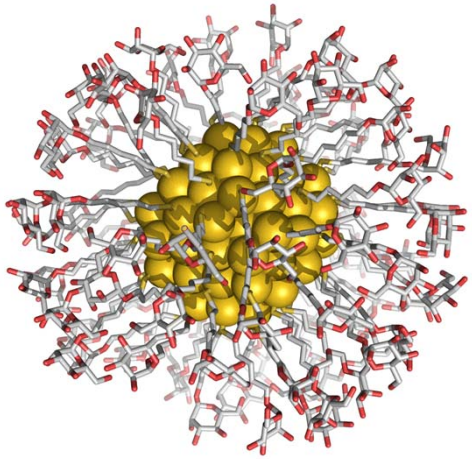
Donostia-San Sebastián, Spain

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales
http://www.cicbiomagune.es

ciber-bbn
Networking Research Centre on Bioengineering, Biomaterials and Nanomedicine
www.ciber-bbn.es



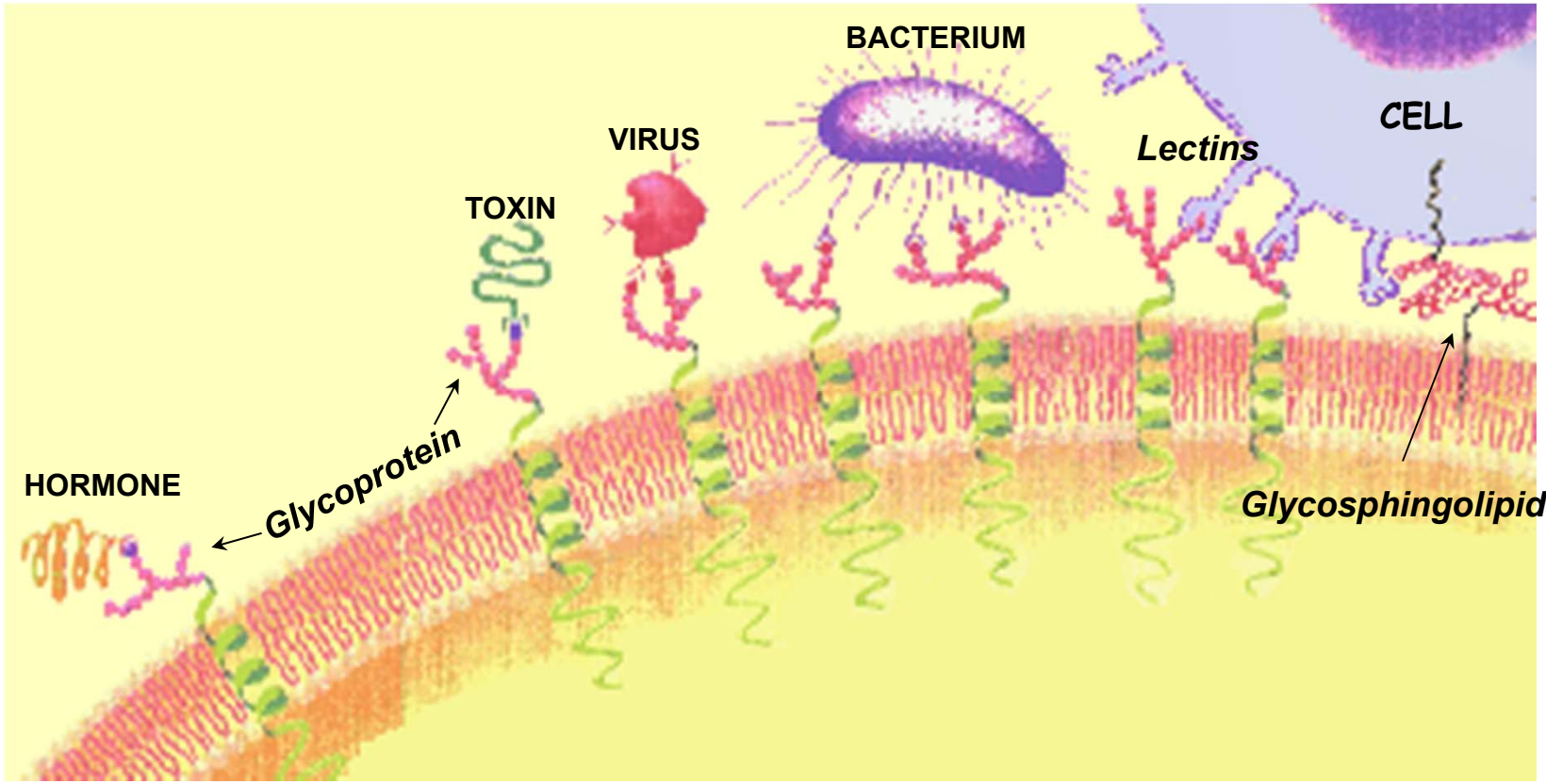
1.6 nm mannose-GNPs

Glyco-NanoParticles (GNPs) and their potential biomedical applications

International Summer School on Fluorescent Nano-Particles in Biomedicine
XIX Escuela Internacional de Verano Nicolás Cabrera
Madrid, Spain, 16th-20th July 2012

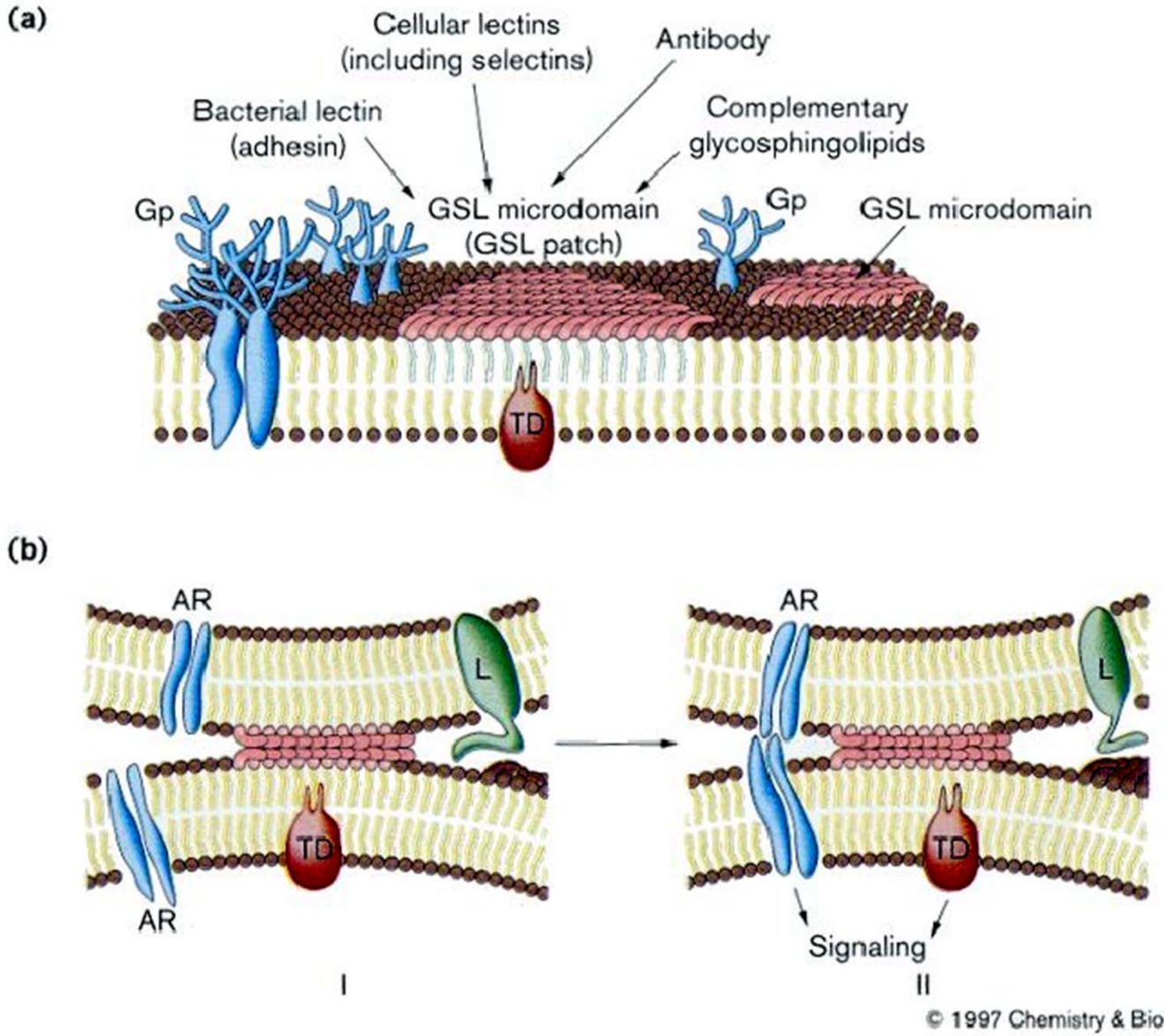
Soledad Penadés
Laboratory of GlycoNanotechnology
Biofunctional Nanomaterials Unit

Carbohydrates in Cell Recognition



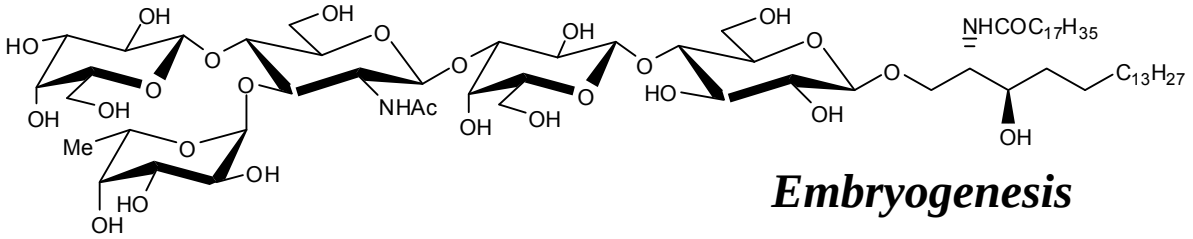
1993, Scientific American

Glycolipid-Glycolipid Interaction and Cellular Adhesion



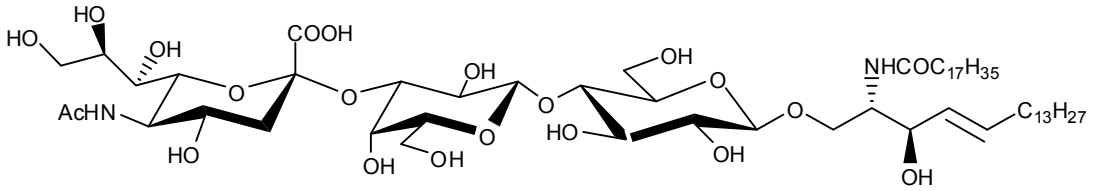
Glycolipids involved in carbohydrate self-recognition

Lewis X
(SSEA-1)



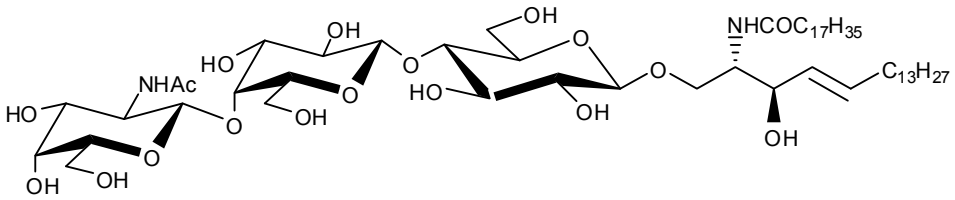
Embryogenesis

GM3



Metastasis

Gg3



Glyconanotechnology

A chemical strategy at the interface Carbohydrate-Nanotechnology

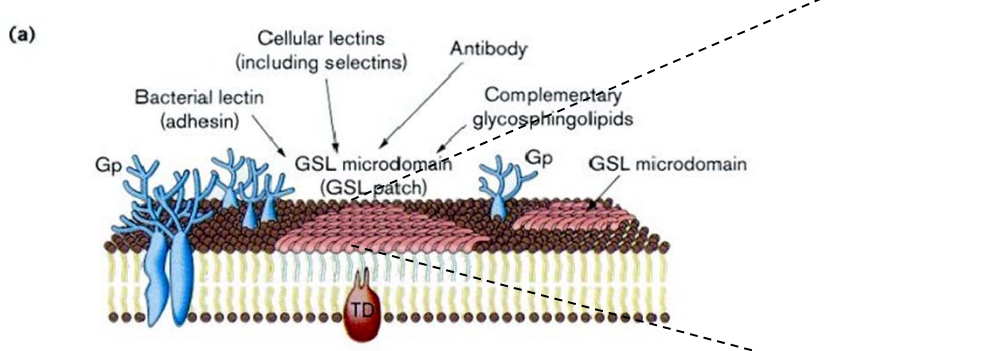
- To create polyvalent tools (SAMs and GNPs),

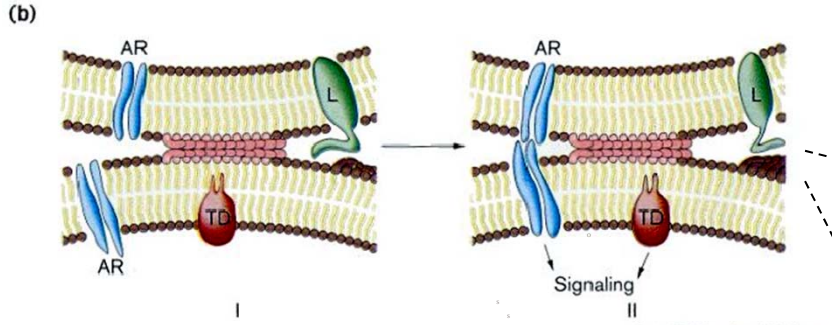
  mimicking carbohydrate presentation at the cell surface

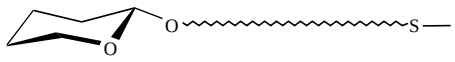
- To study and intervene in carbohydrate-mediated biological processes,

  by means of biophysical techniques (AFM, TEM, SPR,..)

