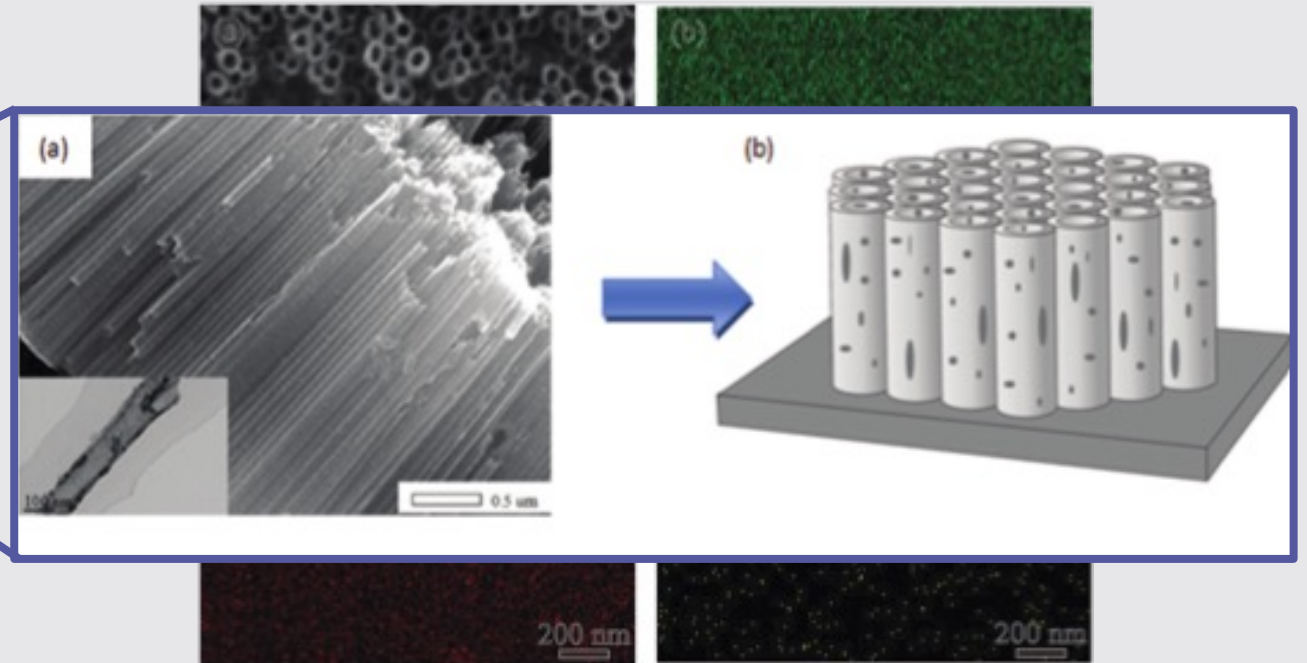
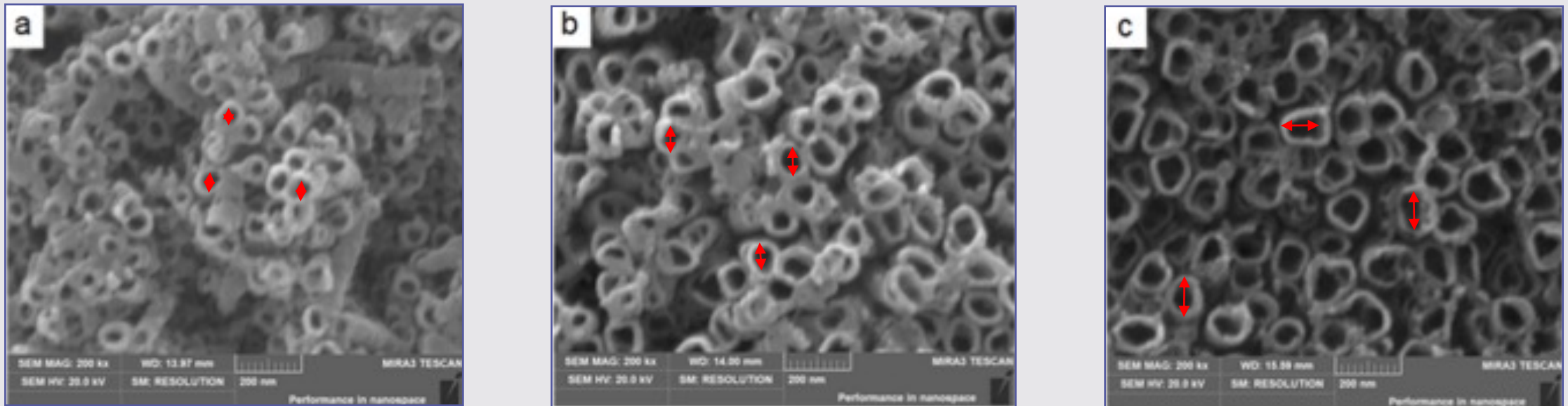


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Chang F, et al. J Nanosci Nanotechnol. 2019 Apr 1;19(4):2070-2077.

# Electrochemical Anodization



**Figure 3.** SEM images of nanotube arrays anodized at the following times: (a) 3 h, (b) 6 h and (c) 12 h, with inner diameters of approximately 44.5, 71.2 and 136.8 nm, respectively.

Zhang X, et al. Materials (Basel). 2019 Jun 20;12(12):1979.

# FDA Guidelines

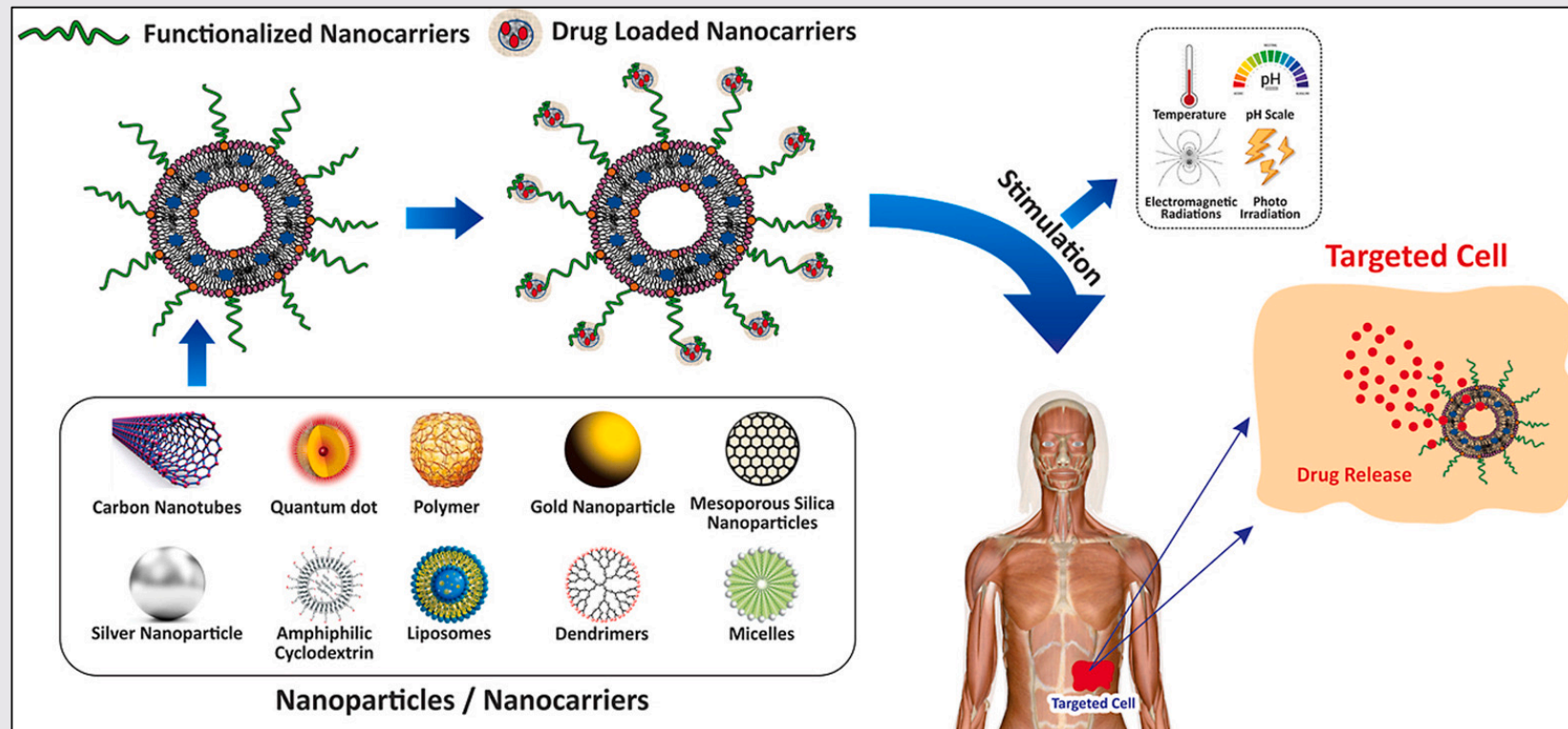
FDA **NO aprueba** el uso individual de materiales o recubrimientos, si no que el dispositivo médico terminado en su conjunto.

## FDA evalúa:

- Análisis metalúrgico.
- Microestructura de la superficie modificada (grosor, forma, tamaño, diámetro o área, diámetro de poro, volumen).
- Propiedades físicas (dureza).
- Propiedades mecánicas (Resistencia/Fatiga).
- Biocompatibilidad.
- Información clínica.

[Consulta en línea: <https://www.fda.gov/regulatory-information/search-fda-guidance-documents/guidance-document-testing-orthopedic-implants-modified-metallic-surfaces-apposing-bone-or-bone>].

# Nanotecnología aplicada a la medicina



Shah A. et al., J Drug Deliv Sci Technol. 2021;61; 102426.



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# Nanopartículas Metálicas

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# Nanopartículas Metálicas



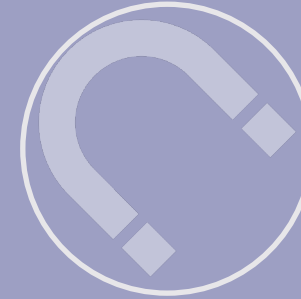
## Son nanomateriales conformados por solo un elemento.

- Pueden poseer átomos individuales o grupos de átomos.
- Au, Ag, Pt, Cu, Pd, Re, Zn, Ru, Co, Cd, Al, Ni y Fe.



## Síntesis por distintos métodos:

- Bio-asistidos
- Hidrotermales
- Microondas
- Entre otros

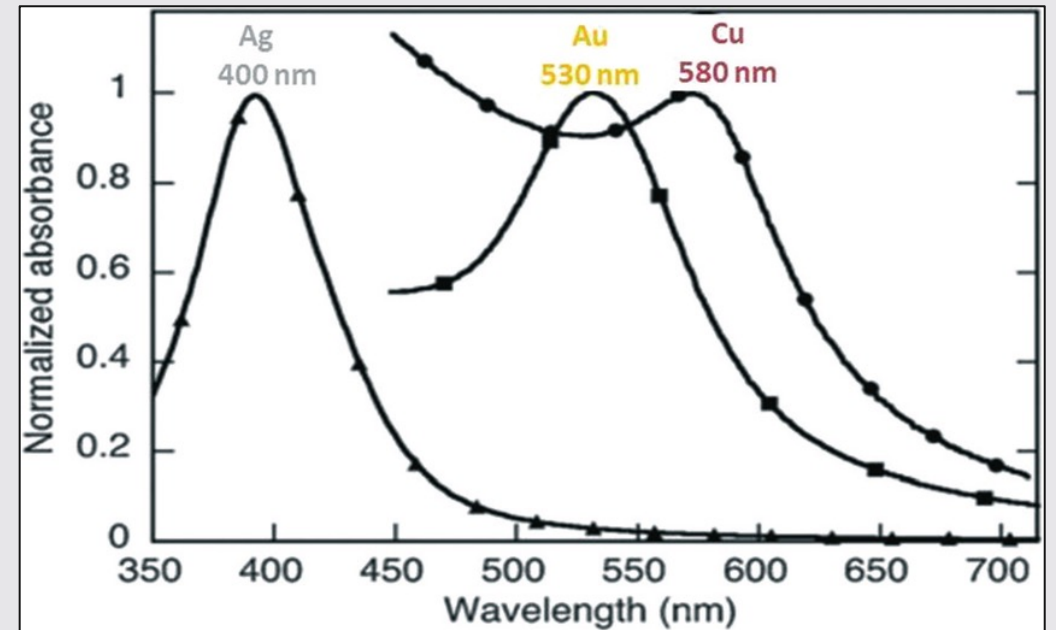
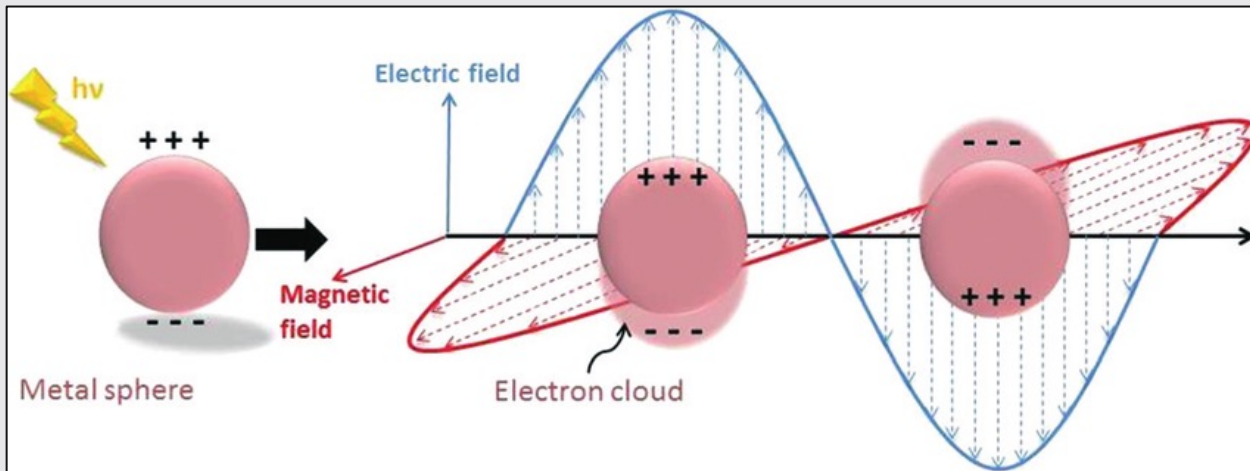


## Distintas propiedades:

- Localized surface plasmon resonance (LSPR)
- Confinamiento Cuántico
- Optoelectrónicas
- Antimicrobianas
- Anticáncer
- Antivirales

Saleh, Tawfik. (2022). Chapter 8: Properties of nanoadsorbents and adsorption mechanisms. 10.1016/B978-0-12-849876-7.00010-5.

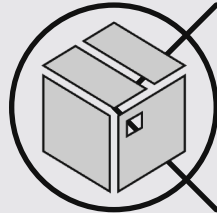
# Localized surface plasmon resonance (LSPR)



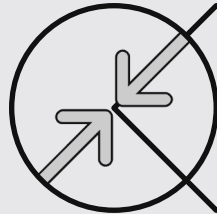
Peiris, Sunari & McMurtrie, John & Zhu, H.. (2015). Metal nanoparticle photocatalysts: Emerging processes for green organic synthesis. Catal. Sci. Technol.. 6. 10.1039/C5CY02048D.



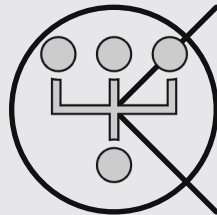
# Confinamiento Cuántico



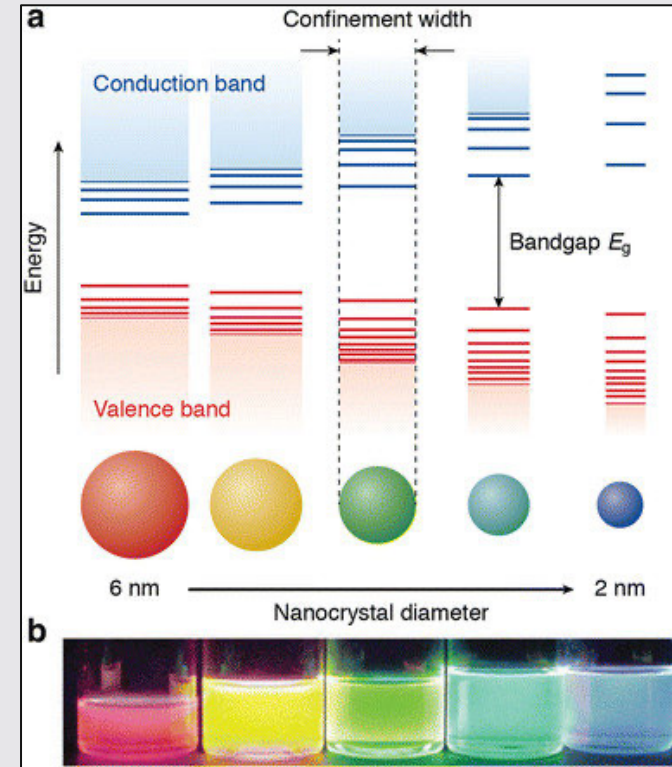
Confinamiento espacial de pares electrón-hueco (excitón) en una o más dimensiones dentro de un material.



Niveles de energía son discretos ( $\approx \lambda$  de Broglie de  $e^-$ ).



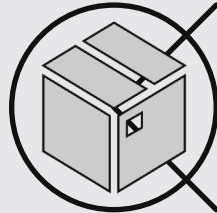
Semiconductores II – VI -  
> Band Gap.



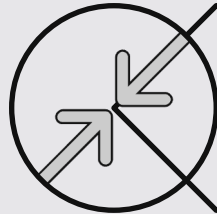
Rabouw, Freddy & Donega, Celso. (2016). Excited-State Dynamics in Colloidal Semiconductor Nanocrystals. Topics in Current Chemistry. 374. 10.1007/s41061-016-0060-0.



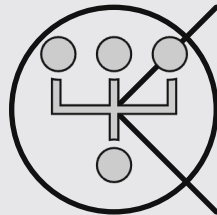
# Confinamiento Cuántico



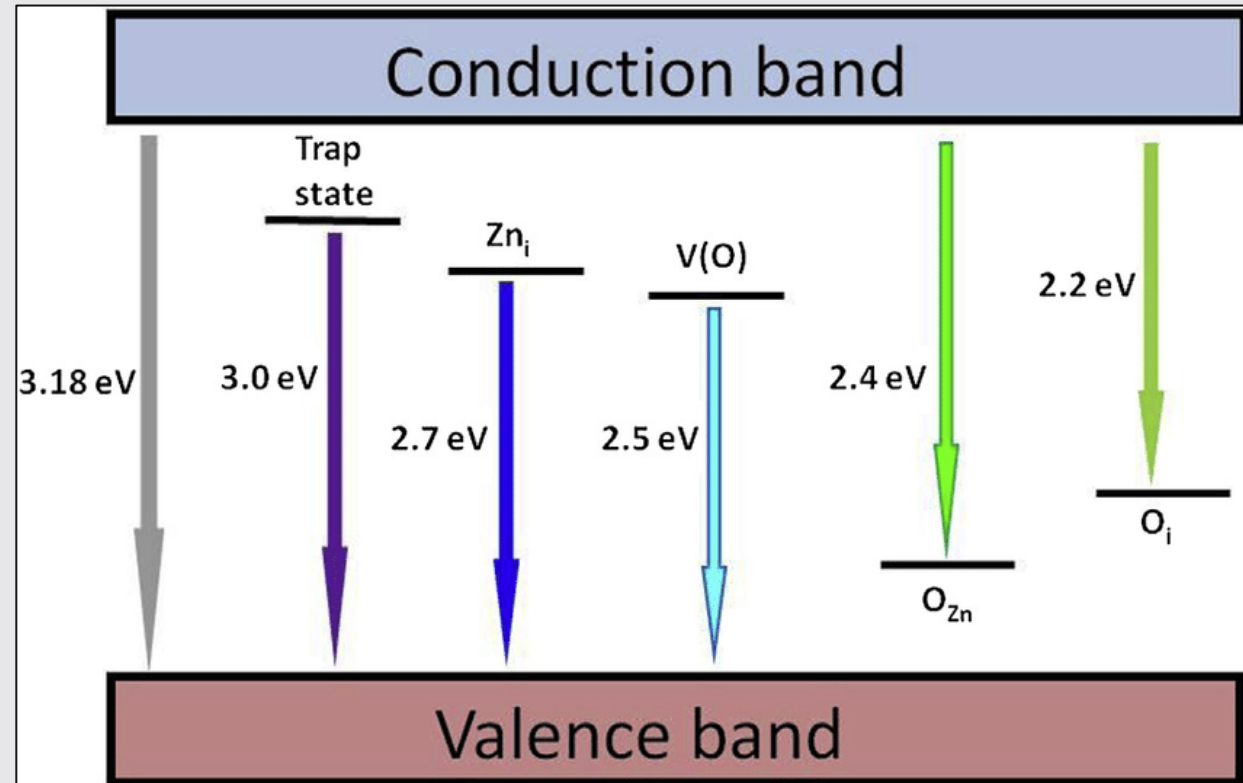
Confinamiento espacial de pares electrón-hueco (excitón) en una o más dimensiones dentro de un material.



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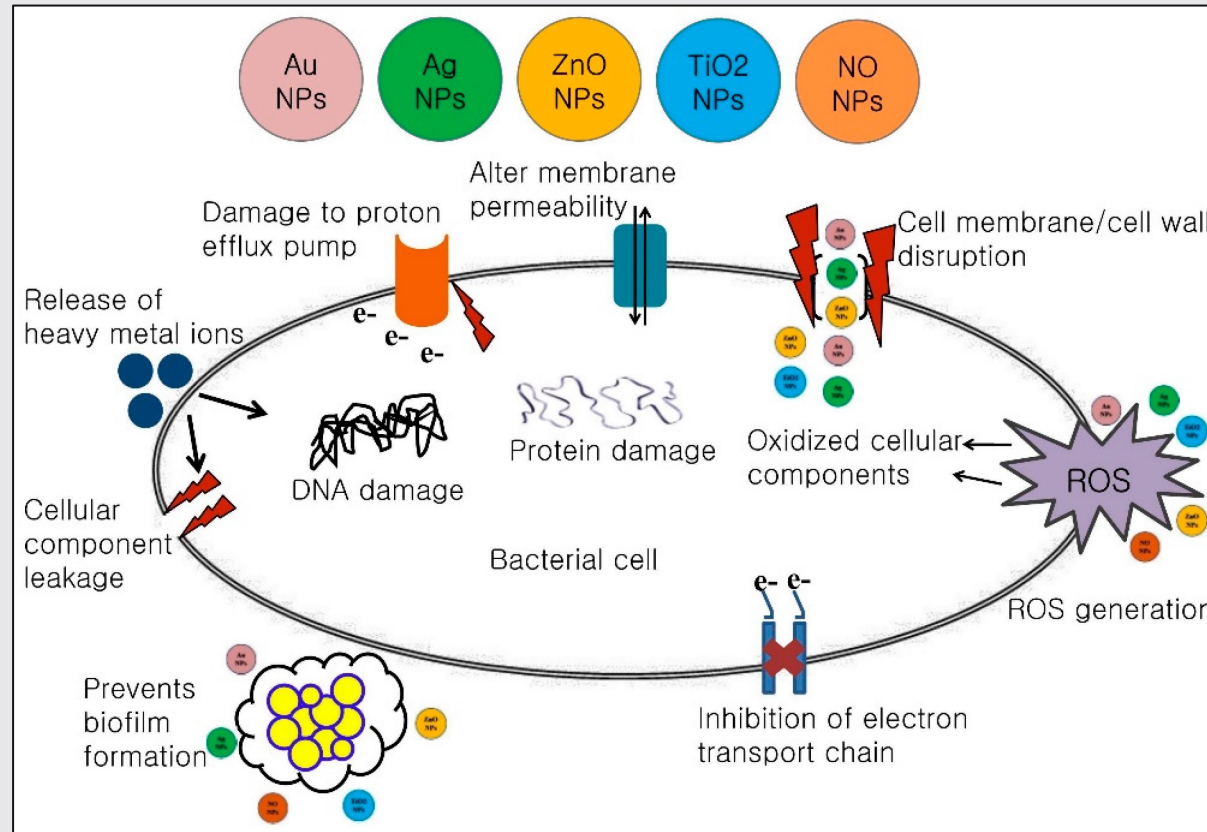


Semiconductores II – VI -  
> Band Gap.