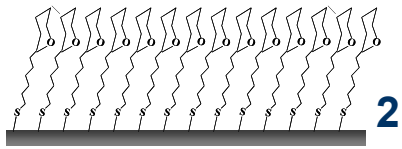
GLYCONANOTECHNOLOGY
Polyvalent Models for Mimicking Carbohydrate Clusters





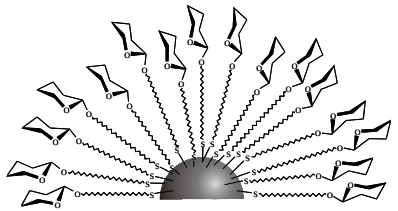


Neoglycoconjugates of Significant Oligosaccharides



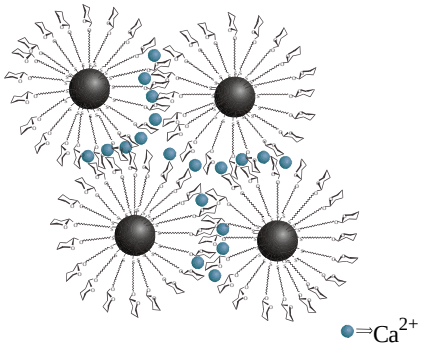
2D-Model

SAMs on Gold



3D-Model

Glyconanoparticles

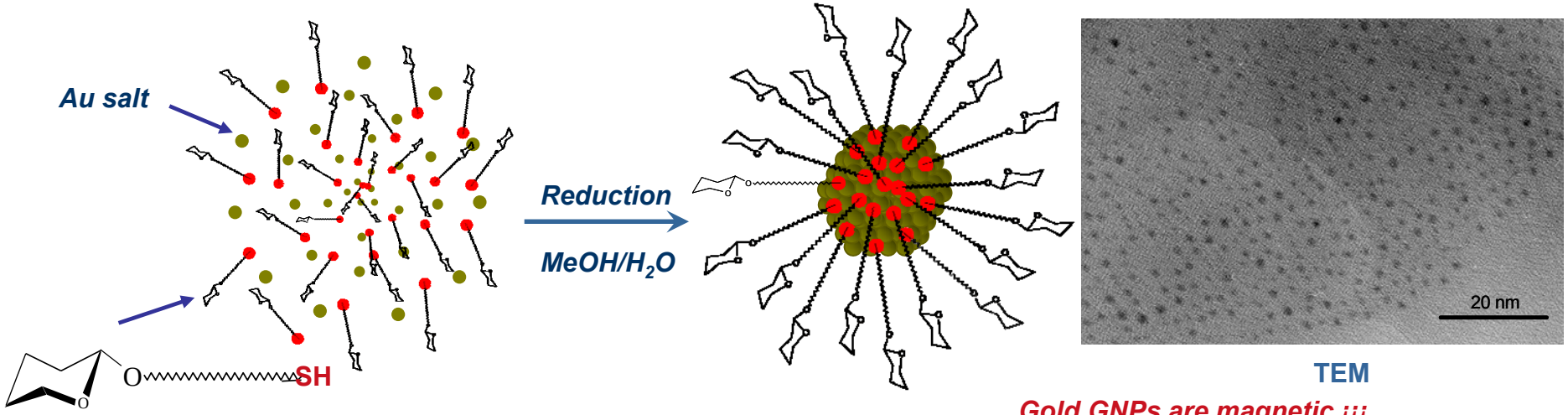


ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

In situ formation of 1.8 nm glyconanoparticles

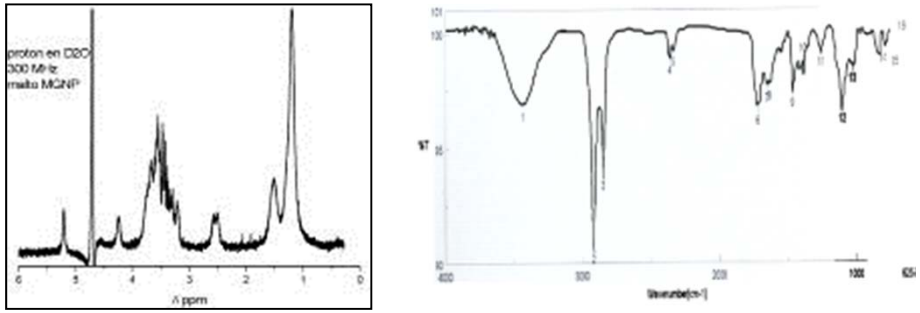
Inspired in Brust-Shiffrin method, *Chem Commun* 1994



Neoglycoconjugates

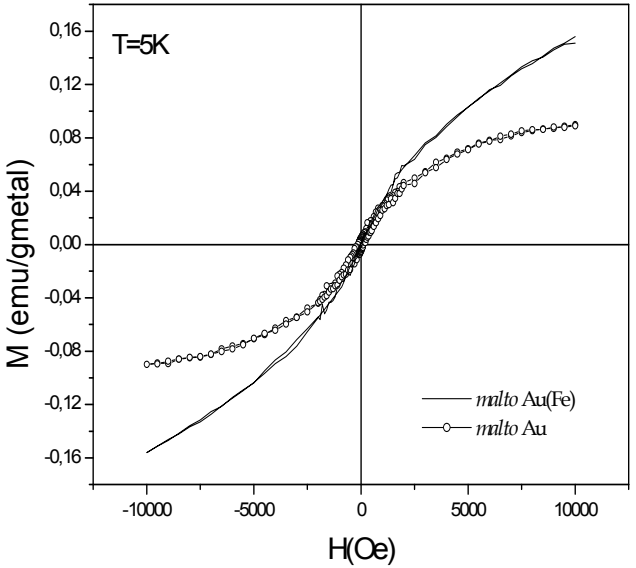
TEM

Gold GNPs are magnetic ¡¡¡



^{1}H-NMR

FT-IR



UV, ICP-AES, Elemental Analysis, MALDI-TOF

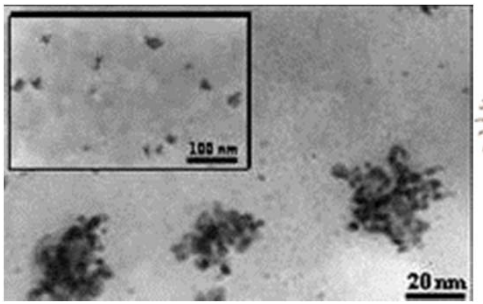
P. Crespo et al., Phys. Rev. Lett., 2004
P. Crespo et al., Phys. Rev. Lett., 2006
J. M de la Fuente et al., J. Phys Chem. B 2006

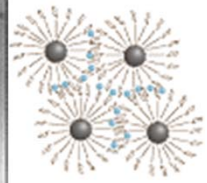
J. M. de la Fuente et al., *Angew Chem. 2001;*
A. G. Barrientos et al., *Chem. Eur. J. 2003*

ciber-bbn

CIC biomaGUNE

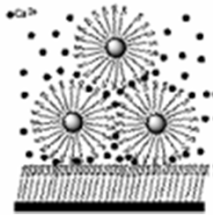
Glyconanotechnology for carbohydrate-carbohydrate interactions

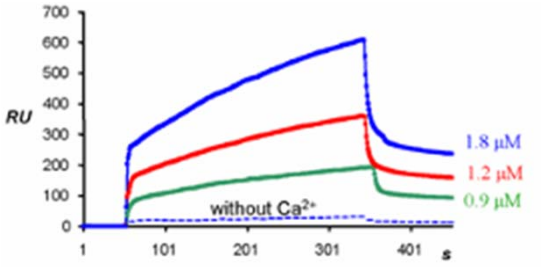




Lewis X

TEM, *Angew. Chem. Int. Ed.* 2001

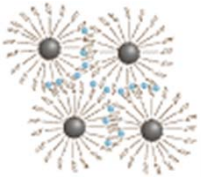


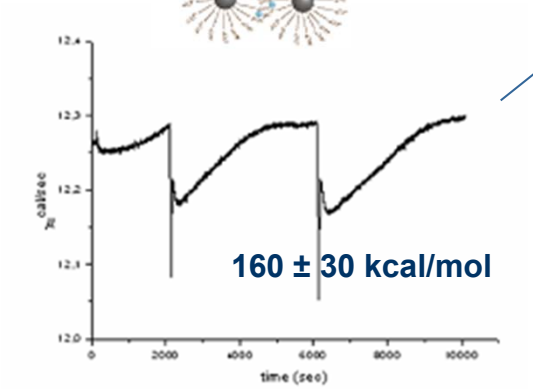


SPR, *Angew. Chem. Int. Ed.* 2002

CARB-CARB INTERACTIONS IN WATER

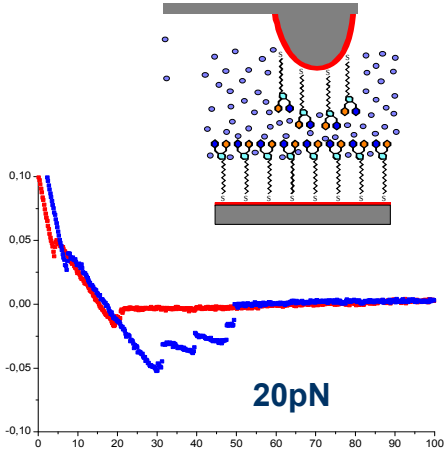
Stabilizing, specific, multivalent and calcium dependent





ITC, *J. Am. Chem. Soc.* 2005

Lewis X self-interaction
A mechanism
for cell-cell adhesion



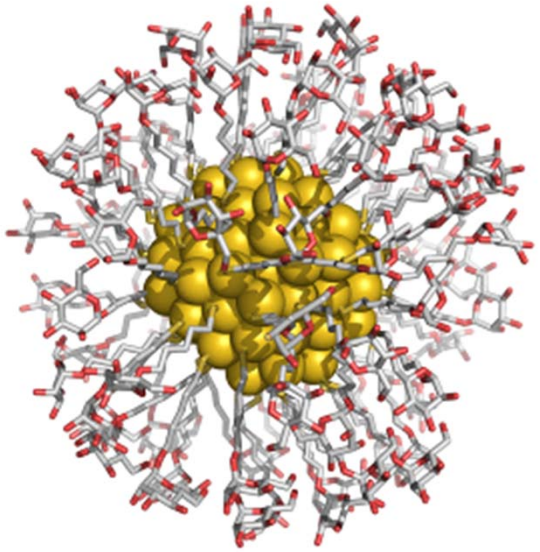
AFM, *Angew. Chem. Int. Ed.* 2001

Reviews: *Glycoconjugate J.* (2004) *21*, 149
BBA-Gen Subjects (2006) *1760*, 636

ciber-bbn

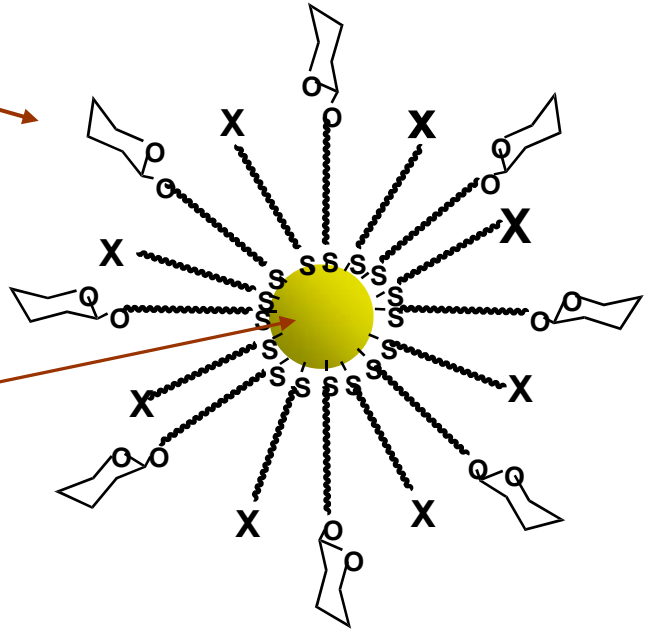
CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

From glyconanoparticles to nanocells



SAMs of antigenic oligosaccharides

Metal cluster
Au, Ag, AuFe, AuCu, FeO@Au CdS, CdSZn, CdSe, CdTe



Gold Glyconanoparticles

- easy to prepare and purify
- exceptionally small (<2nm)
- water soluble, biocompatible
- highly polyvalent
- resistant to enzyme degradation
- not cytotoxic
- singular physical properties
(*permanent magnetism, fluorescent*)

Differing Density and Ligands

- control over density
- control over number of ligands
- up to four different ligands
- different spacer's length

X= DNA, RNA, lipids, peptides, proteins, fluorescence probes, biotin, anti-virales and drugs

Reviews: JM de la Fuente et al., *Glycoconjugate J.* (2004) *21*, 149;
BBA-Gen Subjects (2006) *1760,* 636;
I García et al., *Nanomedicine* (2011), *5, 777*

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

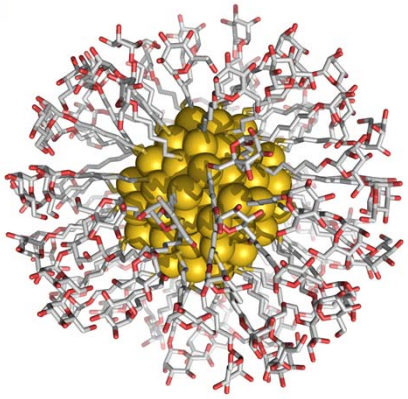
Applications of metallic glyco-nanoparticles

CHEMICAL GLYCOBIOLOGY

- Carb-Carb Interactions
- Carb-Protein Interactions

NANOMATERIALS DESIGN

- Microstructure Manipulation
- Quantum-Dot Bioconjugates
- Magnetic Bioconjugates