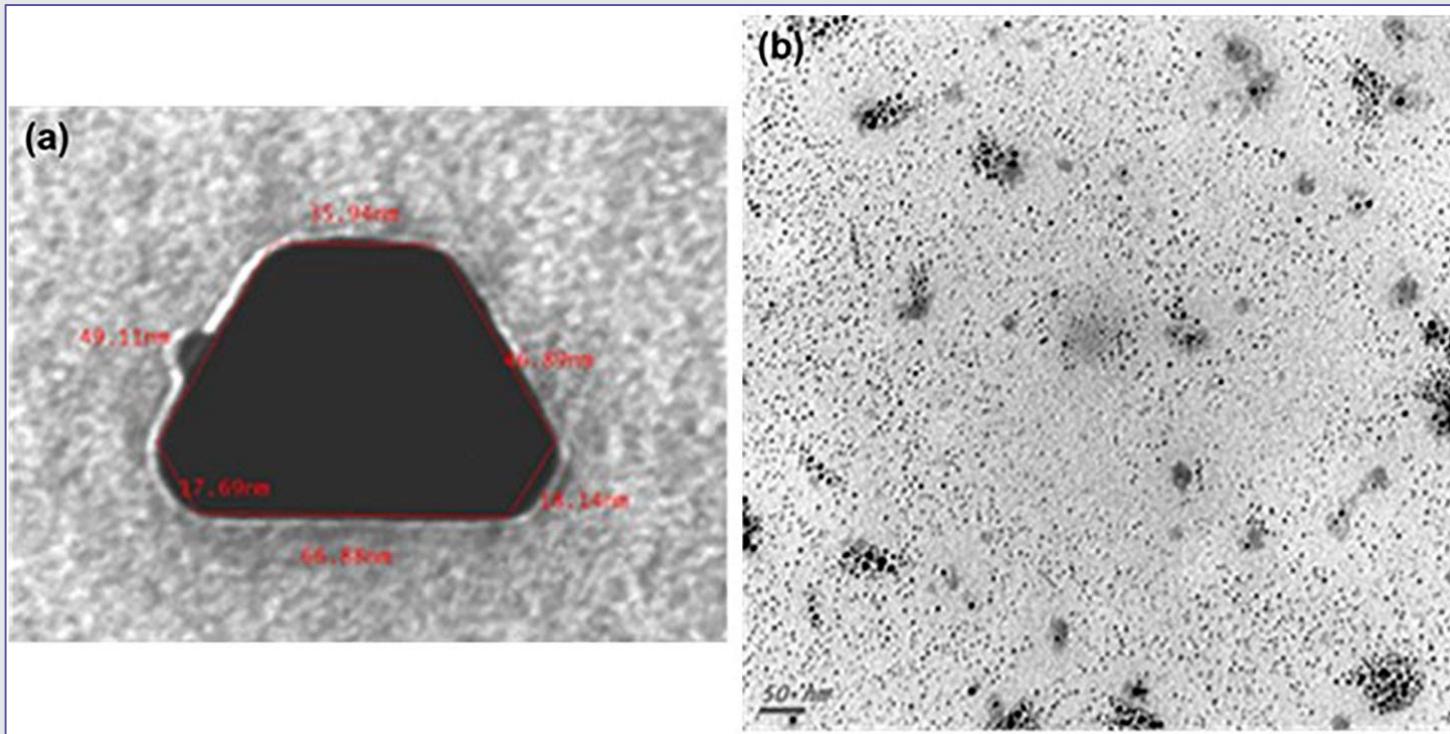
Mrabet, Chokri & Kamoun, Olfa & Boukhachem, A. & Amlouk, Mosbah & Tahar, Manoubi. (2015). Some physical investigations on hexagonal-shaped nanorods of lanthanum-doped ZnO. Journal of Alloys and Compounds. 648. 826-837. 10.1016/j.jallcom.2015.07.009.

# Mecanismos antimicrobianos de Nps metálicas



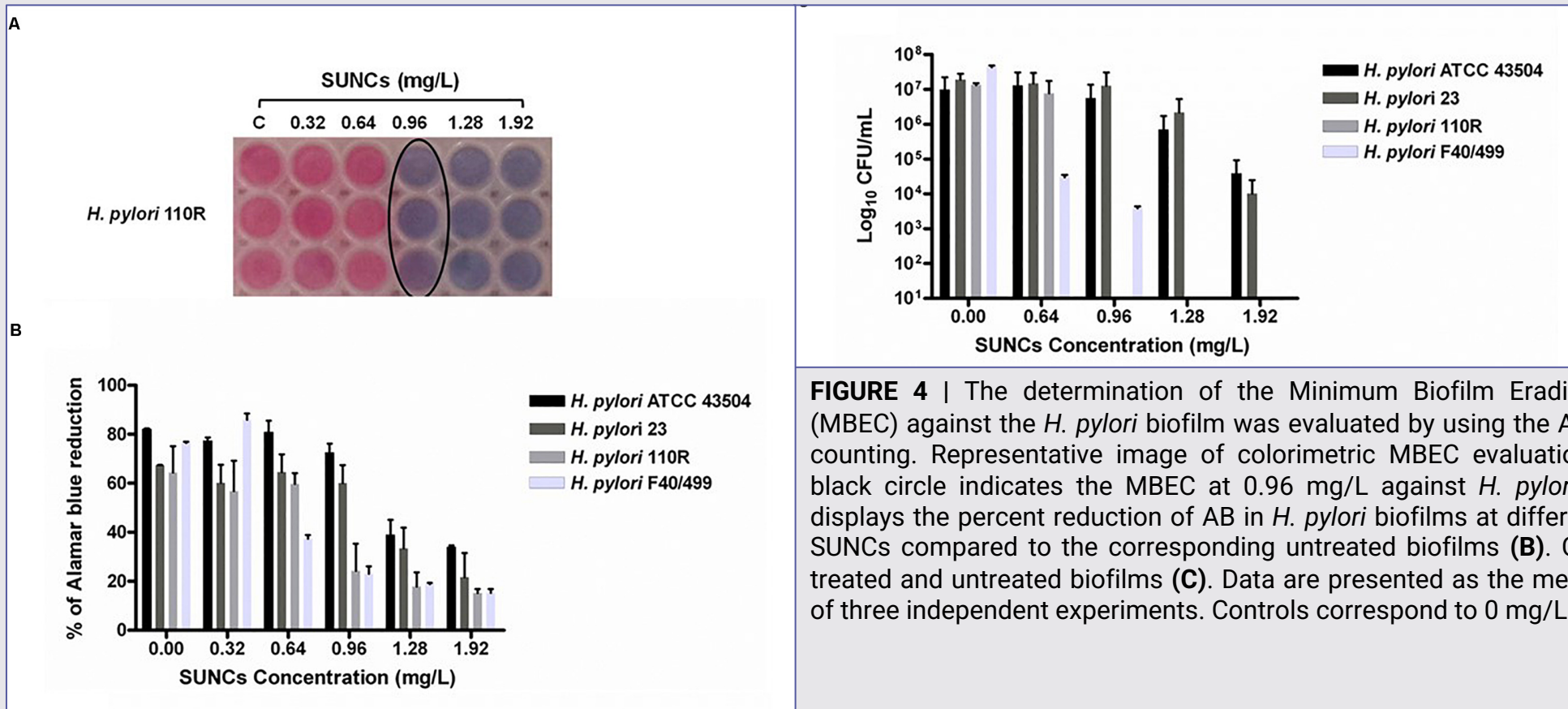
Shaikh S, Nazam N, Rizvi SMD, Ahmad K, Baig MH, Lee EJ, Choi I. Mechanistic Insights into the Antimicrobial Actions of Metallic Nanoparticles and Their Implications for Multidrug Resistance. *International Journal of Molecular Sciences*. 2019; 20(10):2468. <https://doi.org/10.3390/ijms20102468>

# Actividad antibiofilm de Silver Ultra-NanoClusters (SUNCs) contra *Helicobacter pylori*



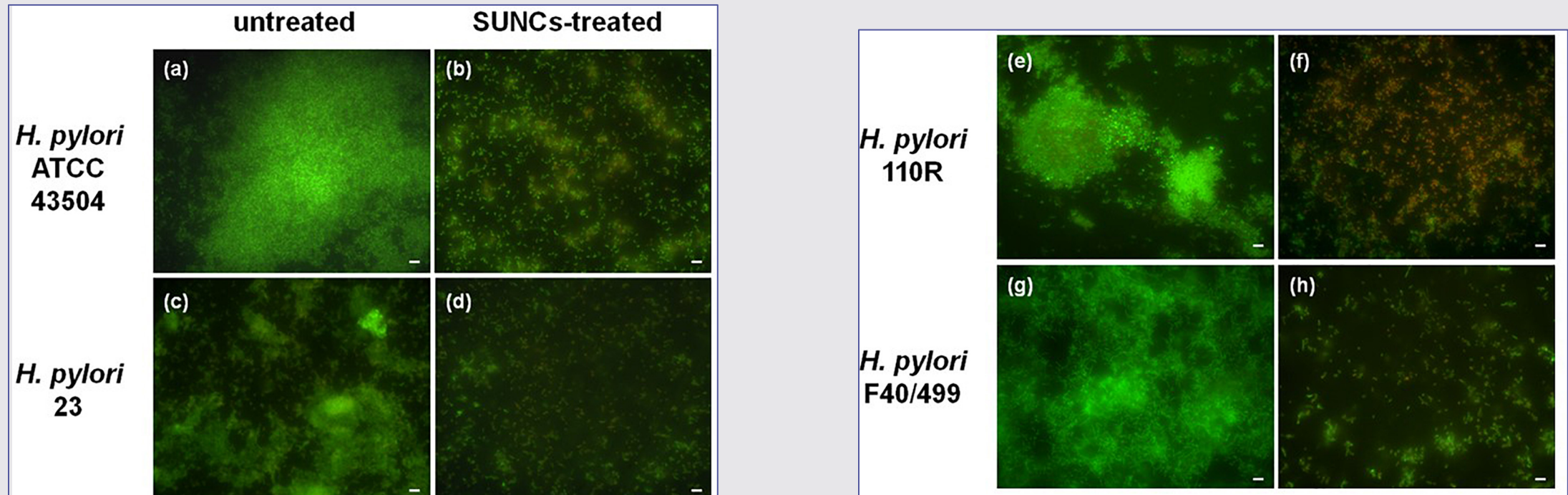
**FIGURE 1** | Transmission electron microscopy of SUNCs. SUNCs were electrochemically synthesized in ultrapure water. Large non-spherical nanocluster before filtration. Magnification: 250,000× **(a)**; ultra-nanoclusters after filtration. A drop of 1:5 diluted stock solution of SUNCs was allowed to evaporate onto 300 mesh formvar-coated nickel grids, and then TEM image was taken at 75 kV by a ZEISS 109 microscope. Scale bar: 50 nm. Magnification: 85,000× **(b)**.

# Actividad antibiofilm de Silver Ultra-NanoClusters (SUNCs) contra *Helicobacter pylori*



Grande R, Sisto F, Puca V, Carradori S, Ronci M, Aceto A, Muraro R, Mincione G, Scotti L. Antimicrobial and Antibiofilm Activities of New Synthesized Silver Ultra-NanoClusters (SUNCs) Against *Helicobacter pylori*. Front Microbiol. 2020

# Actividad antibiofilm de Silver Ultra-NanoClusters (SUNCs) contra *Helicobacter pylori*



**FIGURE 5 |** Representative *H. pylori* biofilms stained with Live/Dead kit and analyzed using fluorescence microscopy. The green fluorescence indicates the live cells, whereas the red fluorescence indicates the dead cells or cells with a damaged cell wall. Panels (a,c,e,g) show the untreated *H. pylori* biofilms, while panels (b,d,f,h) show *H. pylori* biofilms treated with SUNCs at MBEC concentrations of 1.28 mg/L for *H. pylori* strains ATCC 43504 and 23, 0.96 mg/L for 110 R, and 0.64 mg/L for F40/499. Scale bar: 5  $\mu$ m.



3

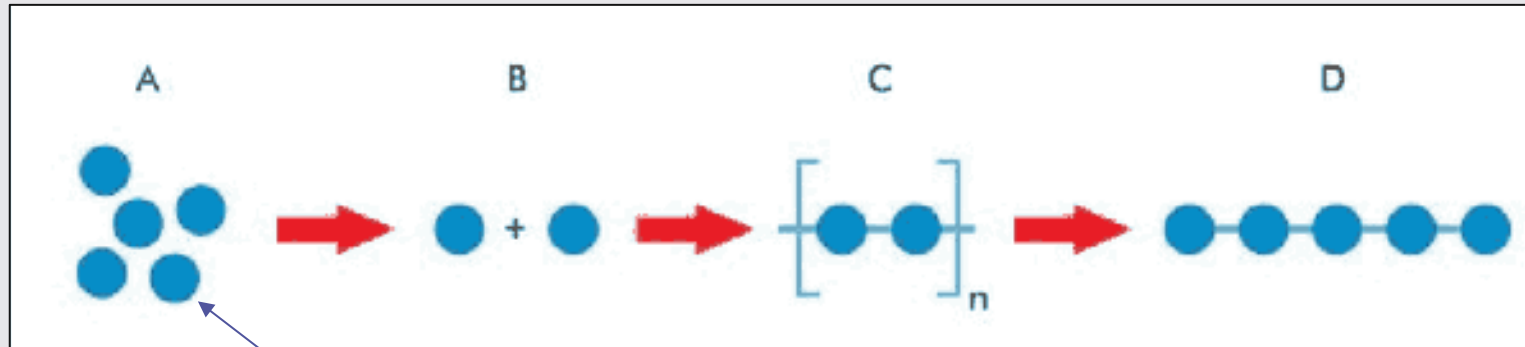
# Nanopartículas Poliméricas

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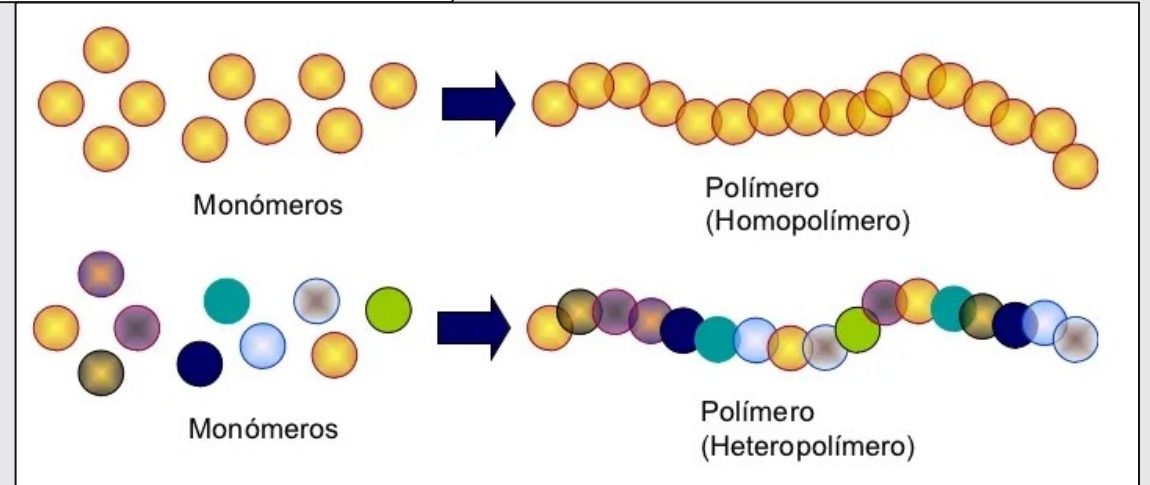
# Definición Polímero



Monómero

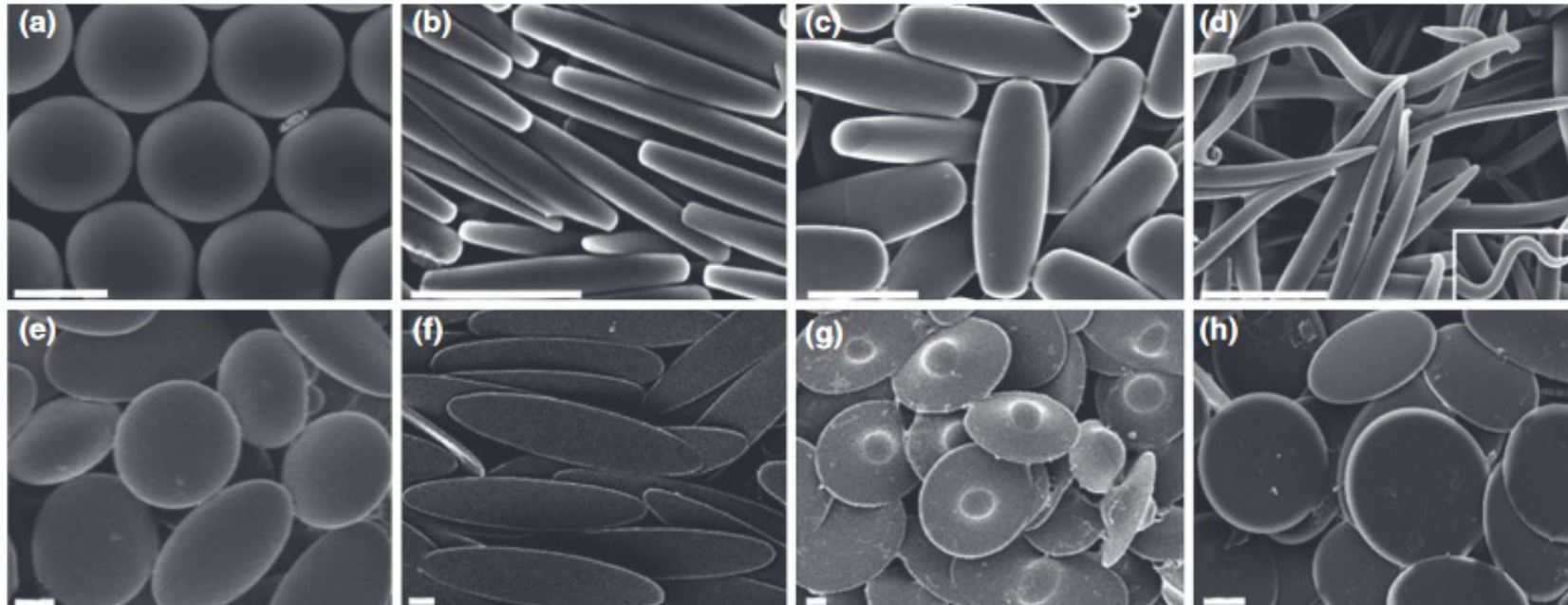
## Griego

- poly: mucho
- mero: parte o segmento



Saleh, Tawfik. (2022). Chapter 8: Properties of nanoadsorbents and adsorption mechanisms. 10.1016/B978-0-12-849876-7.00010-5.

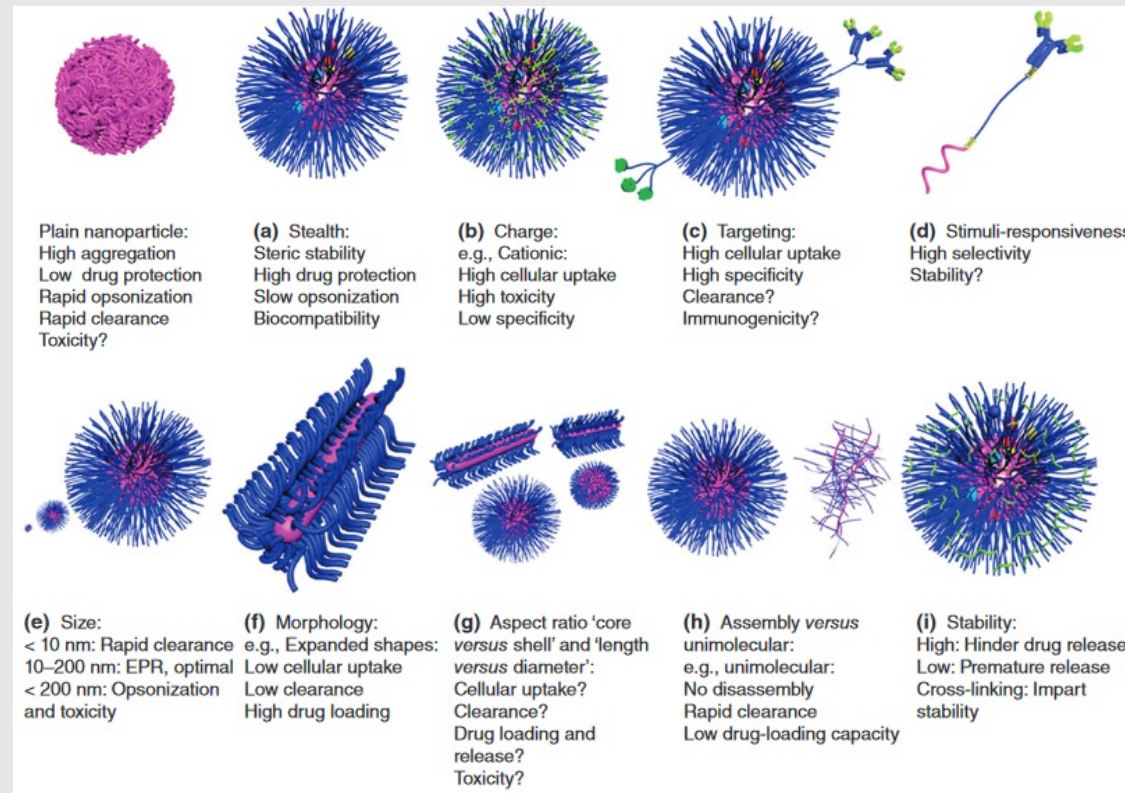
# Características de Nanopartículas Poliméricas



**FIGURE 4** | Micrographs of particle shapes made by using a mechanical stretching technique. (a) Spheres, (b) rectangular disks, (c) rods, (d) worms, (e) oblate ellipses, (f) elliptical disks, (g) unidentified flying objects (UFOs), and (h) circular disks (scale bars: 2  $\mu\text{m}$ ). (Reprinted with permission from Ref 45. Copyright 2007 National Academy of Sciences, U.S.A.)

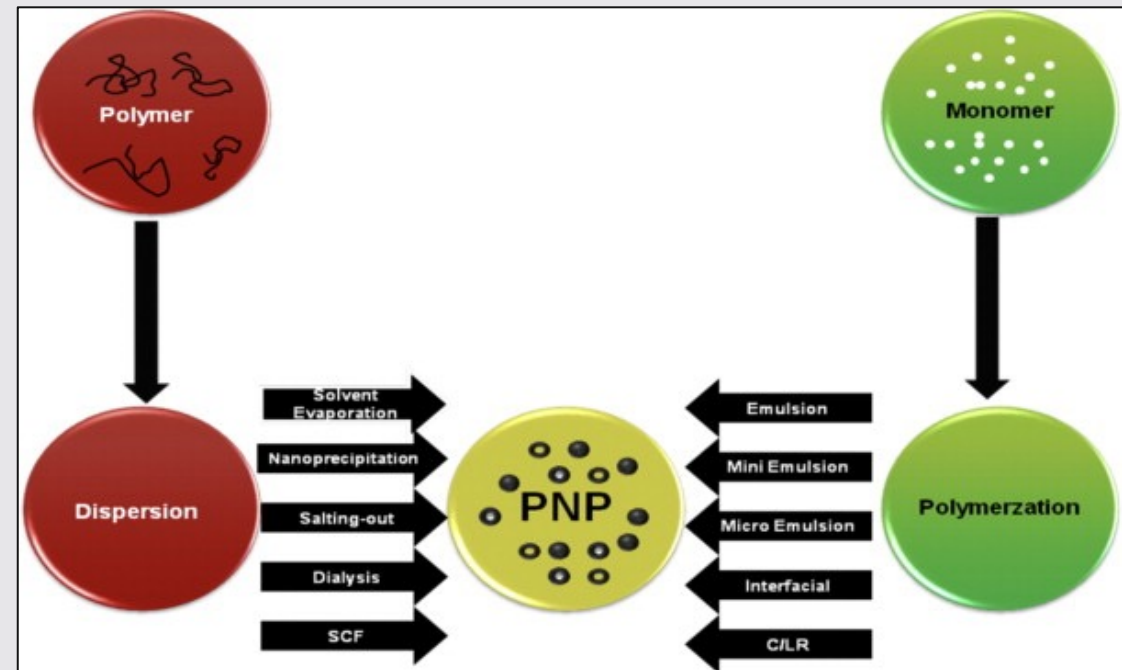
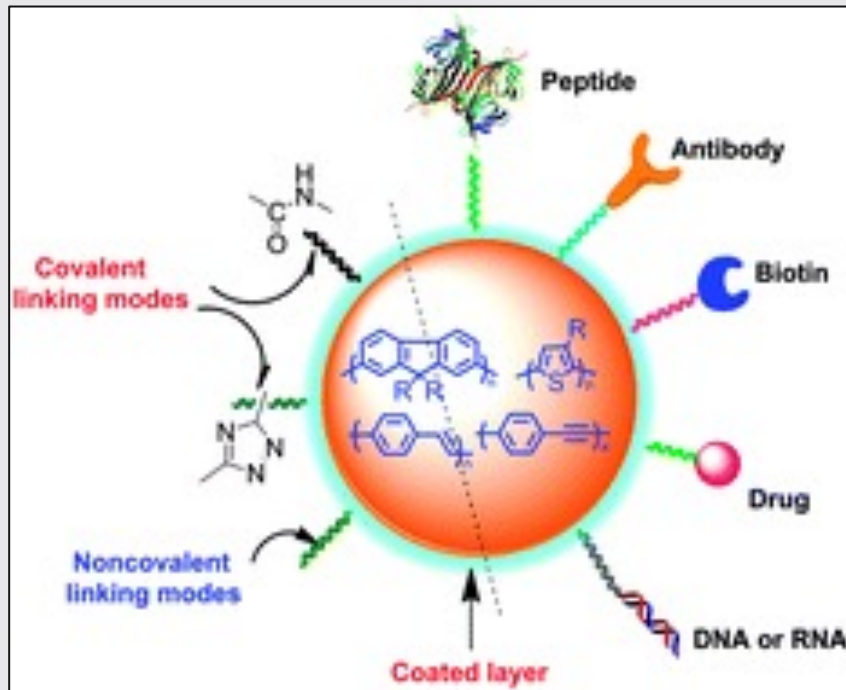
Champion JA, Katare YK, Mitragotri S. Making poly-meric micro- and nanoparticles of complex shapes. Proc Natl Acad Sci USA 2007, 104:11901–11904. doi:10.1073/pnas.0705326104.