BIOTECHNOLOGY AND BIOMEDICINE

- Anti-Adhesion Agents
  - *Metastasis of melanoma cells*
  - *Microbicides against HIV*
- Synthetic Nanovaccines
- Multimodal Contrast Agents
  - *To image brain tumors in vivo*
  - *To label and track cells*

ciber-bbn

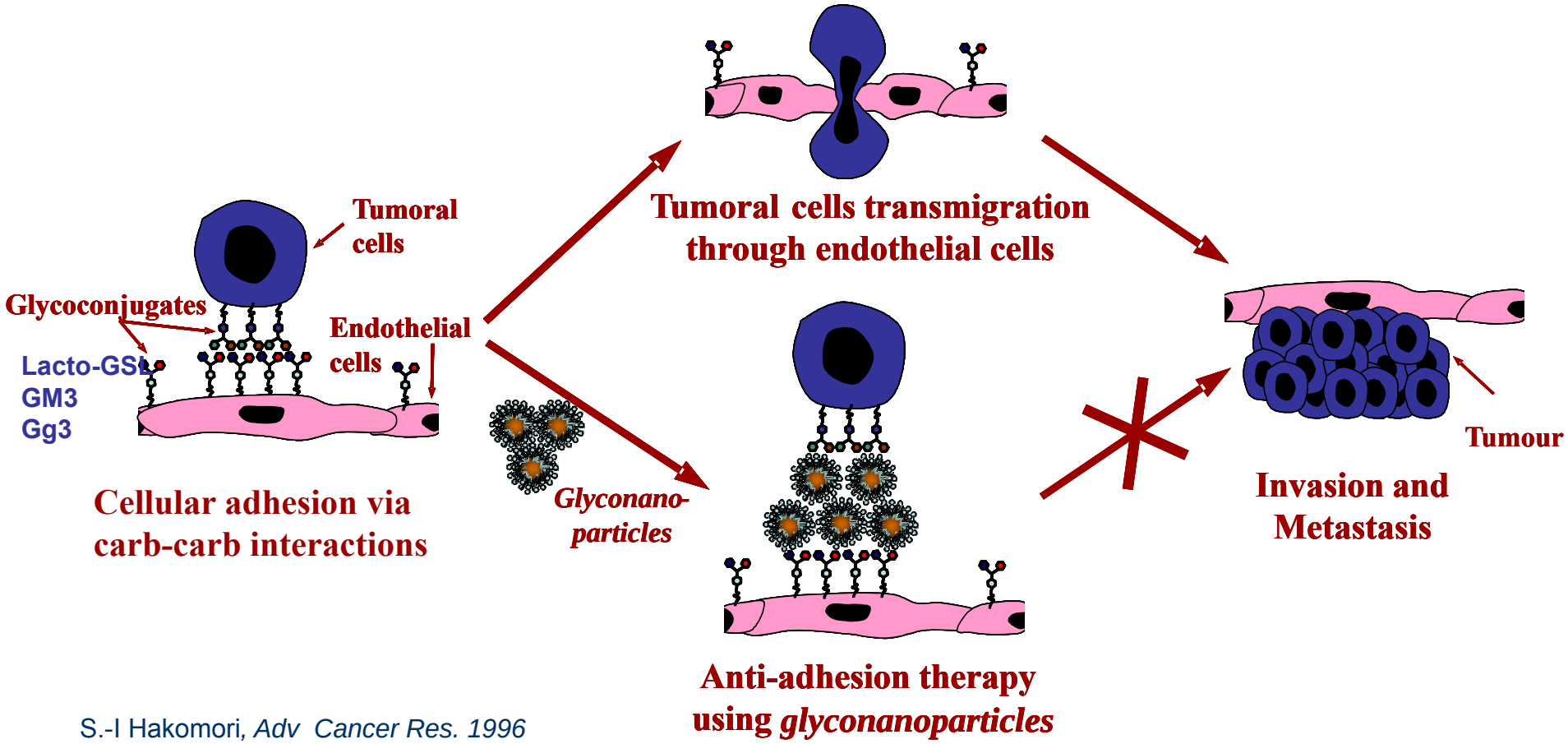
CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

GlycoNanoParticles (GNPs) for biomedical applications

- Glyconanoparticles to study carbohydrate-mediate interactions

- **Glyconanoparticles in biomedical problems**
  - ▲ **Anti-Adhesion Agents and Vaccines**
    - ***- Metastasis of melanoma cells***
    - ***- HIV infection***
    - ***- Synthetic anti-carbohydrate vaccines***
  - ▲ **Multimodal Contrast Agents for Molecular Imaging**
    - **- Sugar/Gd-coated gold nanoparticles**
    - **- Magnetic *glyco*-ferrites@Au**

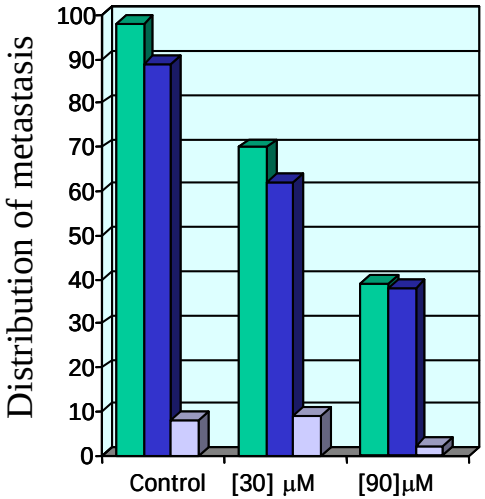
Glyconanoparticles as anti-adhesion agents in metastasis of melanoma

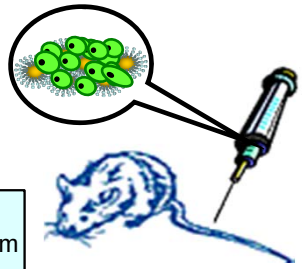


S.-I Hakomori, *Adv Cancer Res. 1996*

A.G. Barrientos, 2002

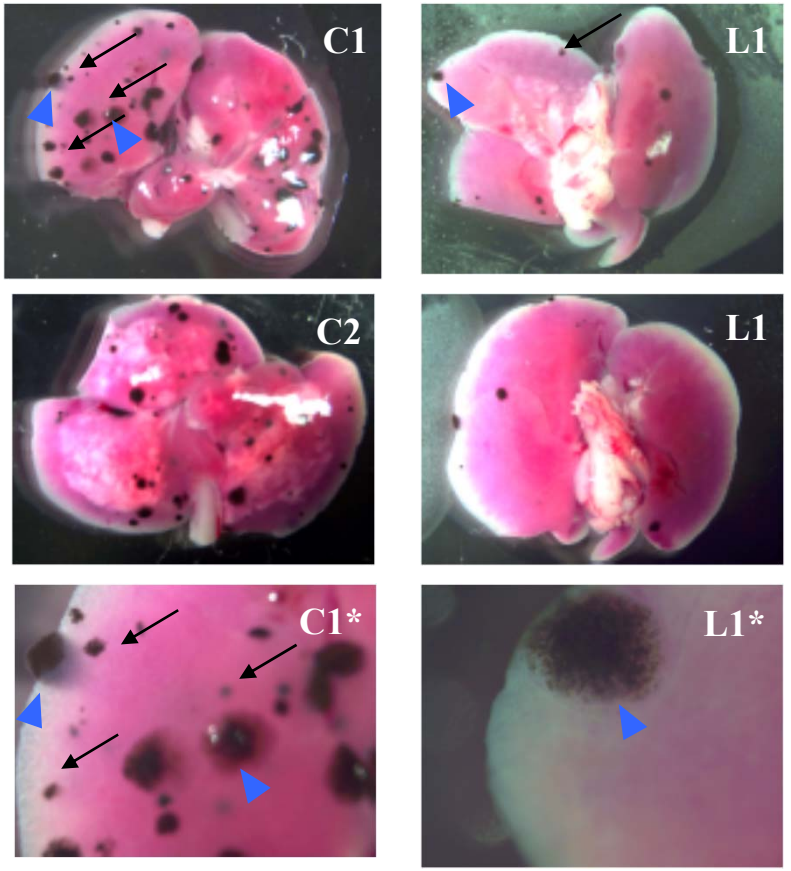
Glyconanoparticles in metastasis of melanoma

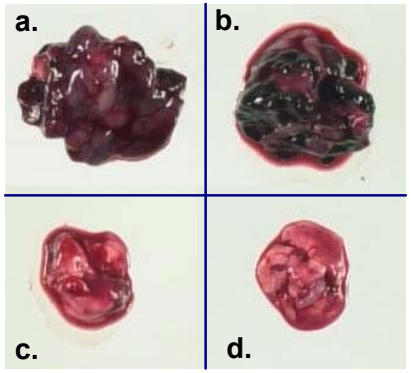




Lacto-GNPs
Gluco-GNPs

B16 Tumoral Cells



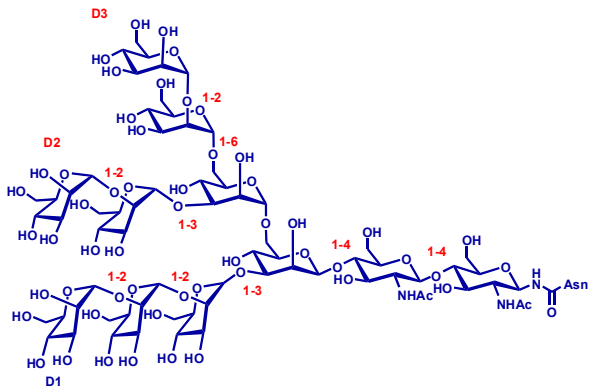


Lungs of mice coinjected with:

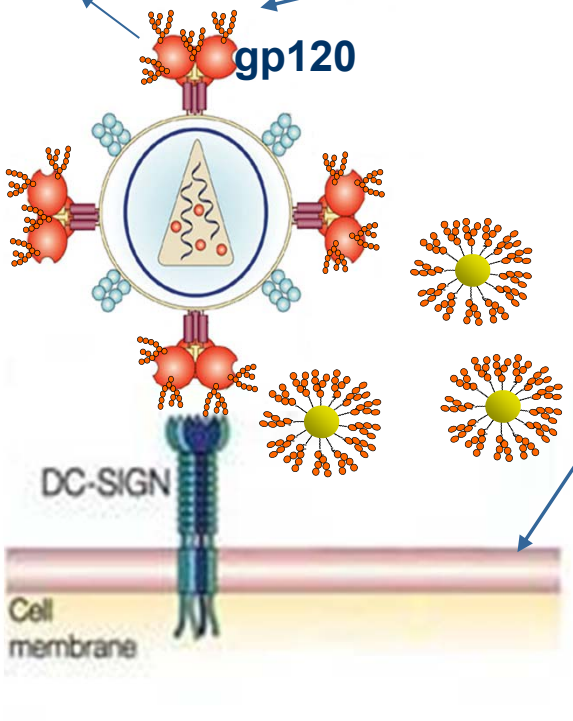
a. **B16 Cells**
b. **B16 Cells + *Gluco*-GNPs**
c. **Negative control**
d. **B16 Cells + *Lacto*-GNPs**

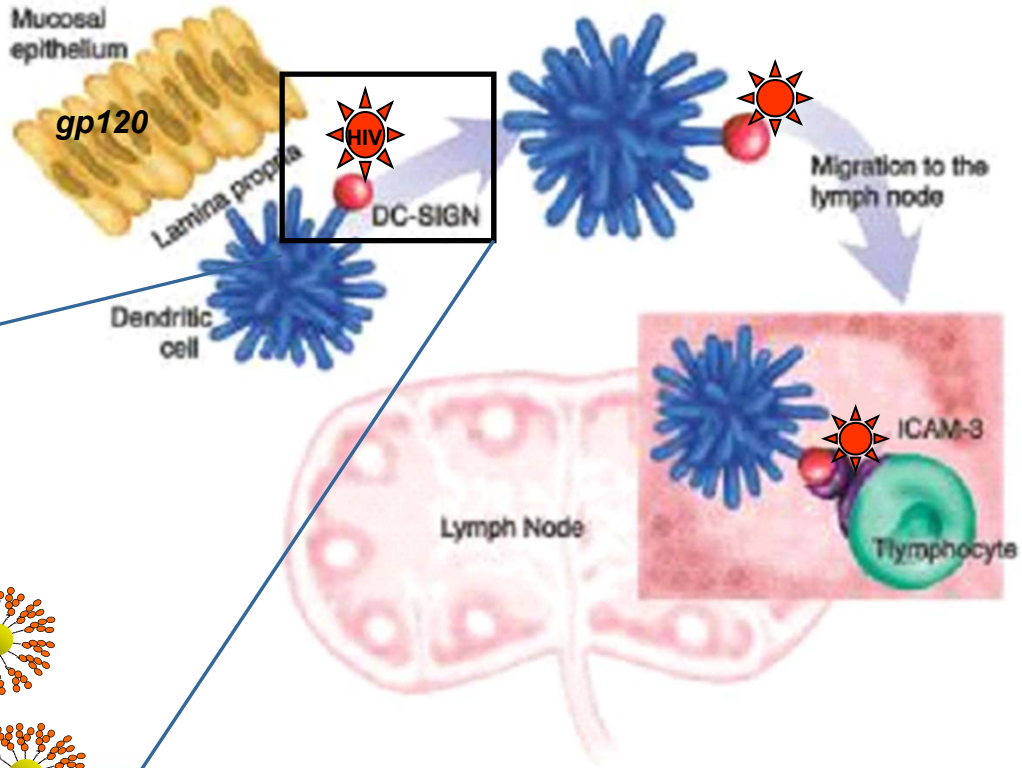
J. Rojo et al., *ChemBioChem, 2004*
(with A. Bernad, J. Riese, *CNB-CSIC)*

*Manno*GNPs in HIV *trans*-Infection of T-cells



High-mannose type glycans





Geijtenbeek et al., *Cell* **2000,** 100, 587
R. Shattock et al. *J Exp Med.* **2004**, 199, 8, 106

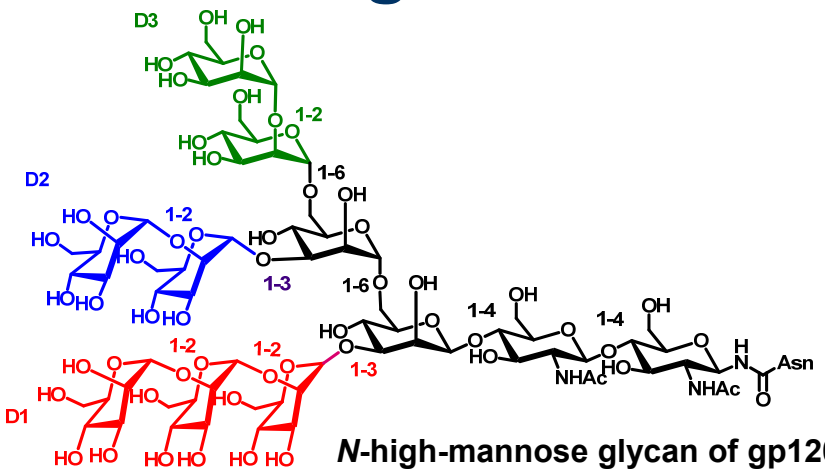
F. Hladik et al., *Immunity* **2007**, 26, 257

Feinberg et al., *Science 2001*
Mitchell et al., *J Biol Chem 2001*

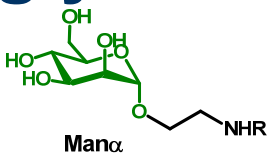
ciber-bbn

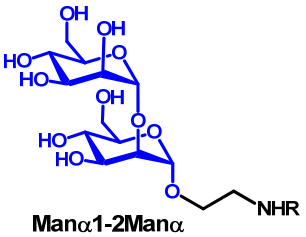
CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

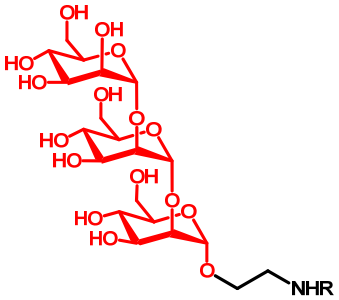
Selected oligomannosides of the HIVgp120 high-mannose glycans

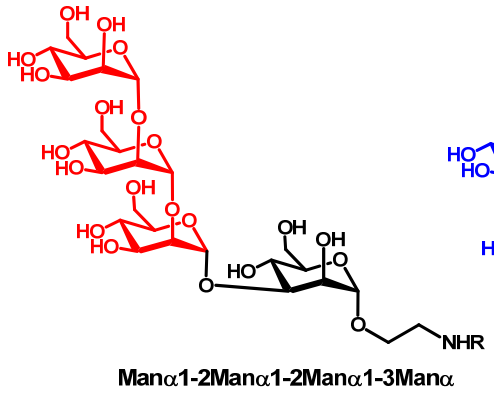


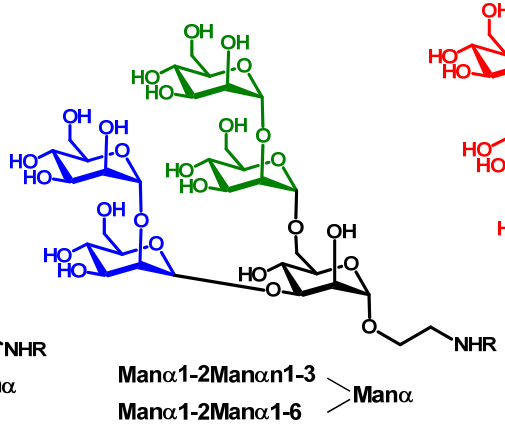
N-high-mannose glycan of gp120

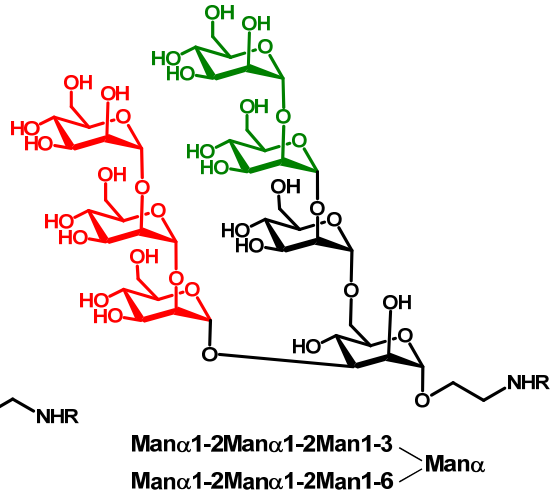




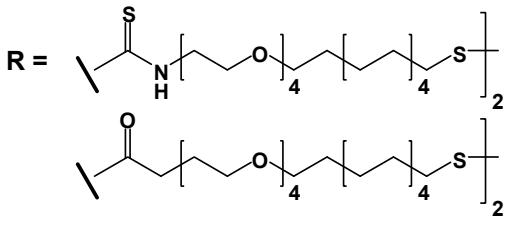








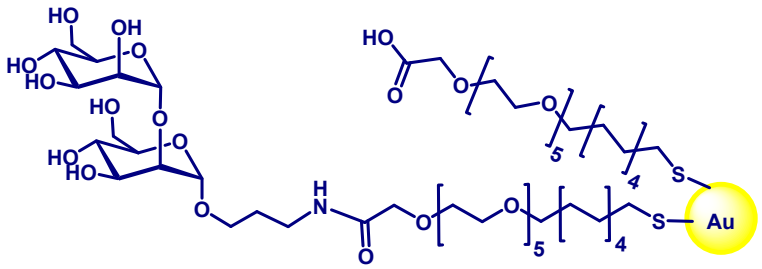
Wong CH et al. *Angew Chem.* 2004, *43*, 1000



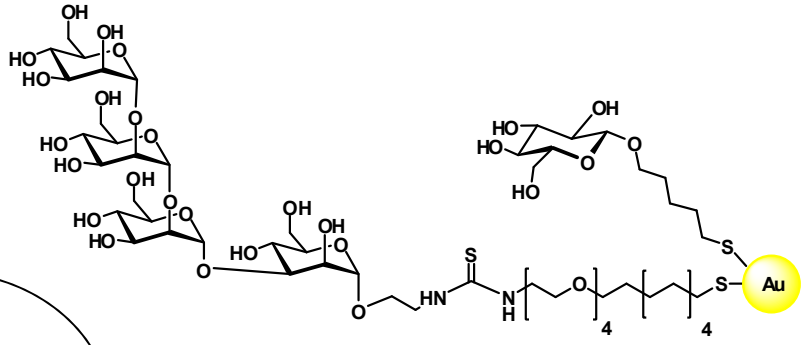
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

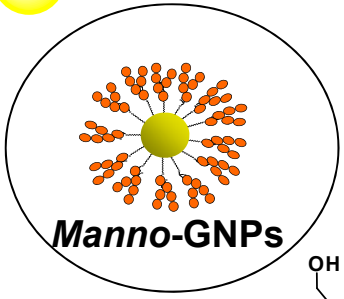
Manno-GNPs with varying density of oligomannosides

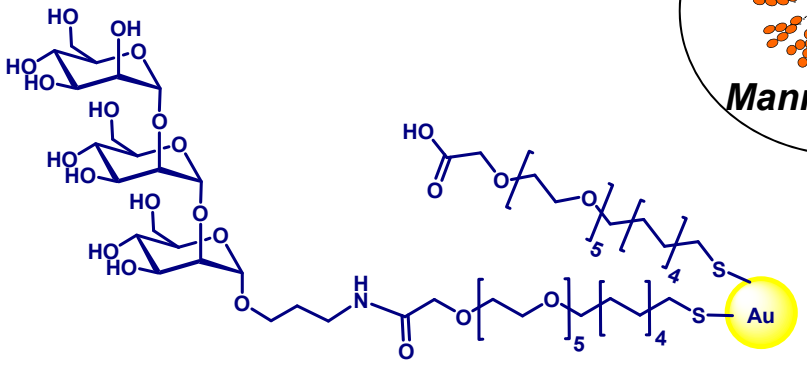


Man2-GNP (D 10, 50, 100%)

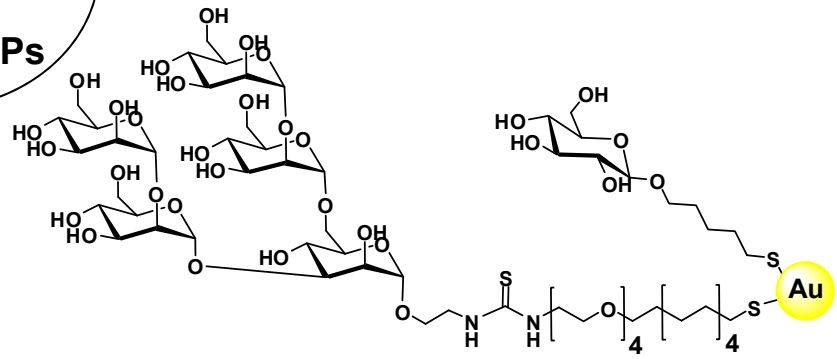


Man4-GNP, (Te 10, 50 %)

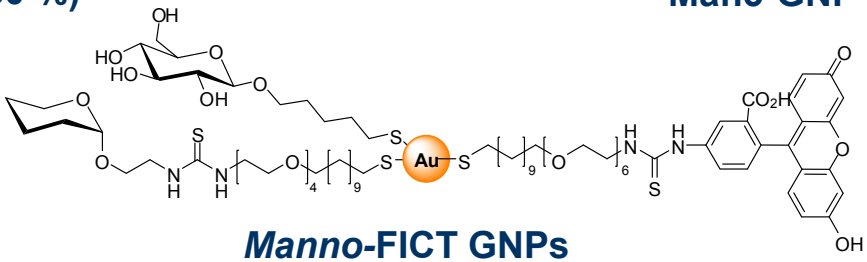




Man3-GNP (T 10, 50 %)



Man5-GNP (P 10, 50 %)



Manno-FICT GNPs

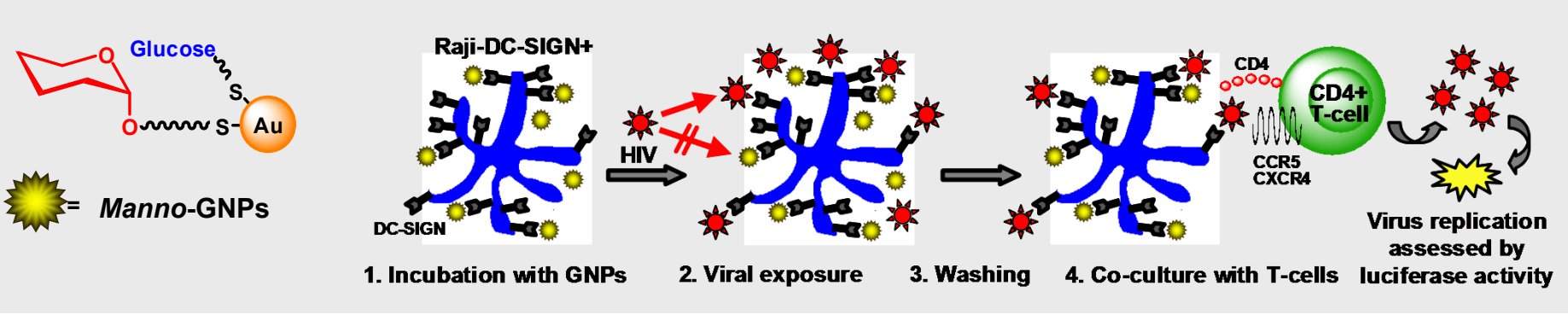
ciber-bbn

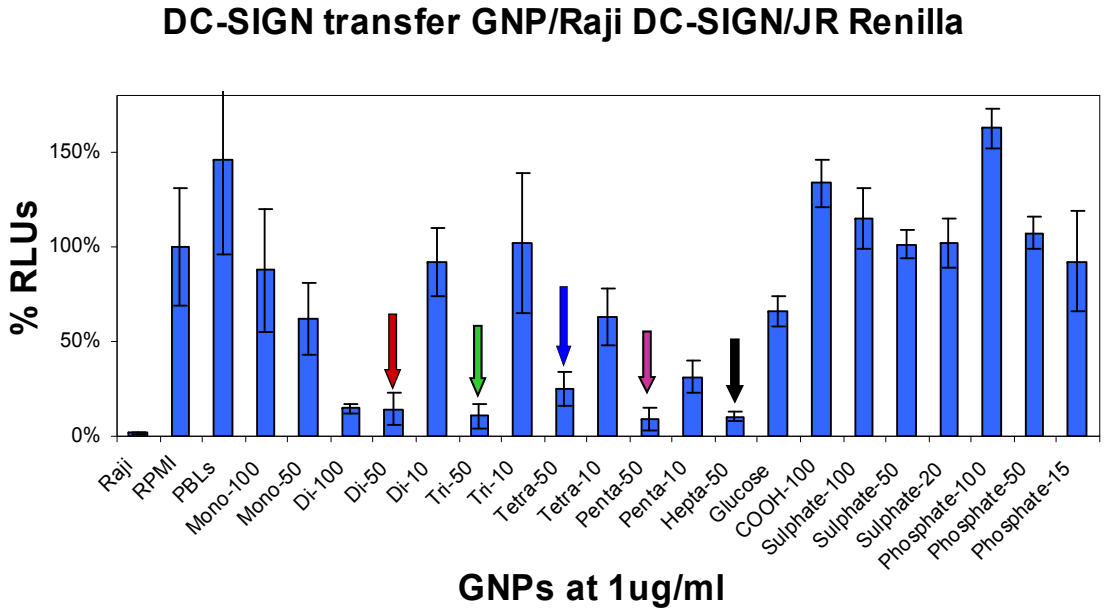
O. Martínez-Ávila et al. *Chem Eur J* 2009
M. Marradi et al., *J. Mol. Biol.* 2011

- ***Biosensor experiments***
- ***NMR techniques***
- ***Cellular assays***

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Manno-GNPs inhibit DC-SIGN-mediated HIV-1 *trans*-infection of human T cells





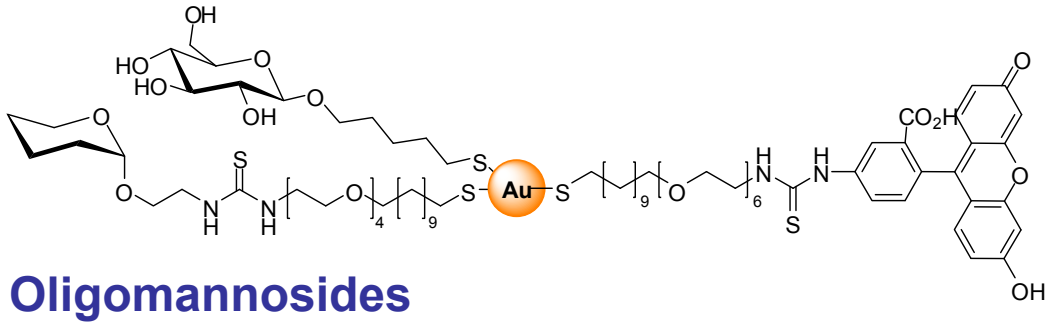
GNP	IC50 (ng/mL)
Man $_2$ 50% GNP	80 (~2.0 nM)
Man $_3$ 50% GNP	166 (~1.6 nM)
Man $_4$ 50% GNP	41 (~ 0.3 nM)
Man $_5$ 50% GNP	58 (~0.6 nM)
Man $_7$ 50% GNP	79 (~0.5 nM)

O. Martínez-Ávila et al., *ChemBioChem 2009*
*(*with L. M. Bedoya, J. Alcamí, AIDS Unit, ISCIII*)*

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Fluorescent *manno*GNPs for in vitro cellular screening