# Características de las nanopartículas poliméricas basadas en el tamaño y la morfología de las partículas



Elsabahy M, Wooley KL. Design of polymeric nanoparticles for biomedical delivery applications. Chem Soc Rev 2012, 41:2545–2561. doi:10.1039/c2cs15327k

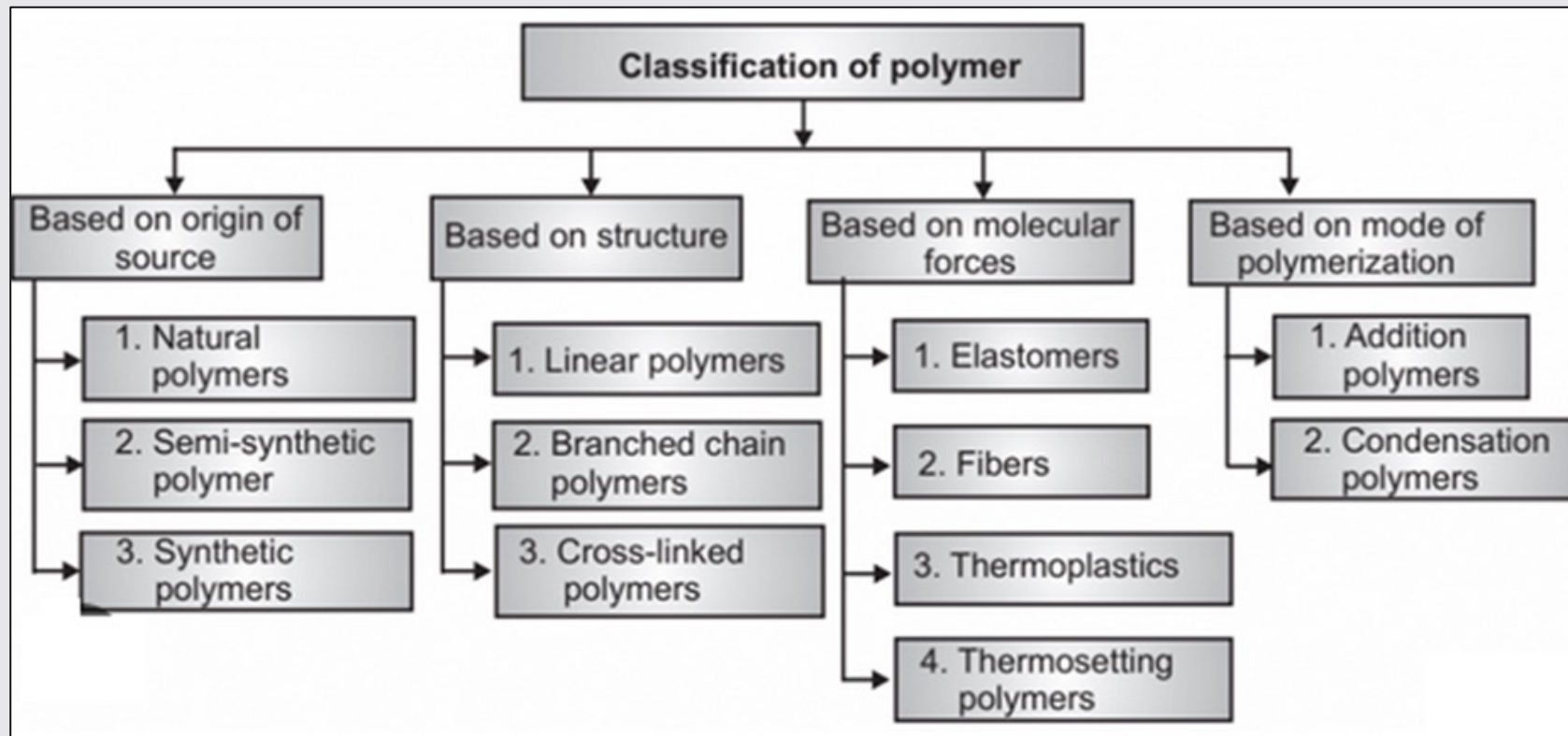
# Características de las nanopartículas poliméricas



Feng L, Zhu C, Yuan H, Liu L, Lv F, Wang S. Conjugated polymer nanoparticles: preparation, properties, functionalization and biological applications. *Chem Soc Rev.* 2013 Aug 21;42(16):6620-33. doi: 10.1039/c3cs60036j.

J. Prasad Rao, Kurt E. Geckeler. Polymer nanoparticles: Preparation techniques and size-control parameters, *Progress in Polymer Science*, Volume 36, Issue 7, 2011, Pages 887-913. <https://doi.org/10.1016/j.progpolymsci.2011.01.001>.

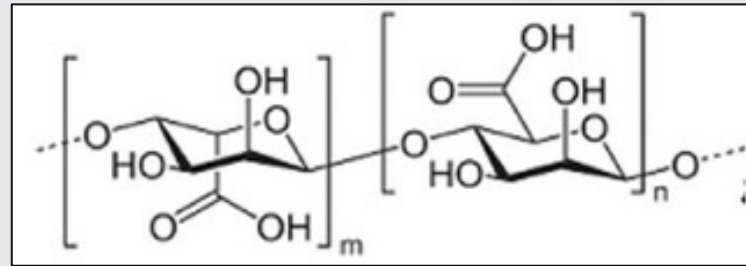
# Características de las nanopartículas poliméricas



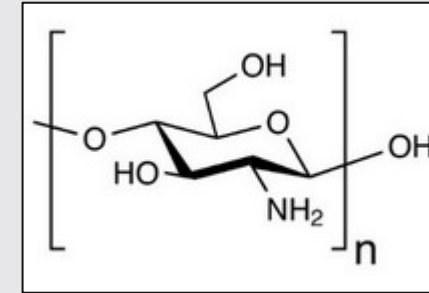
J. Prasad Rao, Kurt E. Geckeler. Polymer nanoparticles: Preparation techniques and size-control parameters, Progress in Polymer Science, Volume 36, Issue 7, 2011, Pages 887-913. <https://doi.org/10.1016/j.progpolymsci.2011.01.001>.

# Características de las nanopartículas poliméricas

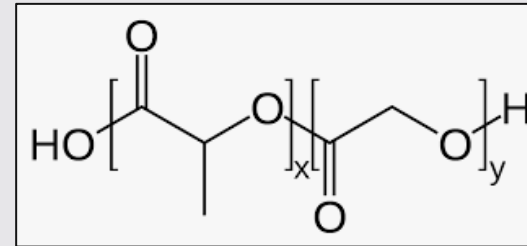
Biodegradables y biocompatibles



Alginato



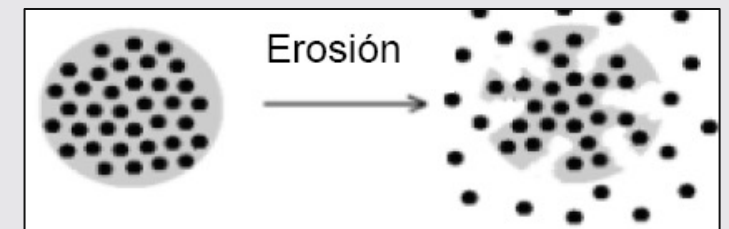
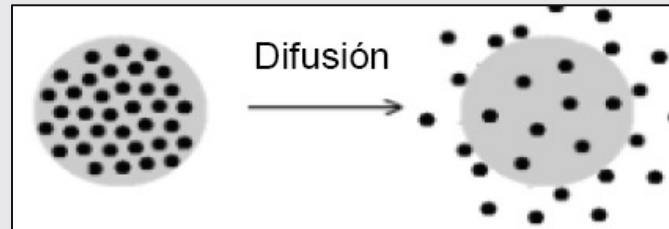
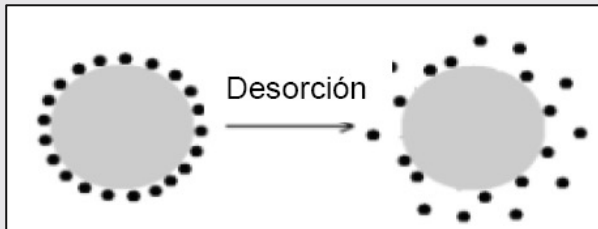
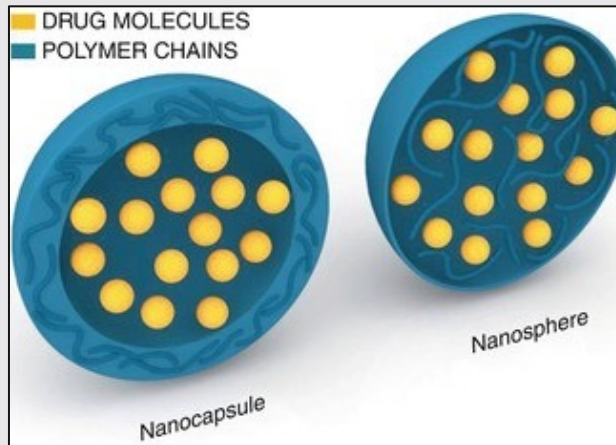
Quitosana



Ácido polilácticoco-glicólico

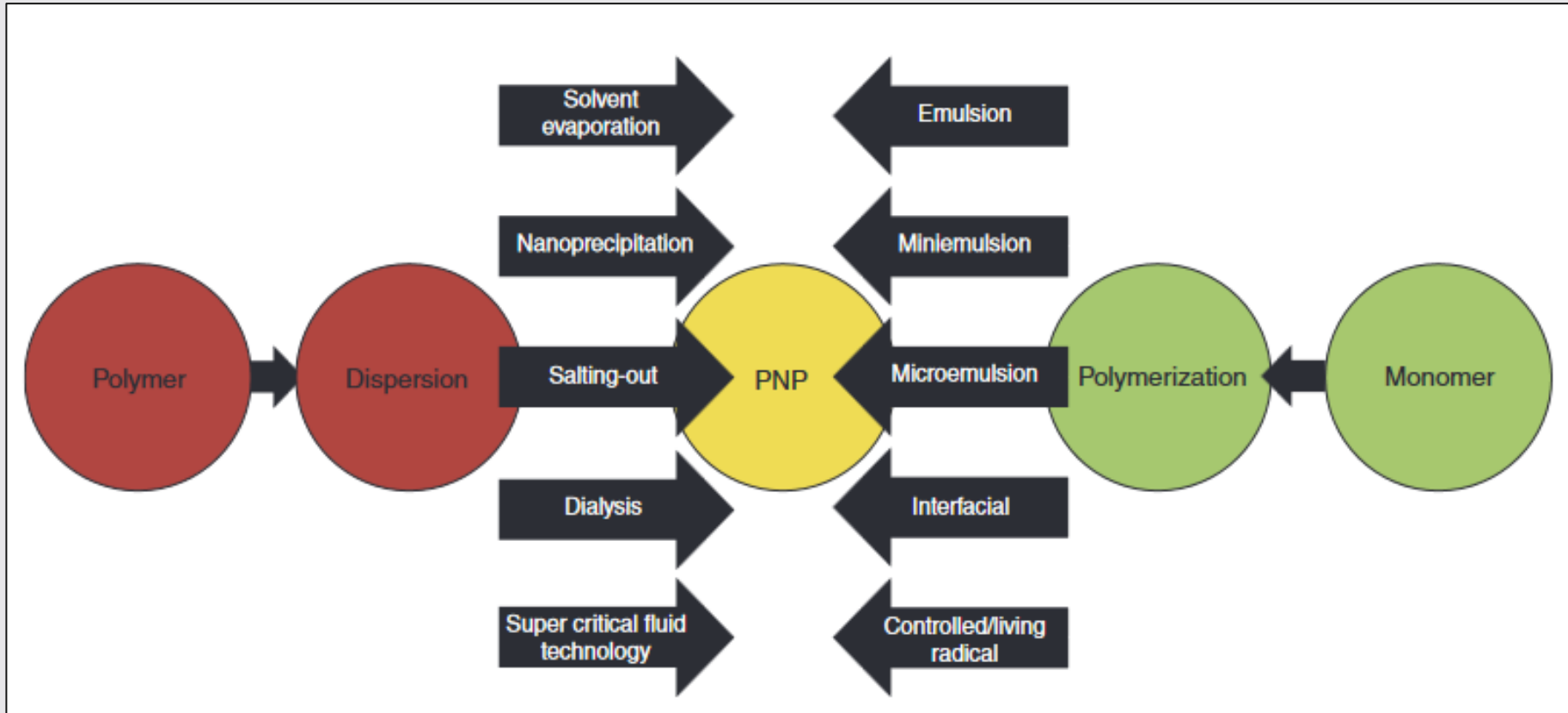
Del Amo L, Cano A, Ettcheto M, Souto EB, Espina M, Camins A, García ML, Sánchez-López E. Surface Functionalization of PLGA Nanoparticles to Increase Transport across the BBB for Alzheimer's Disease. *Applied Sciences*. 2021; 11(9):4305. <https://doi.org/10.3390/app11094305>

# Sistemas de liberación controlada



Sobot, D., Mura, S., Couvreur, P. (2014). Nanoparticles: Blood Components Interactions. In: Kobayashi, S., Müllen, K. (eds) Encyclopedia of Polymeric Nanomaterials. Springer, Berlin, Heidelberg. [https://doi.org/10.1007/978-3-642-36199-9\\_227-1](https://doi.org/10.1007/978-3-642-36199-9_227-1)

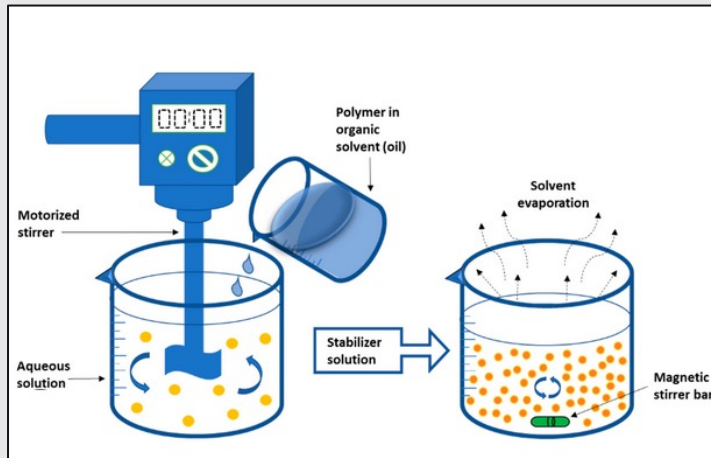
# Síntesis de nanopartículas poliméricas



Rao JP, Geckeler KE. Polymer nanoparticles: preparation techniques and size-control parameters. Prog Polym Sci 2011, 36:887–913. doi:10.1016/j.progpolymsci.2011.01.001.