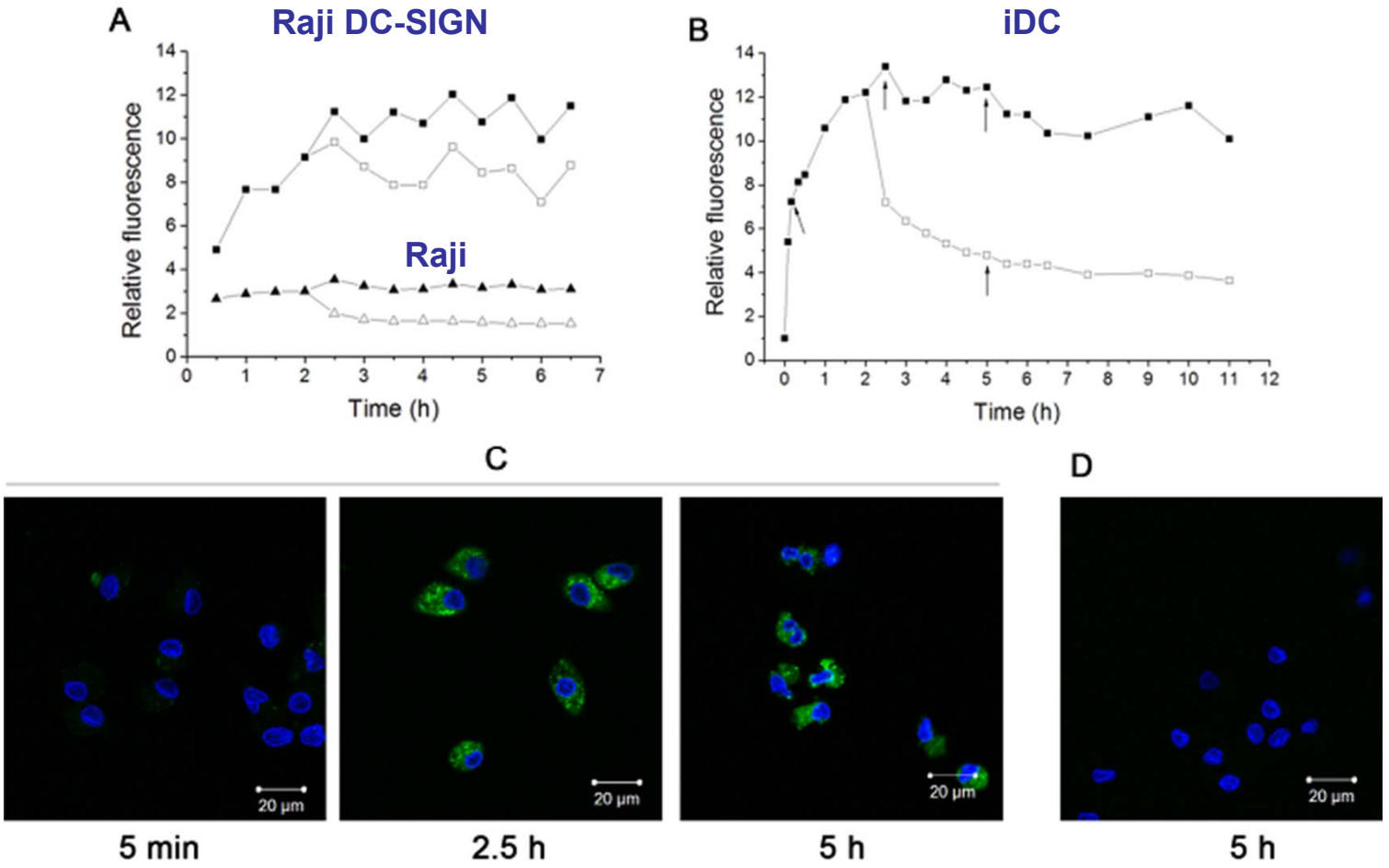


FITC

HIVgp120 Oligomannosides

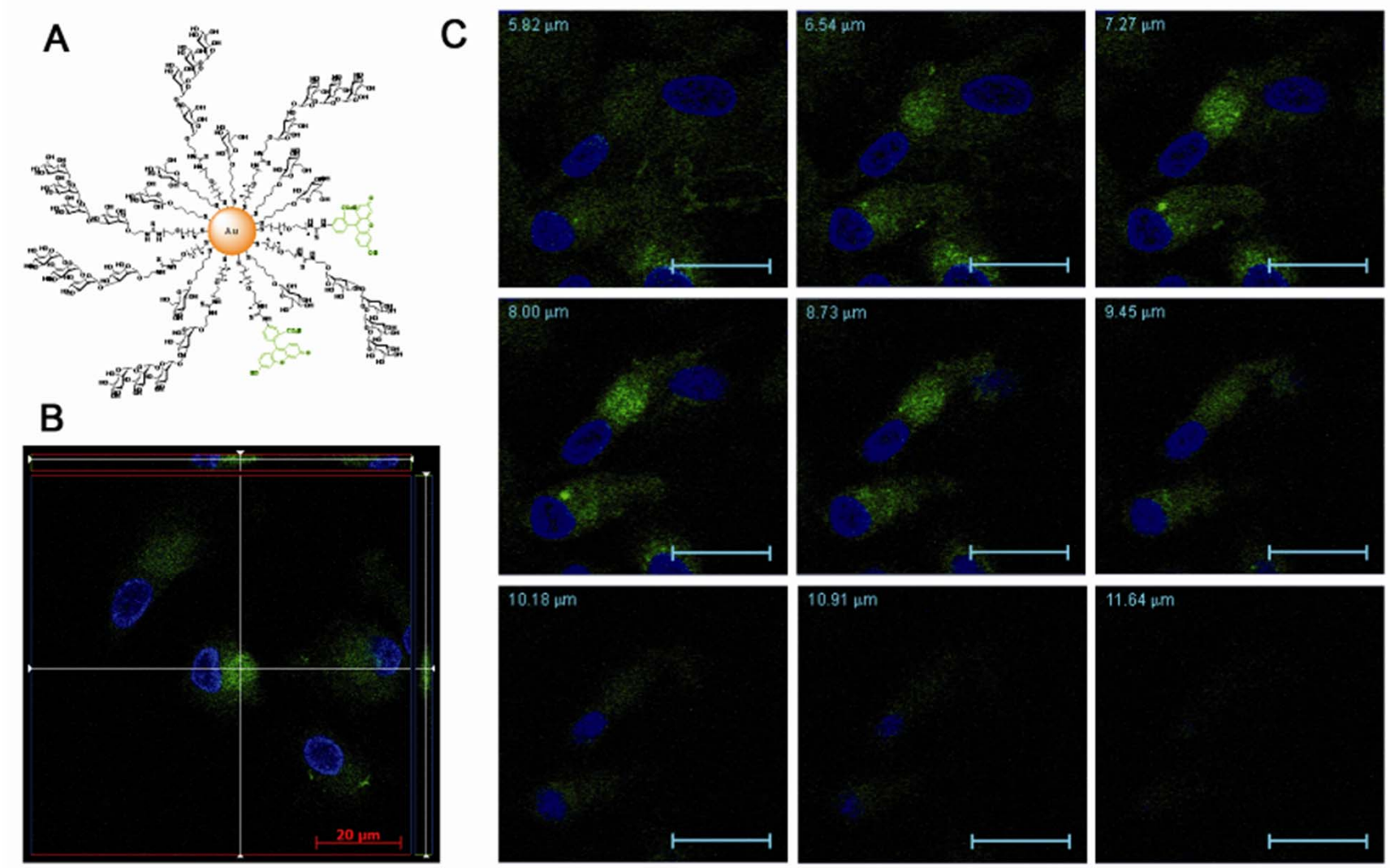
- Uptake and fate of FITC-*manno*GNPs in DCs by Flow Cytometry and Confocal Microscopy

FC analysis of the uptake of FITC-*manno*GNPs by Raji DC-SIGN, Raji, and iDCs



B. Arnáiz et al. *Bioconjugate Chem.***2012**

Confocal images of single plane series of a Z-stack of iDCs incubated with FITC-Te50GNP

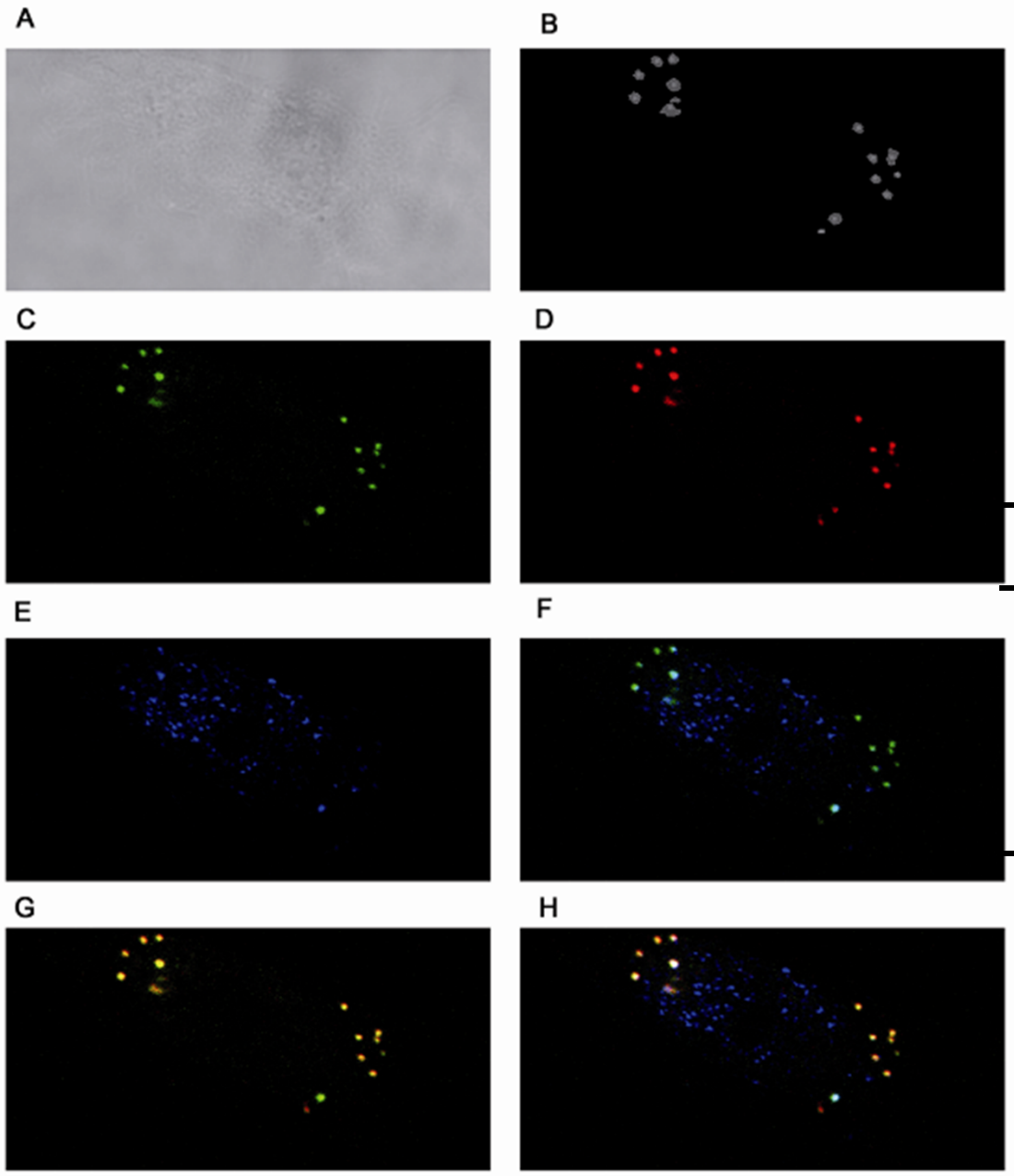


B. Arnáiz et al. *Bioconjugate Chem.***2012**

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Quantitative colocalization of FITC-Te50GNPs with Early Endosome and DC-SIGN



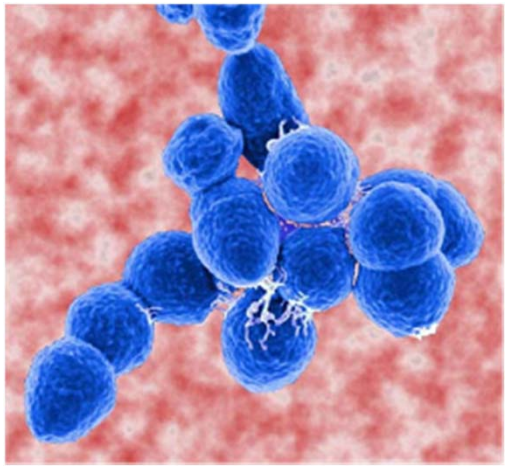
Objects	Nr. Counts	Percentage (%)
FITCTe50GNPs^{+} organelles (green)	1413	100
EEA1^{+} organelles (red)	603	43
DC-SIGN^{+} organelles (blue)	871	62
Triple colocalization	518	36

B. Arnáiz et al. *Bioconjugate Chem.* **2012**

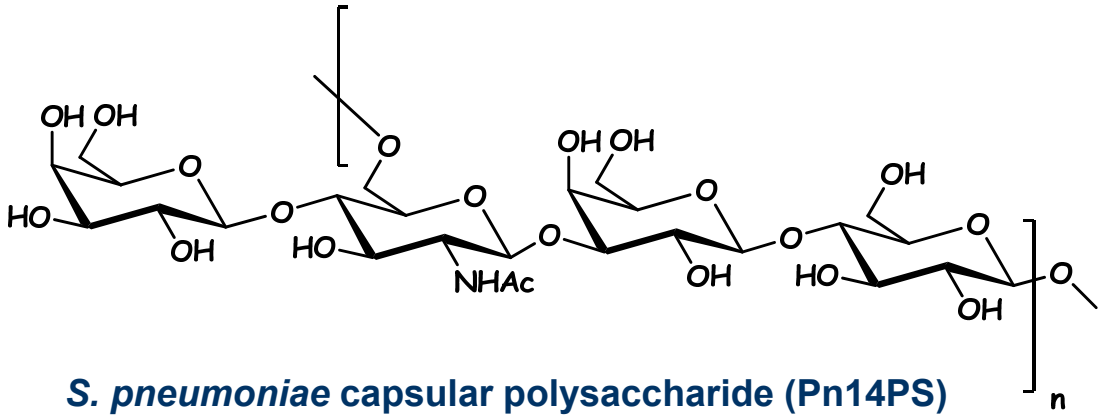
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

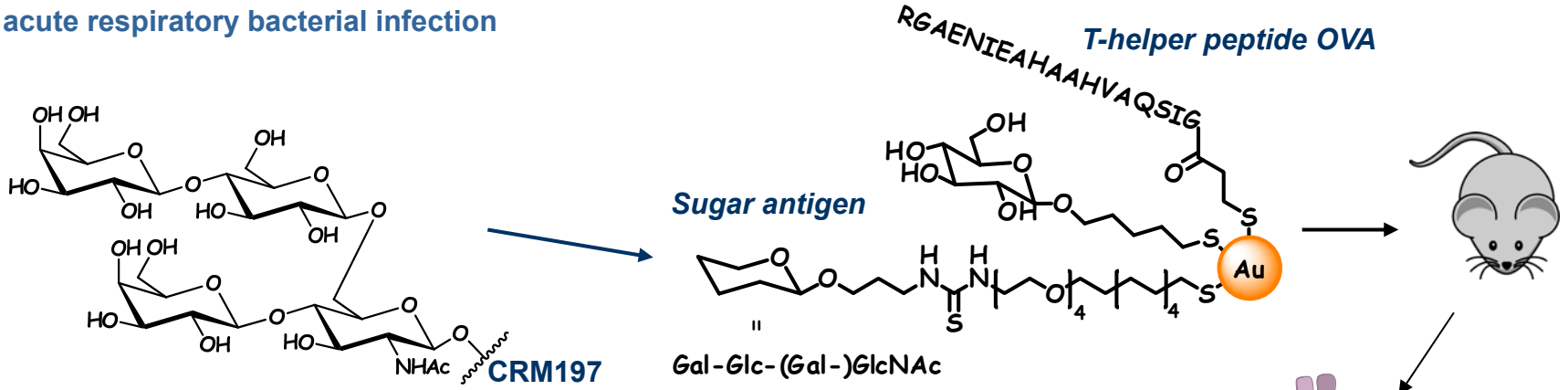
Gold GNPs as carrier for vaccine against *S. pneumoniae*



S. pneumoniae: major cause of acute respiratory bacterial infection



S. pneumoniae capsular polysaccharide (Pn14PS)



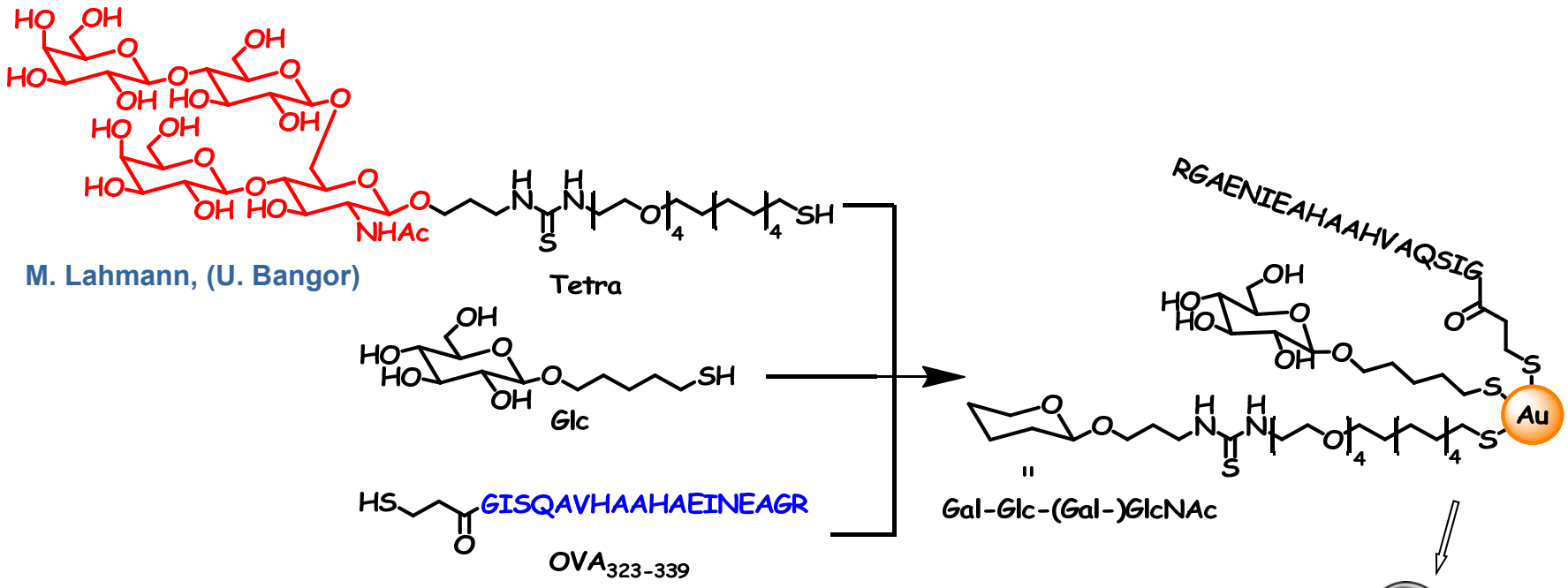
Gal(β1→4)Glc(β1→6)[Gal(β1→4)]GlcNAc

(Safari, D. et al. *Infect. Immun.* 2008, 76, 4615-4623)

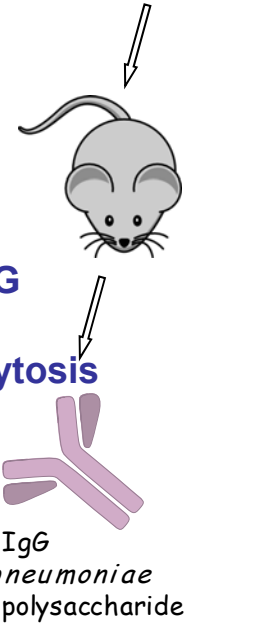
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Gold GNPs coated with a synthetic epitope of Pn14PS



GNPs	Metal core diameter	Tetra:Glc:OVA
GNP-1	1.8 ± 0.5 nm	45 : 50 : 5
GNP-2	1.9 ± 0.3 nm	50 : 50 : 0
GNP-3	1.9 ± 0.5 nm	0 : 90 : 10
GNP-4	2.1 ± 0.4 nm	40 : 50 : 10
GNP-5	1.7 ± 0.6 nm	20 : 70 : 10



M. Marradi et al., *Nanomedicine UK* **2012**
with H. Snippe and D. Safari (Utrecht)

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

GlycoNanoParticles (GNPs) for biomedical applications

- Glyconanoparticles to study carbohydrate self-interactions
- Glyconanoparticles as Anti-Adhesion Agents
- Glyconanoparticles as Synthetic Anti-Carbohydrate Vaccines

- **Magnetic Glyconanoparticles as Multimodal Probes for Molecular Imaging**

  - for in vivo glioma imaging

  - for labelling cell surface receptors

  - for in vivo labelling and tracking neural stem cells

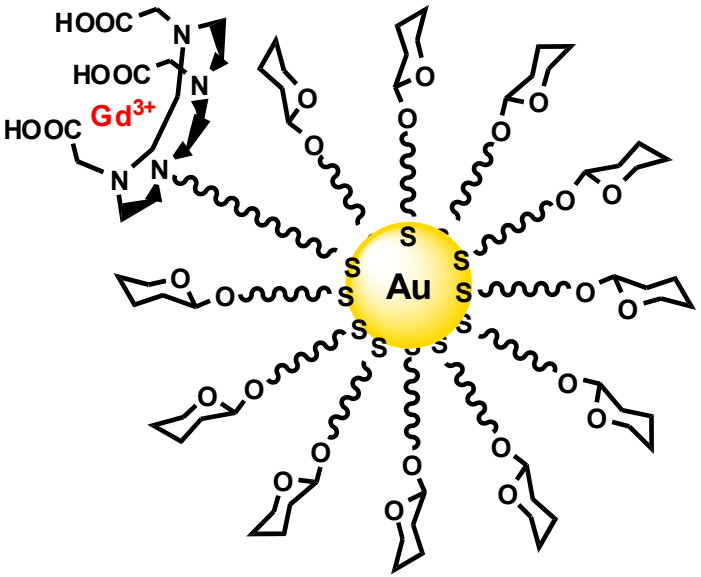
  - for detection the vulnerability of atherosclerotic plaques

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Magnetic glyconanoparticles as MRI probes

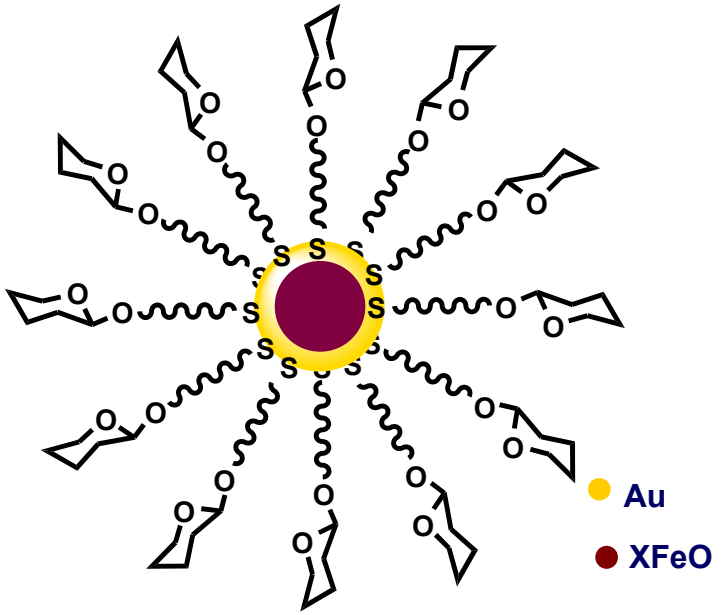
Organic Shell Modification



Paramagnetic GNPs (Agents in T_1)

M. Marradi et al, *Chem Commun 2009,*

Gold Core Modification

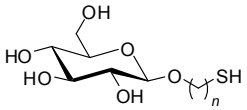


Superparamagnetic core/shell XFeO@Au glyco-ferrites (Agents in T_2)

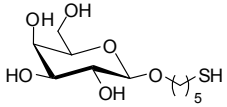
J. Gallo et al., *J. Mat. Chem 2010*

Gd-Based Paramagnetic Glyconanoparticles in MRI

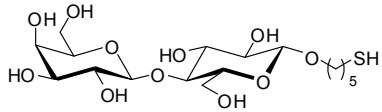
NEOGLYCOCONJUGATES



n=2 *glc*C_2S
n=5 *glc*C_5S

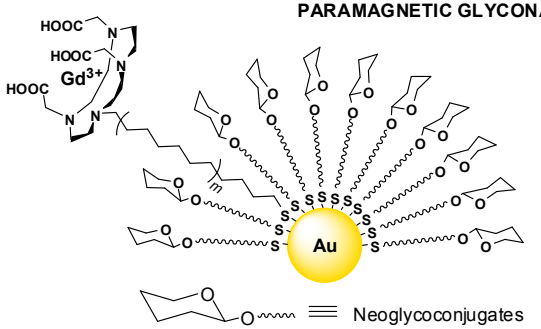


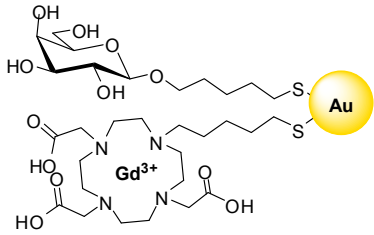
galC_5S



lacC_5S

PARAMAGNETIC GLYCONANOPARTICLES



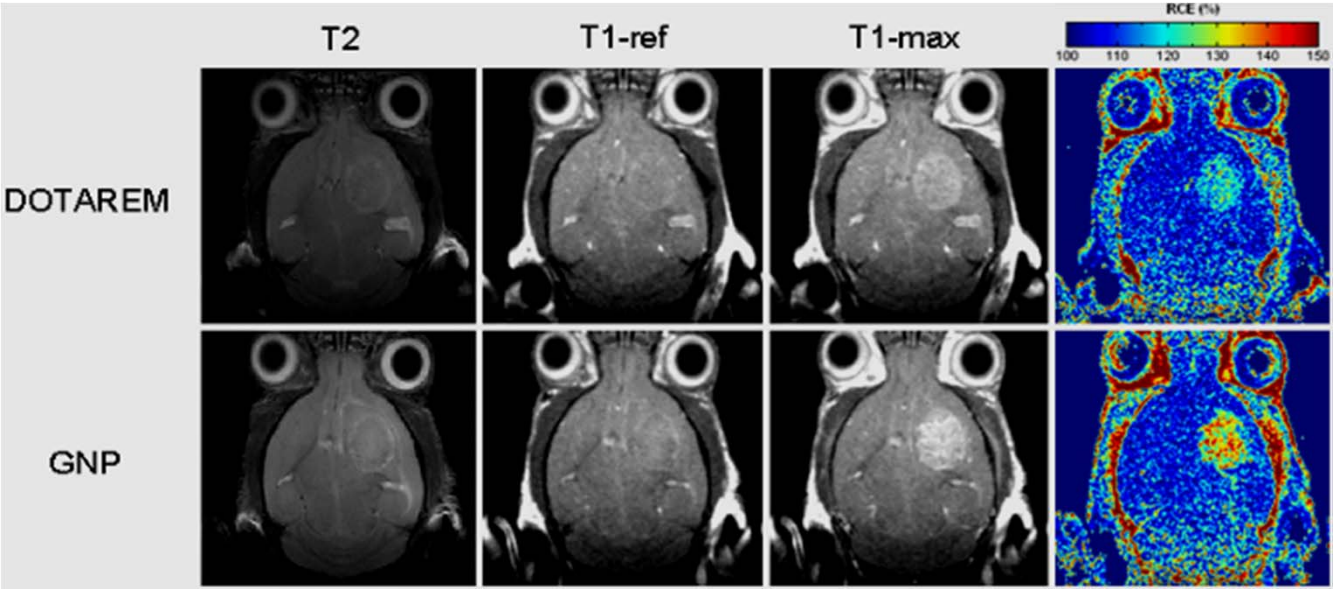


***gal*C_5S-Au-SC_5DO3A-Gd**
(Δl ~ 3.92 Å)

m=0
1: *glc*C_2S-Au-SC_5DO3A-Gd
2: *glc*C_5S-Au-SC_5DO3A-Gd
3: *gal*C_5S-Au-SC_5DO3A-Gd
4: *lac*C_5S-Au-SC_5DO3A-Gd

m=1
5: *glc*C_2S-Au-SC_{11}DO3A-Gd
6: *glc*C_5S-Au-SC_{11}DO3A-Gd
7: *gal*C_5S-Au-SC_{11}DO3A-Gd
8: *lac*C_5S-Au-SC_{11}DO3A-Gd

In vivo T1-weighted images of GL261 glioma in mice with GlcC5/DO3AC11-GNP



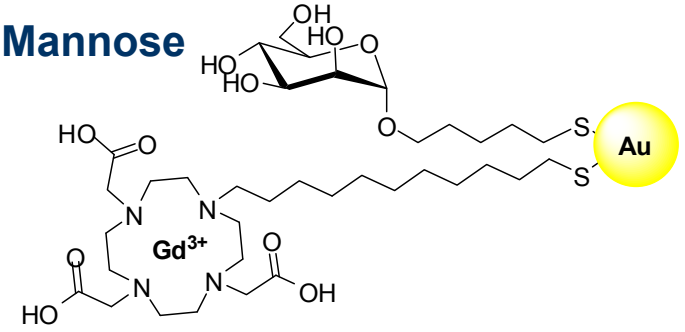
A. Irure, M. Marradi 2009
(with C. Arus, UAB/CIBER-BBN)