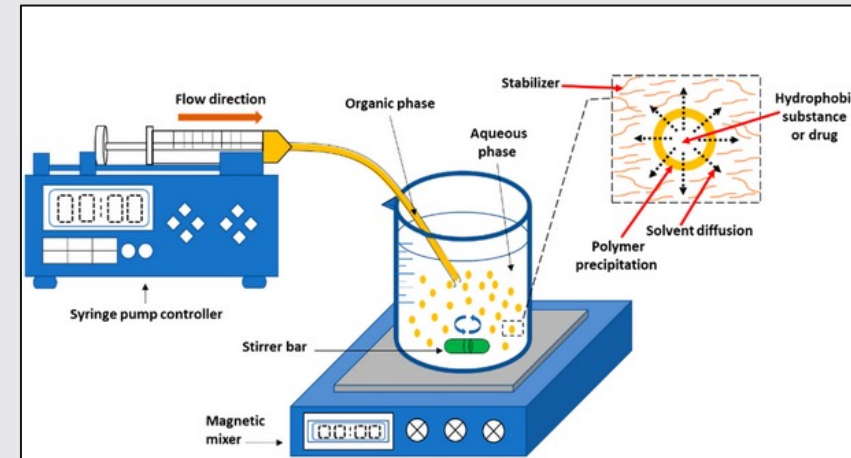


# Síntesis de nanopartículas poliméricas



## Evaporación de solvente

- Ventajas: escalable, tamaño y morfología controlable
- Desventaja: proceso lento

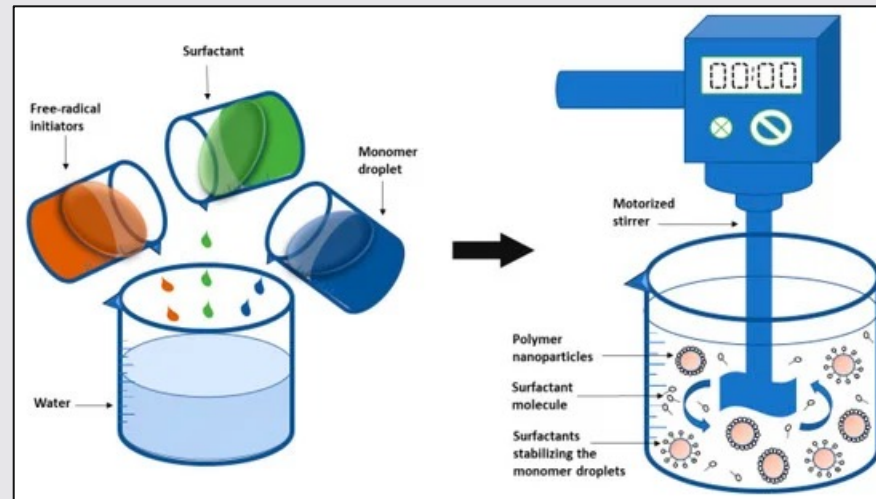


## Nanoprecipitación

- Ventajas: método simple, rápido y reproducible
- Desventaja: limitado disolventes miscibles en agua

Pulingam T et al. Exploring Various Techniques for the Chemical and Biological Synthesis of Polymeric Nanoparticles. *Nanomaterials*. 2022; 12(3):576. <https://doi.org/10.3390/nano12030576>

# Síntesis de nanopartículas poliméricas



## Polimerización por emulsión

- Ventajas: Producir polímeros con alta masa molar. Utiliza agua como medio de dispersión. Excelente disipación de calor
- Desventaja: Desventaja: Requiere eliminación de surfactante.
- (micro: 10–100 nm, mini: 100 nm – 1  $\mu$ m, macro: >1  $\mu$ m).

Pulingam T et al. Exploring Various Techniques for the Chemical and Biological Synthesis of Polymeric Nanoparticles. *Nanomaterials*. 2022; 12(3):576. <https://doi.org/10.3390/nano12030576>

¿De qué manera podemos utilizar la NT para el control de BF?

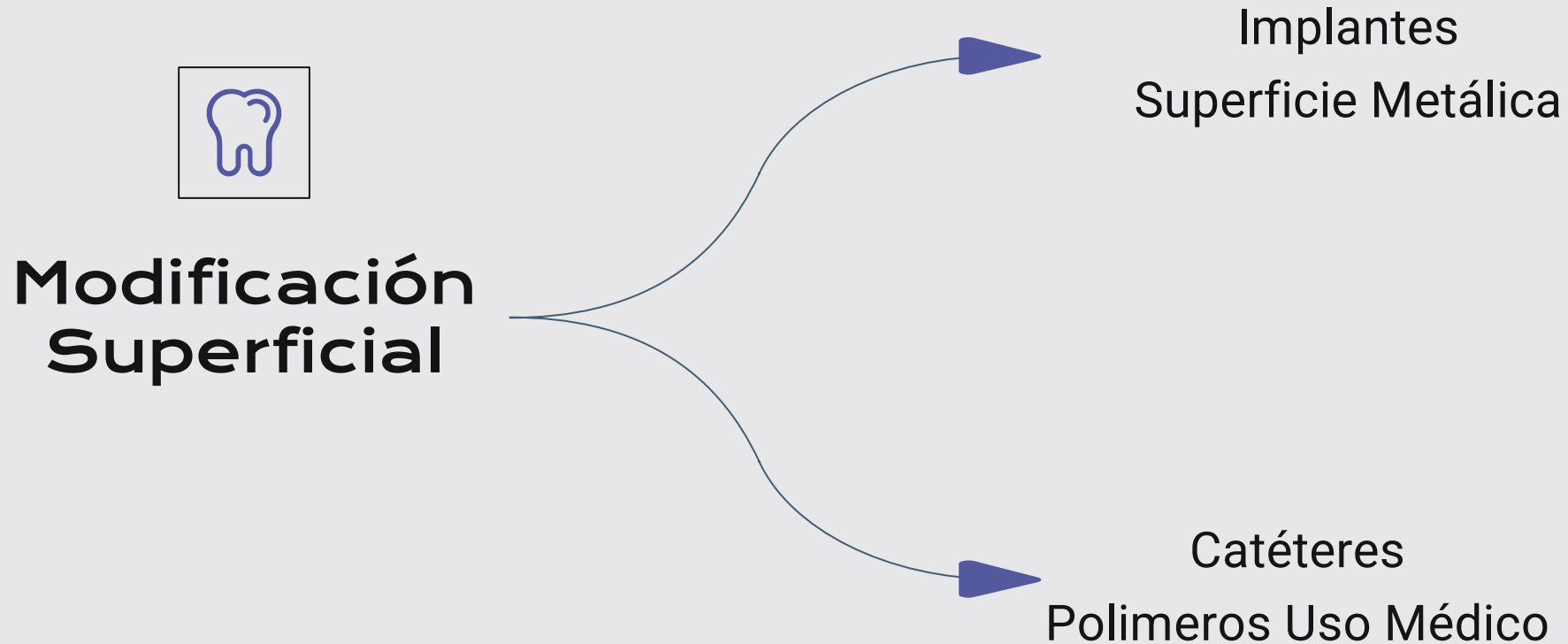


**Modificación  
Superficial**

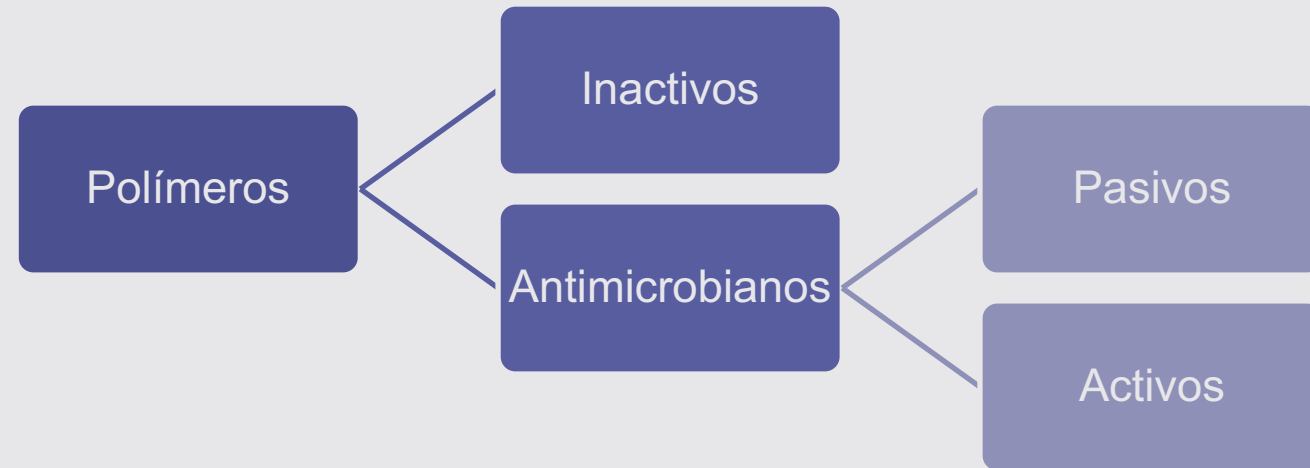


**Nanocarriers  
ATB/ATM**

# ¿De qué manera podemos utilizar la NT para el control de BF?

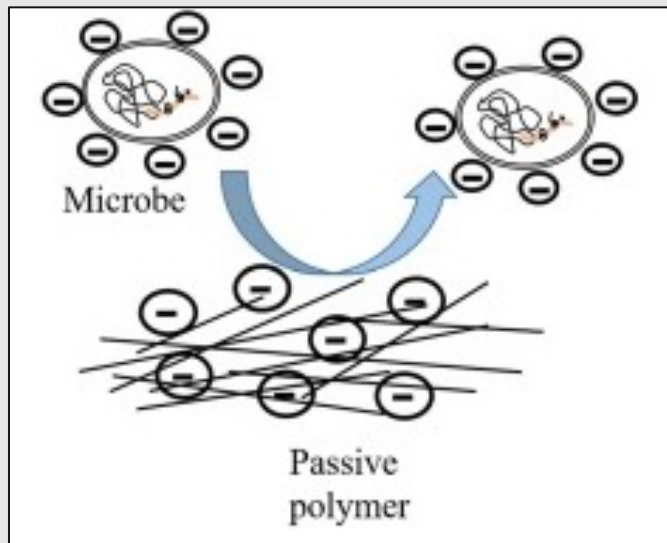


# Mecanismo antibacteriano de los polímeros



# Mecanismo antibacteriano de los polímeros

## Polímero antimicrobiano pasivo



Garantiza una adsorción mínima de proteínas

No son citotóxicos

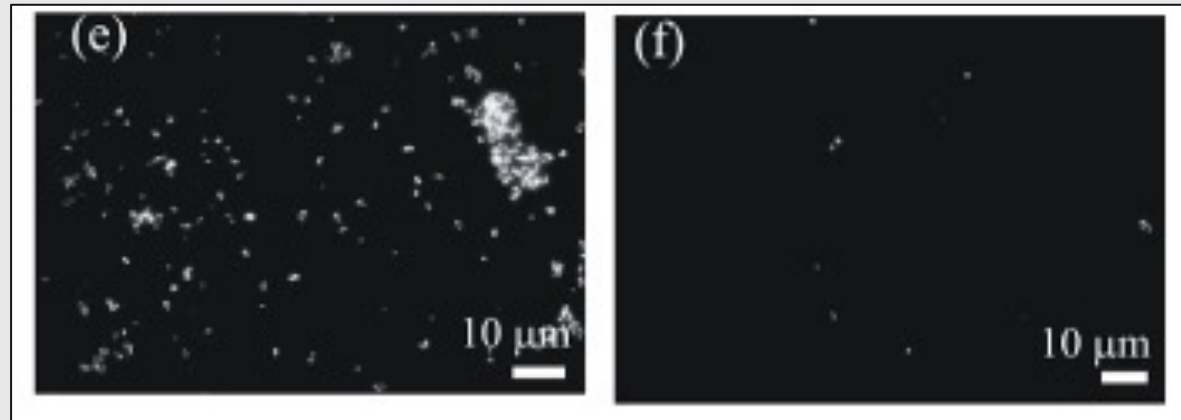
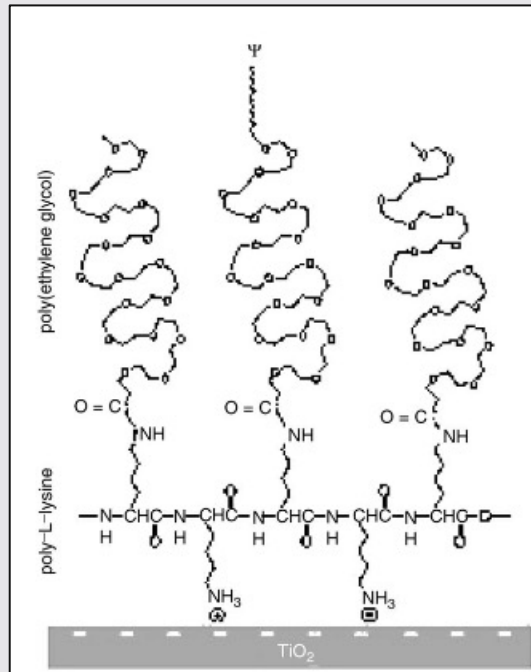
Polímero con carga negativa, hidrofílico o baja energía libre superficial