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Gd-based paramagnetic glyconanoparticles for labeling cell surface receptors by MRI

Mannose

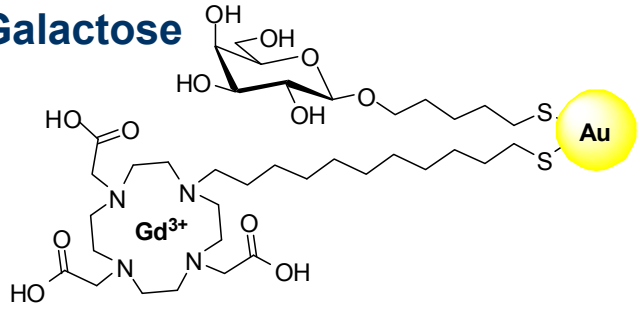


$ManC_5S$-Au-SC_{11}DO3A-Gd

Raji-DC-SIGN/ Raji

DC-SIGN

Galactose

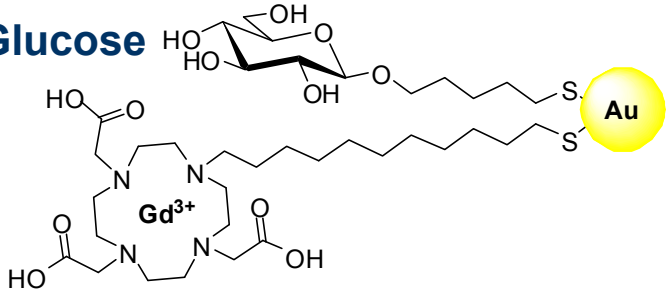


$GalC_5S$-Au-SC_{11}DO3A-Gd

HepG2

Asialoglycoprotein

Glucose

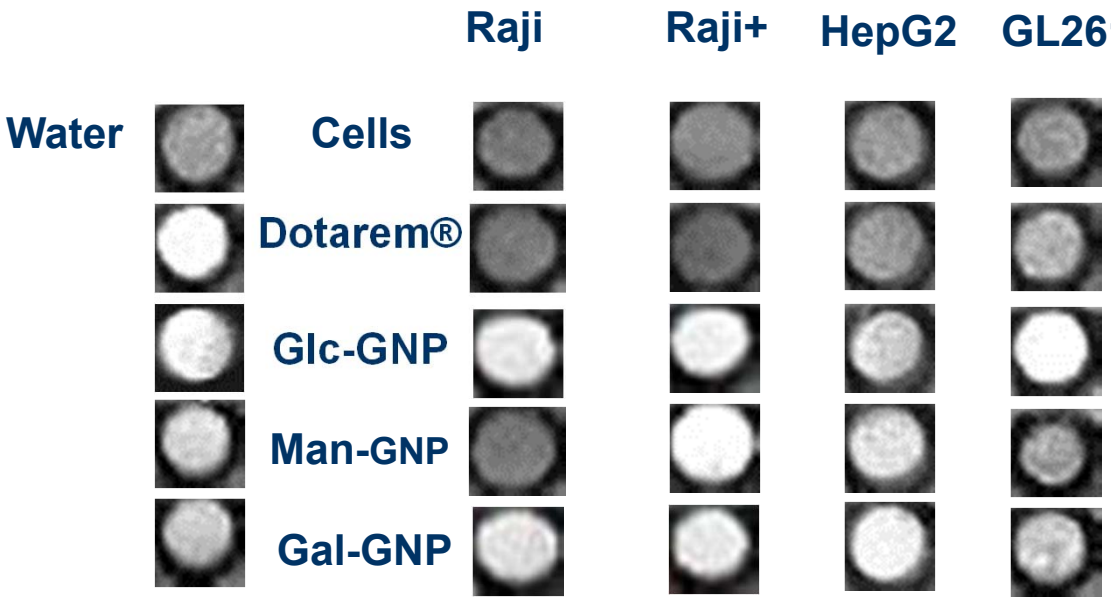


$GlcC_5S$-Au-SC_{11}DO3A-Gd

GL261

Glucose Transporter

Gd-based paramagnetic GNPs for labeling cell surface receptors by MRI



T1-weighted images

Gd-GNP	Raji	Raji+	HepG2	GL261
$GlcC_5S$-Au-SC_{11}DO3A-Gd	70%	71%	37%	70%
$ManC_5S$-Au-SC_{11}DO3A-Gd	65%	74%	54%	53%
$GalC_5S$-Au-SC_{11}DO3A-Gd	57%	66%	66%	57%

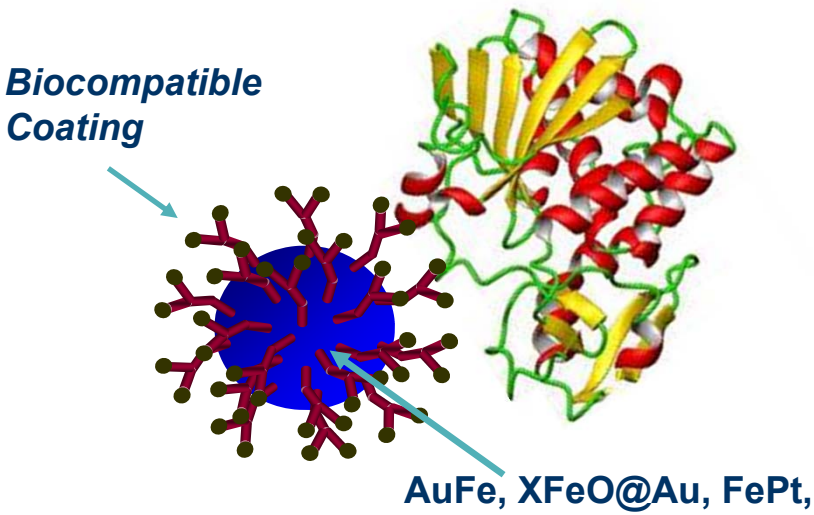
%ΔT1

M. Marradi, A. Irure, N. Genicio, B. Arnáiz, D. Padro, 2011

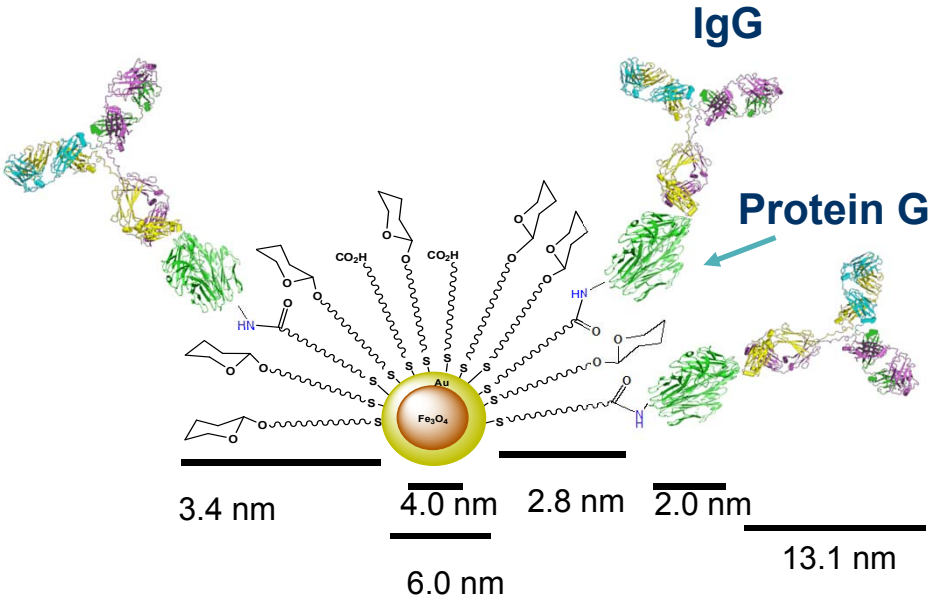
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Targeted superparamagnetic *immuno-glyco*-ferrites for labelling in vivo cells, tissue, and organs



Superparamagnetic GNPs (Agents in T_2)



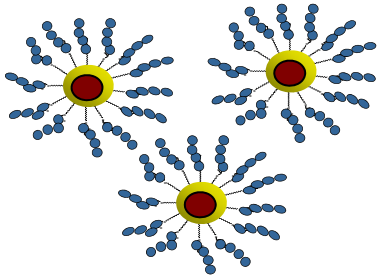
***Core/shell X*FeO@Au *immuno glyco*-ferrites**

Cerdan et al Magn Reson Med 1989
Lewin et al. Nat Biotech 2000
Lee JH et al. Nature Med 2007
Veiseh et al. Cancer Res 2009
Van Kastern et al. Proc Natl Acad Sci USA, 2009
Hadjipanayis et al. Cancer Res. 2010
De la Fuente et al., ACSNano 2011

ciber-bbn

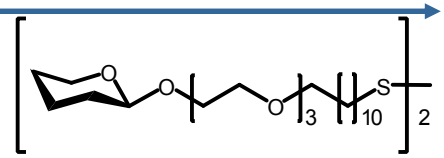
CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Water-soluble superparamagnetic GNPs (*glyco*-ferrites)



Hexane

Water



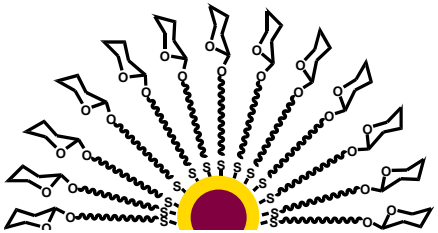
= Lacto, Glc, GlcNAc

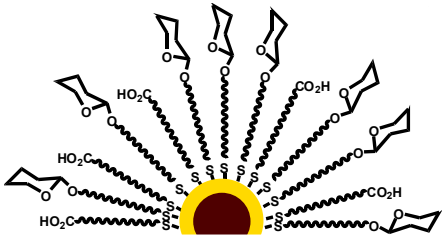
HOOC SH

oleic acid, oleyl amine

XFe_3O_4@Au

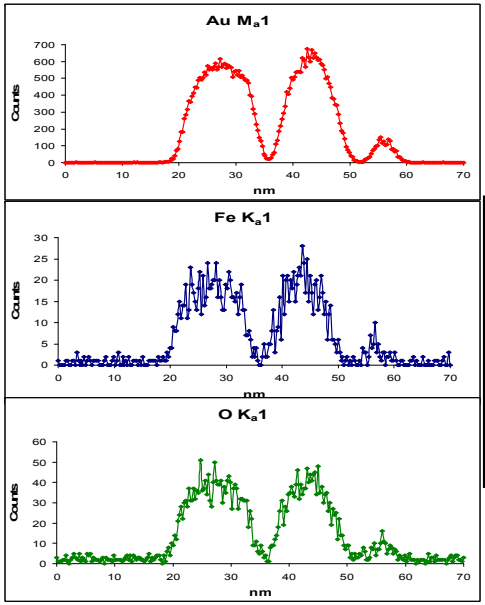
L. Wang *et al. J. Mater. Chem.* 2005

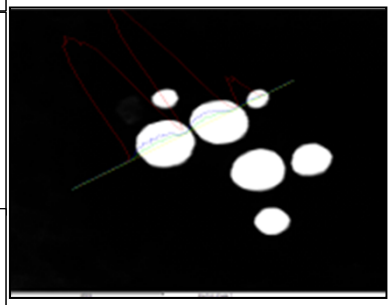




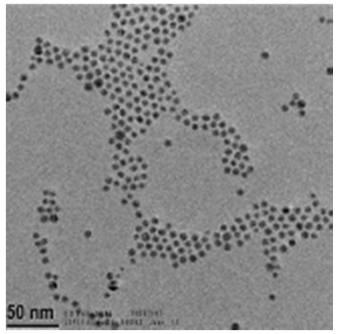
XFe_2O_3@Au

glyco-ferrites

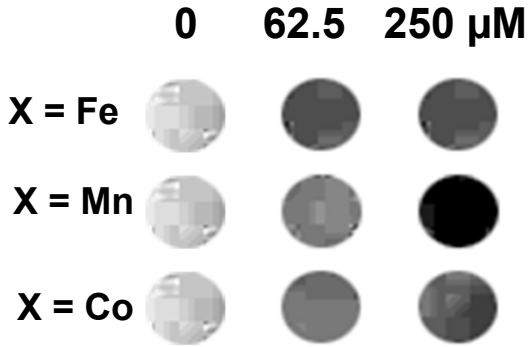




STEM-EDXS



TEM



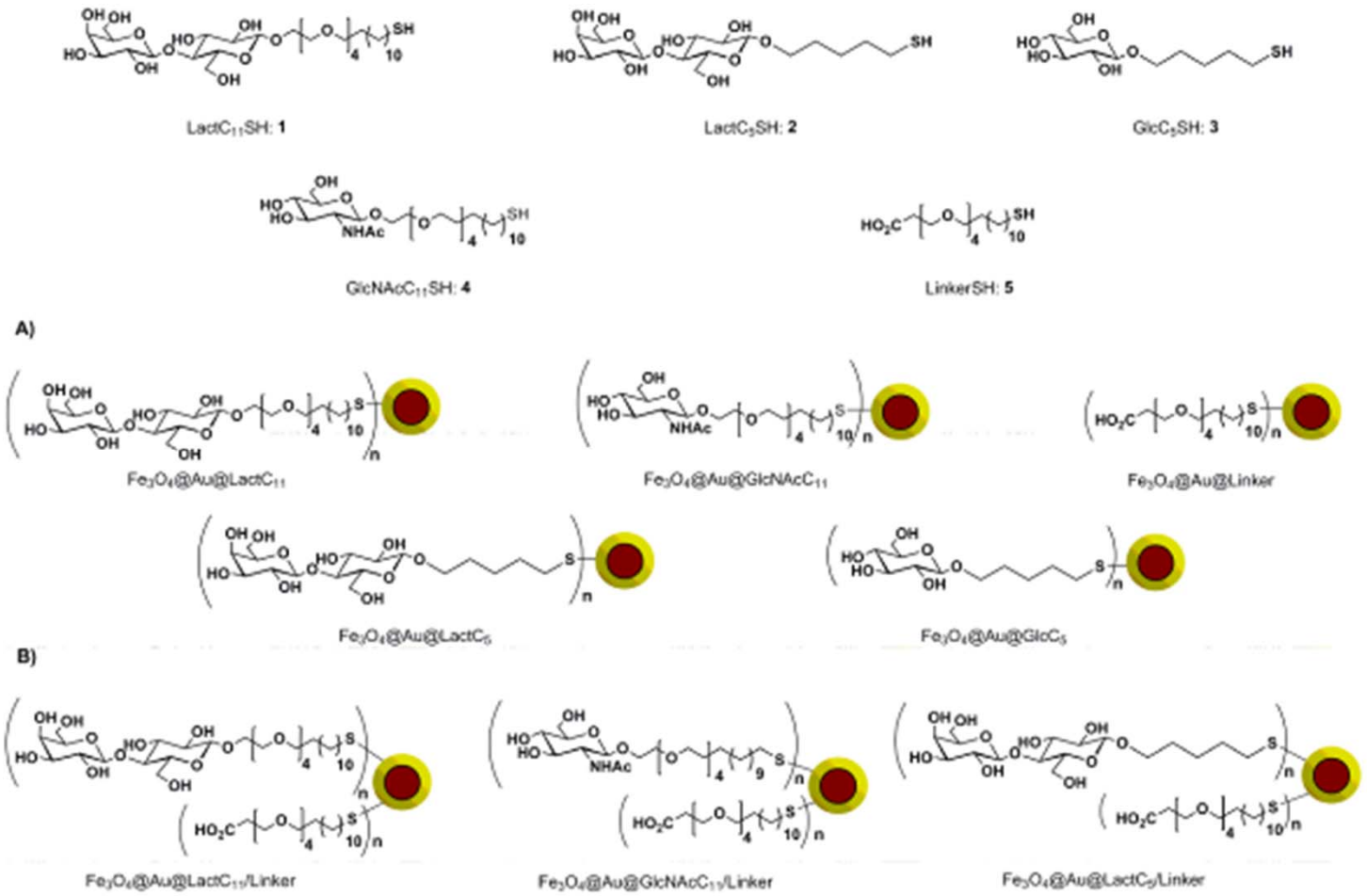
MRI

ciber-bbn

J. Gallo et al., *J. Mat. Chem.* 2010

CIC biomaGUNE

Superparamagnetic Fe_3O_4@Au *glyco*-ferrites



Glyco*-ferrites, *r2 157 [mM-1s-1]
Resovist……. r2 150 [mM-1s-1]