Las repulsiones electrostáticas entre el polímero y la pared celular bacteriana evitan la adhesión

<https://doi.org/10.1016/B978-0-323-95169-2.00012-2>

# Mecanismo antibacteriano de los polímeros

## Polímero antimicrobiano pasivo

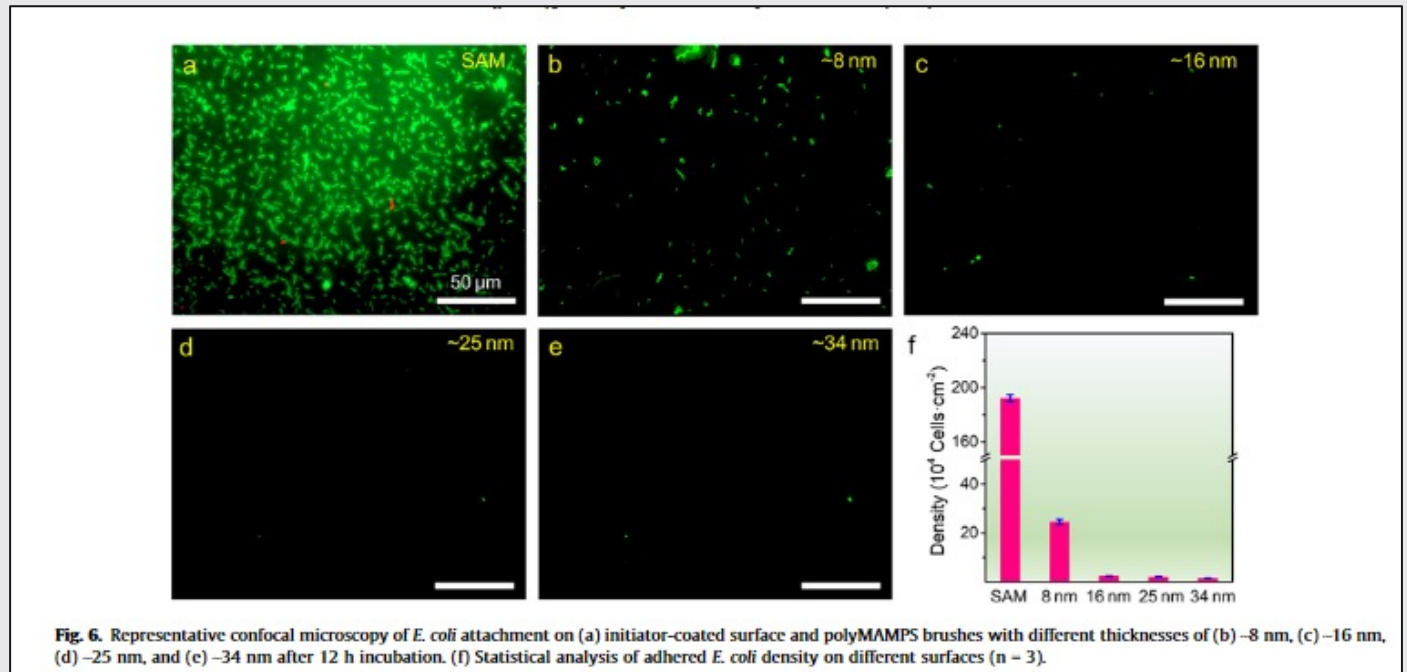
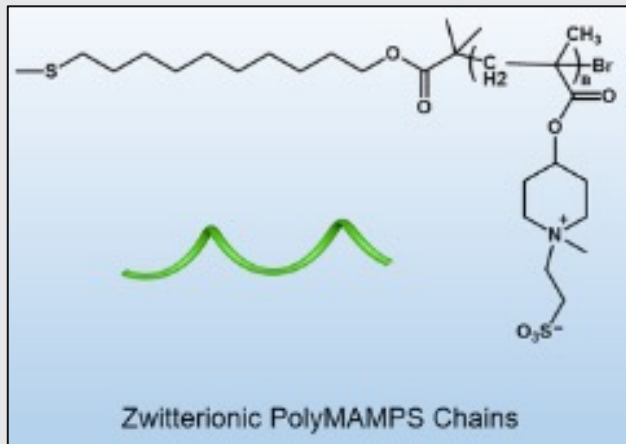


Representative fluorescence microscopy images of *S. aureus* adhering to (e) bare titanium surface, and (f) PLL-g-PEG coated titanium surface, incubated stationary at 37°C for 1h. Fluorescent redox dye, CTC

Harris, Llinos & Tosatti, Samuele & Wieland, Marco & Textor, Marcus & Richards, Robert. (2004). Staphylococcus aureus adhesion to titanium oxide surfaces coated with non-functionalized and peptide-functionalized poly(L-lysine)-graft-poly(ethylene glycol) copolymers. *Biomaterials*. 25. 4135-48. 10.1016/j.biomaterials.2003.11.033.

# Mecanismo antibacteriano de los polímeros

Polímero antimicrobiano pasivo

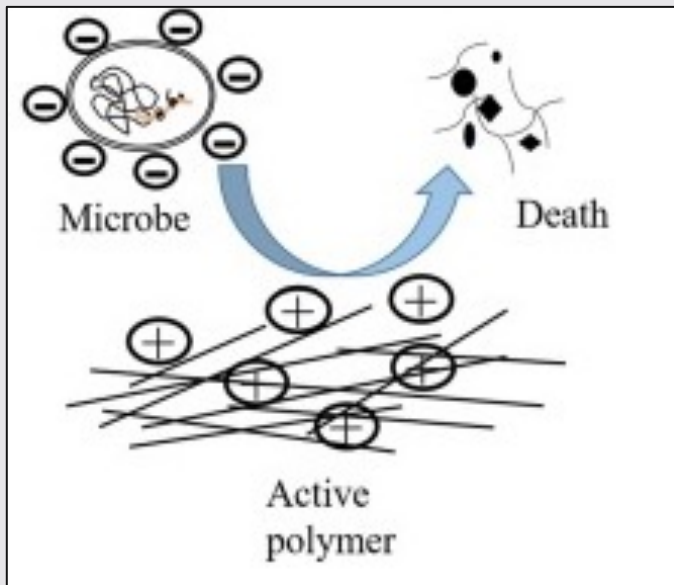


Zhang D, Ren B, Zhang Y, Liu Y, Chen H, Xiao S, Chang Y, Yang J, Zheng J. Micro- and macroscopically structured zwitterionic polymers with ultralow fouling property. *J Colloid Interface Sci.* 2020 Oct 15;578:242-253. doi: 10.1016/j.jcis.2020.05.122. .



# Mecanismo antibacteriano de los polímeros

Polímero antimicrobiano activo



Poseen un agente activo

Determinar el mecanismo de destrucción de las bacterias

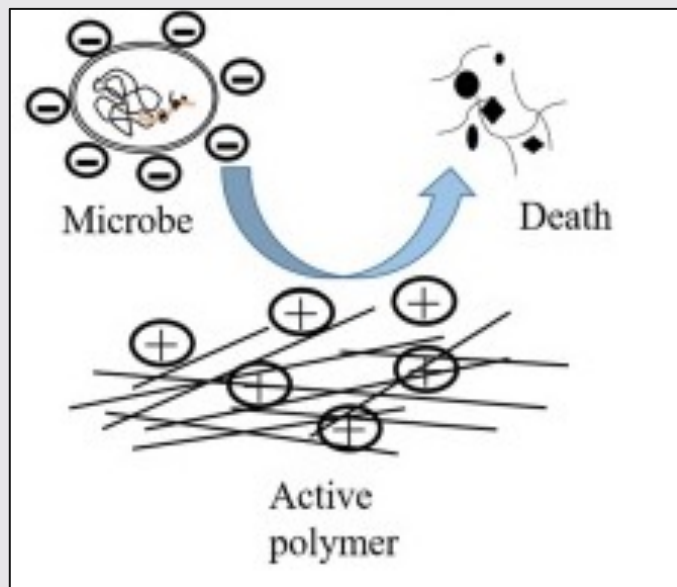
Funcionalización  
(Moléculas  
catiónicas)

Cargados en el  
interior y/o  
superficie (ATB, Nps,  
péptidos)

<https://doi.org/10.1016/B978-0-323-95169-2.00012-2>

# Mecanismo antibacteriano de los polímeros

Polímero antimicrobiano activo



Desestabilización de la membrana

Salida del contenido celular

Muerte

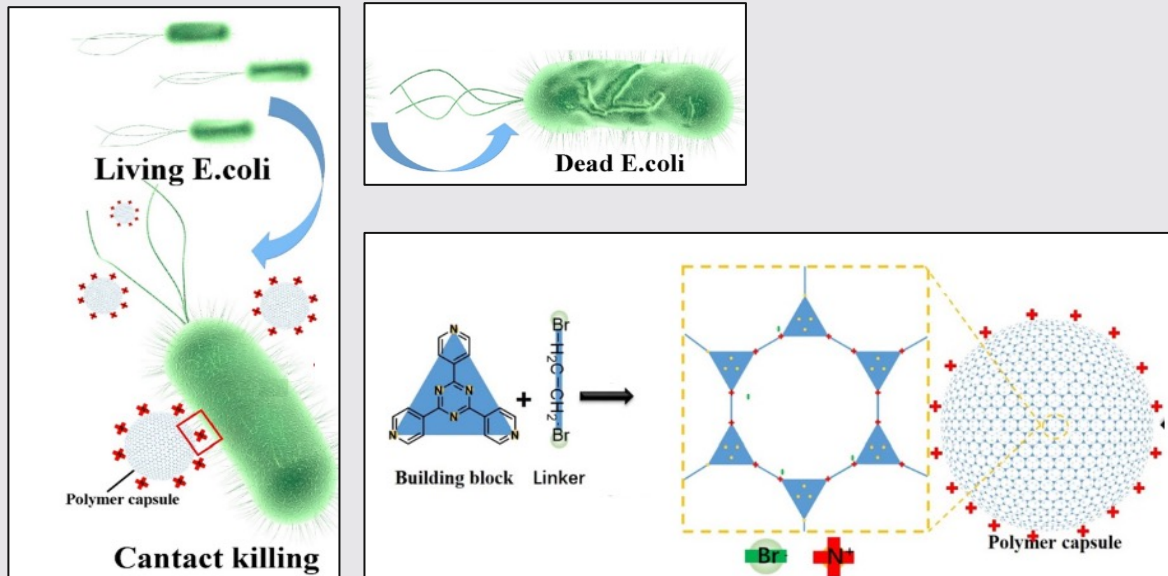
Interacciones electrostáticas

Inactivación celular y daño a la membrana al alterar los puentes de sal de calcio y los receptores de membrana.

<https://doi.org/10.1016/B978-0-323-95169-2.00012-2>

# Mecanismo antibacteriano de los polímeros

Ejemplo de polímeros antimicrobianos activo catiónico



2,4,6-tris(4-pyridyl)-1,3,5-triazine (TPT)

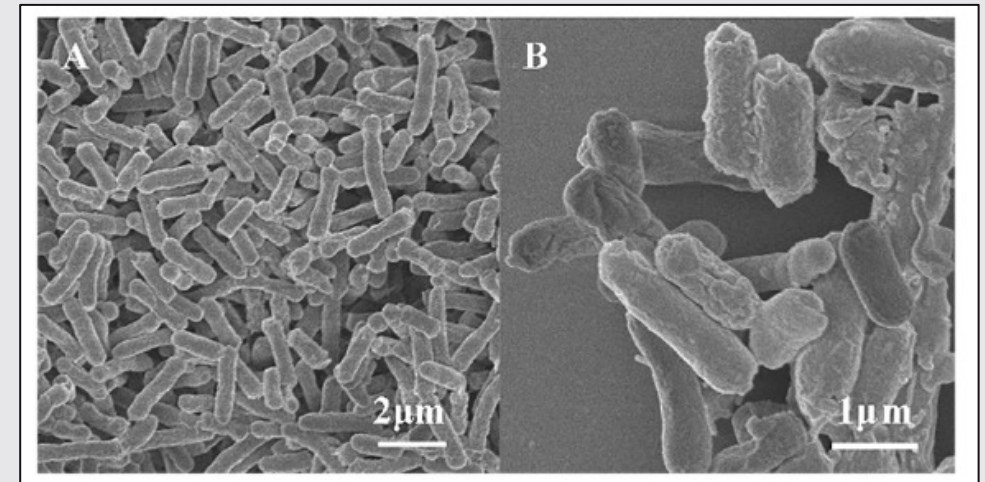
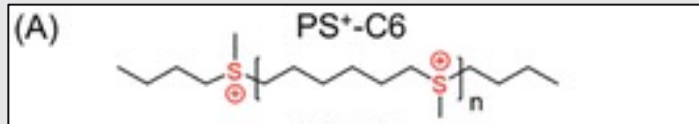


Fig. 8. SEM observation of E. coli (A) untreated control (no polymer vesicles or monomers), (B) mixed with polymer nanocapsules.

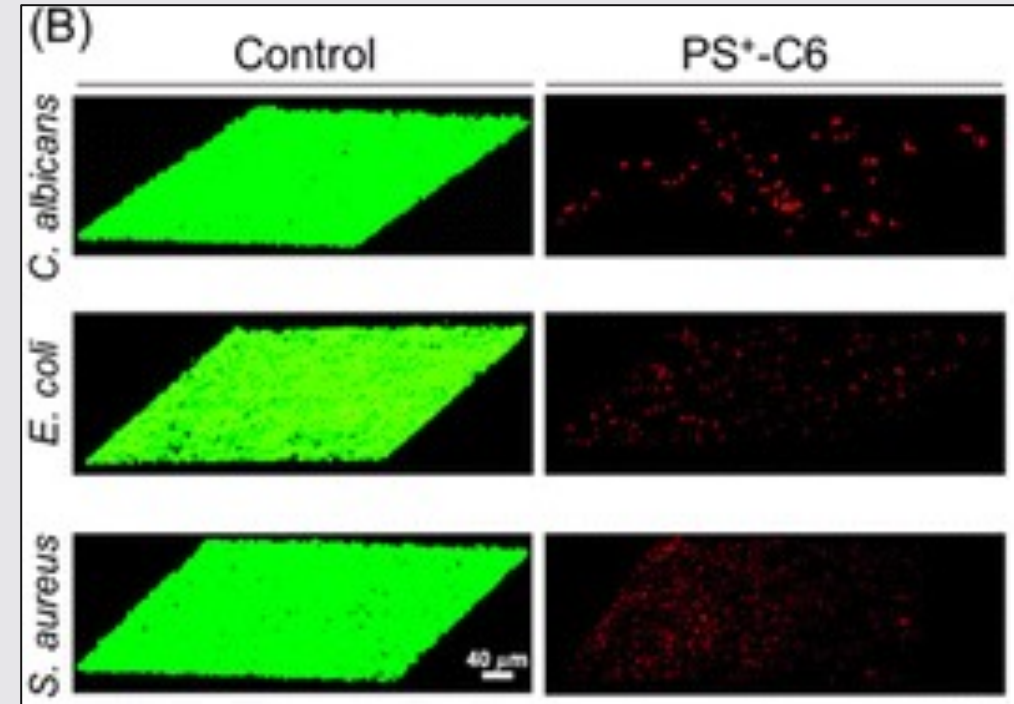
Zeng M, Xu J, Luo Q, Hou C, Qiao S, Fu S, Fan X, Liu J. Constructing antibacterial polymer nanocapsules based on pyridine quaternary ammonium salt. Mater Sci Eng C Mater Biol Appl. 2020 Mar;108:110383. doi: 10.1016/j.msec.2019.11038

# Mecanismo antibacteriano de los polímeros

Ejemplo de polímeros antimicrobianos activo catiónico



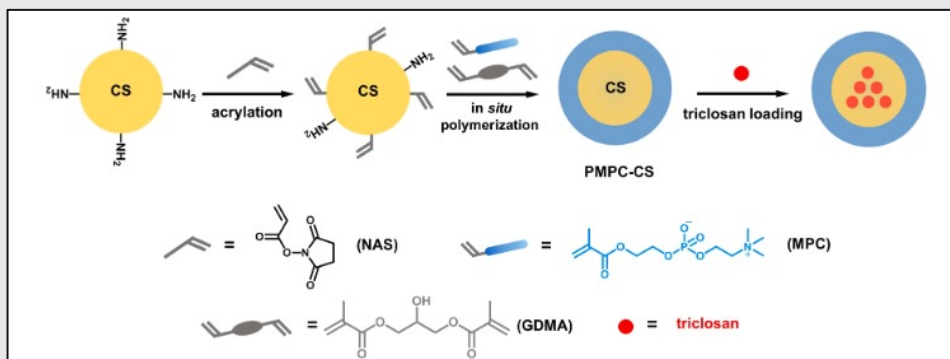
**Fig. 8** (A) Chemical structure of main chain sulfonium-containing homopolymer. (B) CLSM images of *C. albicans*-, *E. coli*- and *S. aureus*-constructed biofilms treated with the control solution and PS<sup>+</sup>-C6. Treatment with the PS<sup>+</sup>-C6 polymer for 24 h, thick biofilms produced mostly red fluorescent signals that signified the existence of dead microorganisms; however, most of the cells in the control groups were still alive



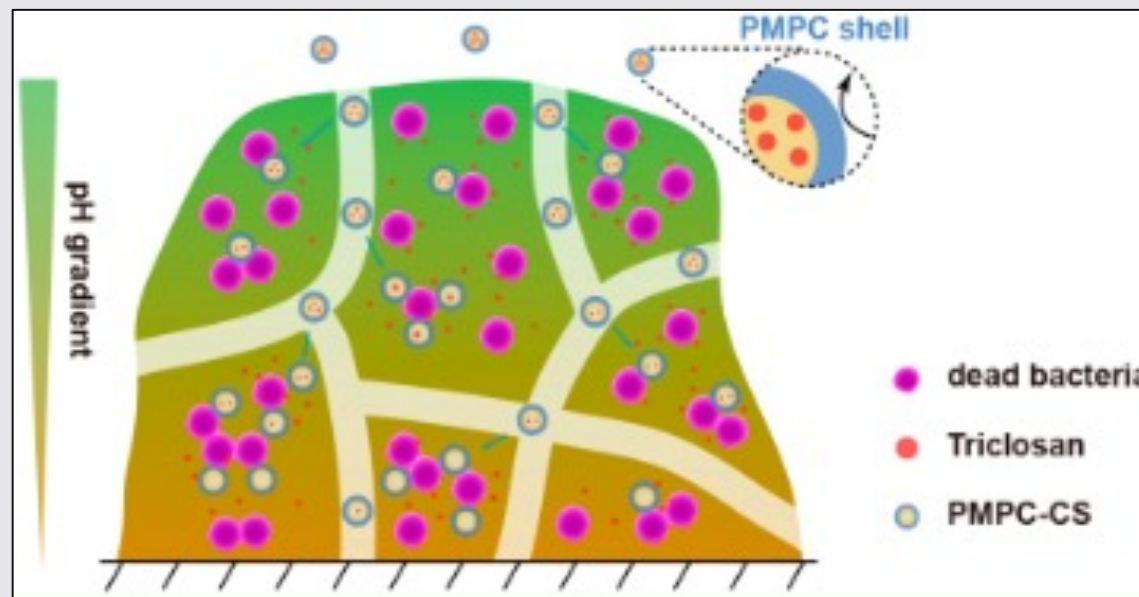
X. Wang, G. Wang, J. Zhao, Z. Zhu and J. Rao, ACS Macro Lett., 2021, 10, 1643–1649

# Mecanismo antibacteriano de los polímeros

## Ejemplo de polímeros antimicrobianos activo



Nanopartículas de quitosana (CS) encapsuladas con poly(2- methacryloyloxyethyl phosphorylcholin (PMPC) y cargadas con antimicrobiano (triclosan)



# Mecanismo antibacteriano de los polímeros

Ejemplo de polímeros antimicrobianos activo

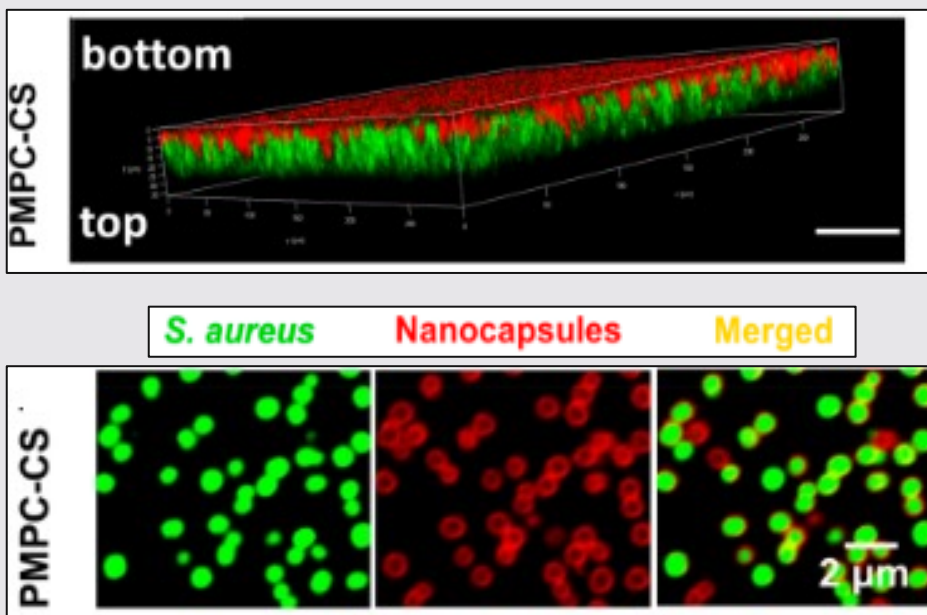
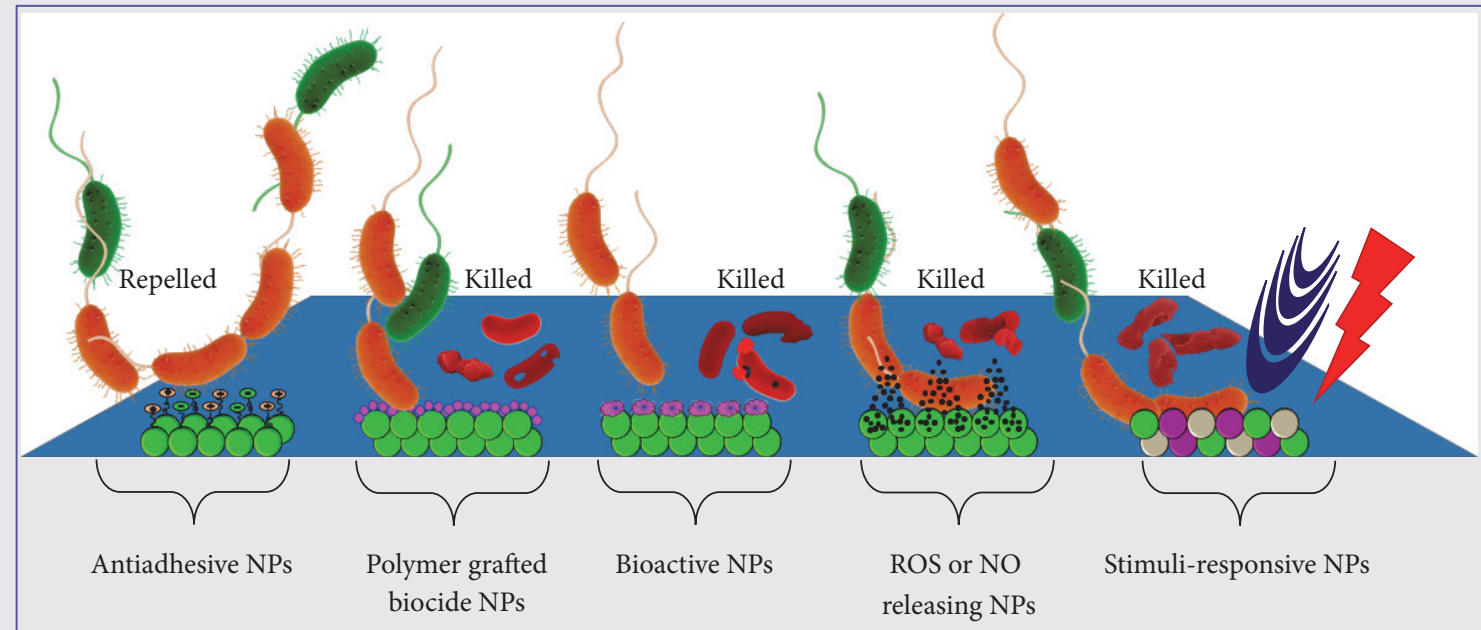


Figure 2. Penetration and accumulation of different Cy5-labeled nanocapsules (red) into a *S. aureus* ATCC12600 GFP biofilm (green). (a) Three-dimensional confocal laser scanning micrographs, showing penetration and accumulation of nanocapsules into a *S. aureus* biofilm (scale bar, 50 μm) (b) Fluorescence images of the attachment of different Cy5-labeled nanocapsules (red) to *S. aureus* ATCC12600GFP (green) cell surfaces in PBS at pH 5.0 (scale bar, 2 μm).

# Modificación Superficies Catéteres

- Utilización polímeros con propiedades bactericidas.
- Bajo costo.
- Utilización de materiales “aprobados” por FDA.
- En conjunto con moléculas activas (Nps/ATB).



Ramasamy M, Lee J. Recent Nanotechnology Approaches for Prevention and Treatment of Biofilm-Associated Infections on Medical Devices. Biomed Res Int. 2016.



## Desafíos

Biocompatibilidad

Citotoxicidad a largo plazo

Acumulación Tejidos

Metabolización/Excreción



# Gracias!



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