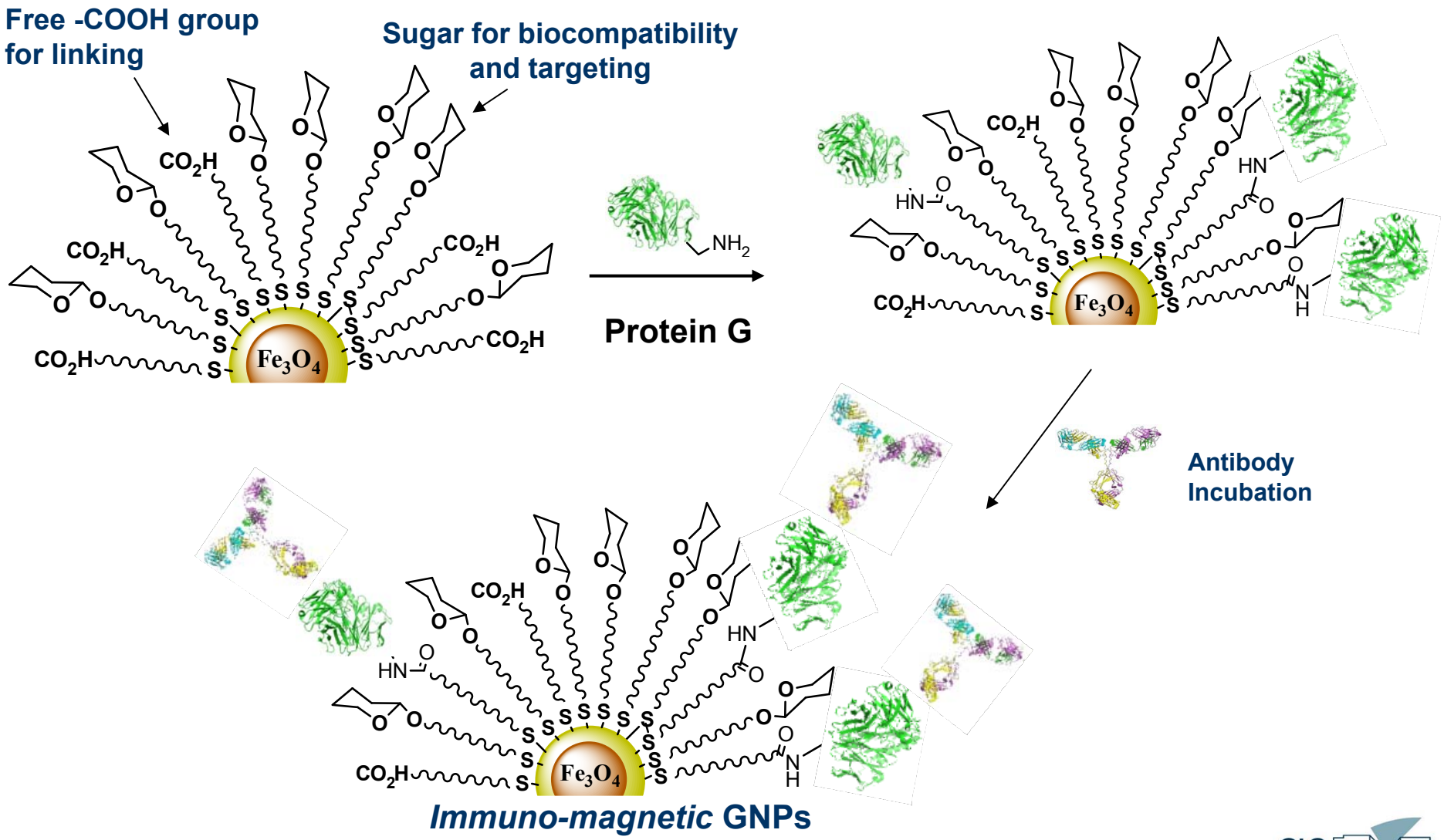
J. Gallo et al., *J. Mat. Chem. 2010*

ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

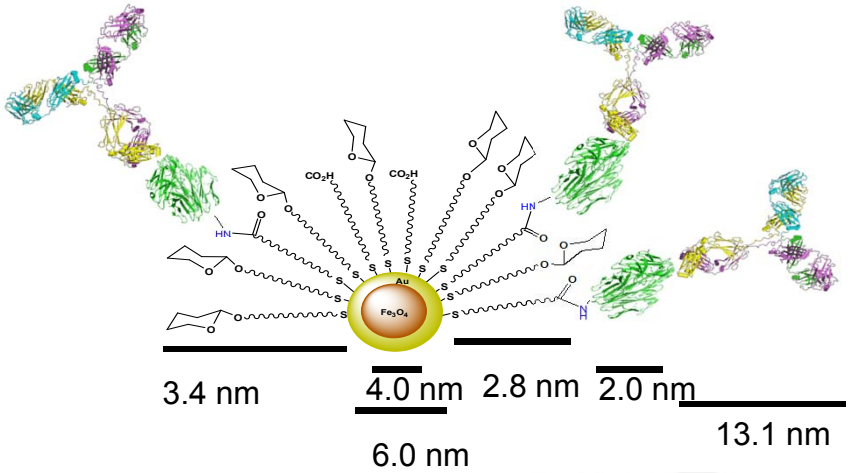
Glyco-nanoferrites as a versatile platform to attach antibodies

Protein G immobilización → ***Oriented antibody***

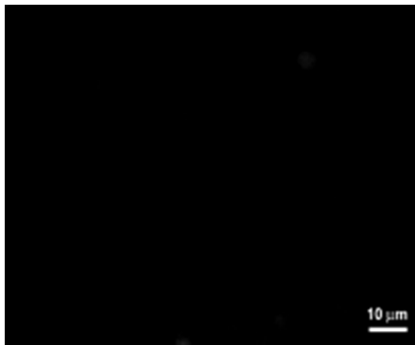


Immuno-magnetic **GNPs**

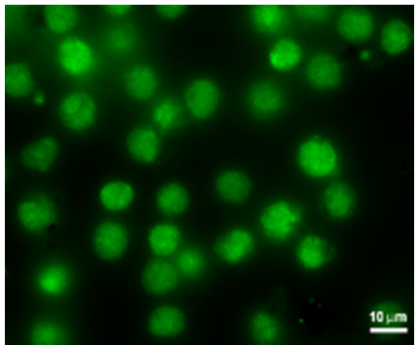
In vitro selective labelling of cells by *immuno*-magnetic-GNPs



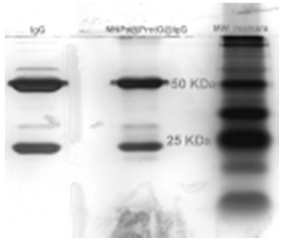
Raji cells

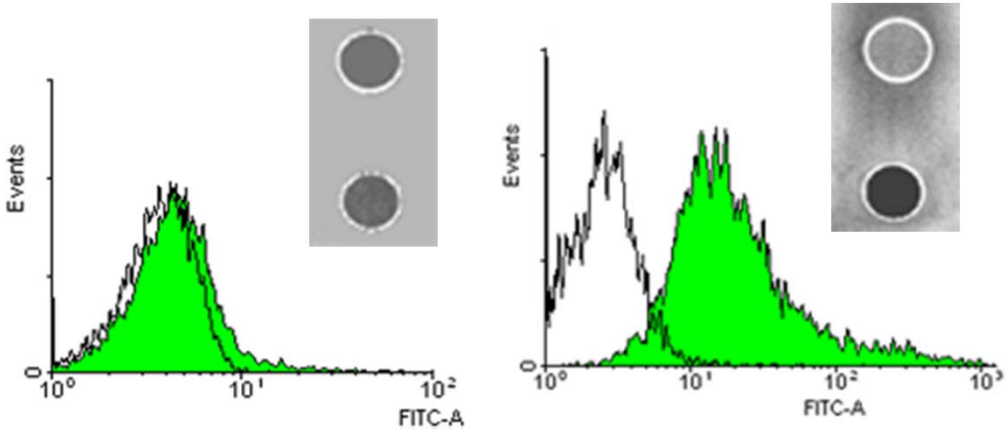


Raji DC-SIGN cells

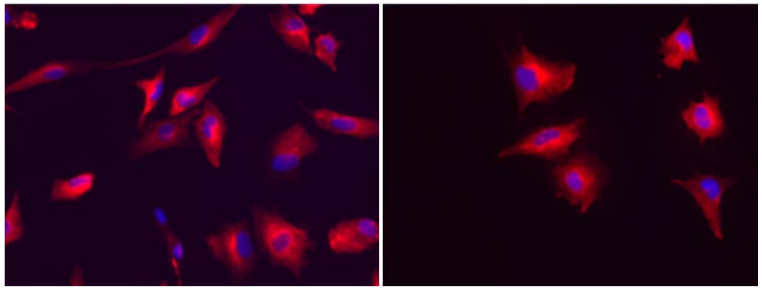


MALDI-TOF
QCM
SDS-PAGE





Labelled with anti-DC-SIGN IgG-GNPs



Stained by free anti-β tubulin IgG

Stained by anti-β tubulin IgG-GNPs

I. García et al., *Bioconjugate Chem. 2011*

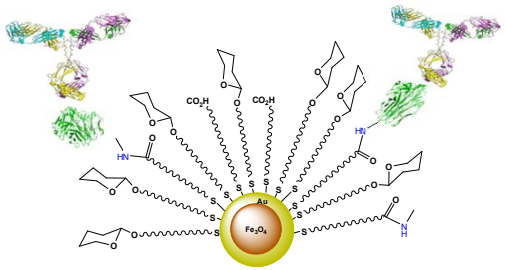
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

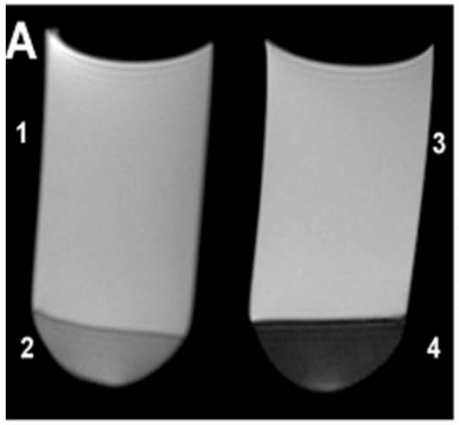
Ex vivo specific labelling of blood cell populations with *immuno*-fluorescent *glyco*-ferrites

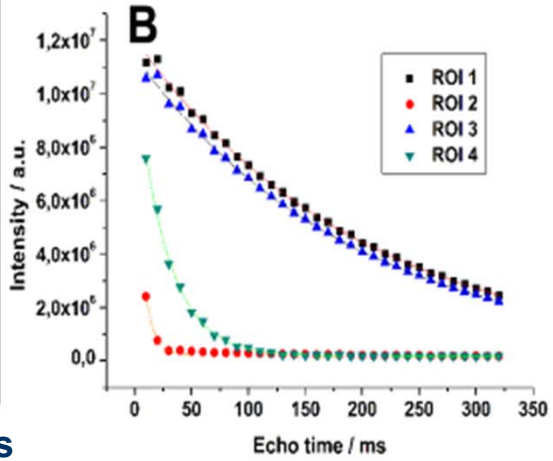
Erythrocytes

anti-CD235a



Blood | Blood + FMGNPs





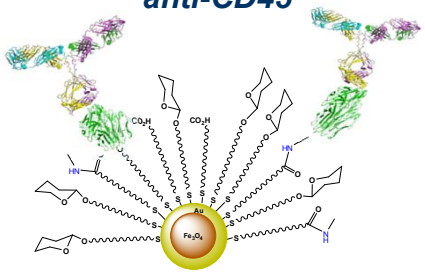
C

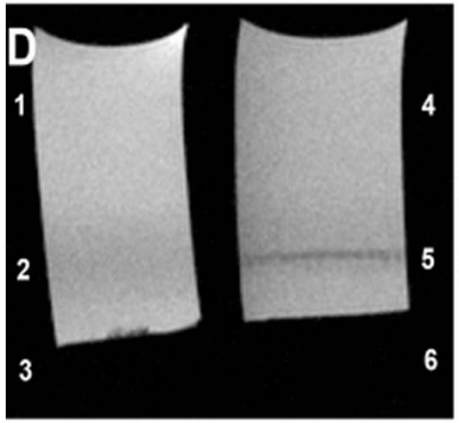
ROI	T_2
1	192 ± 8
2	28 ± 1
3	198 ± 8
4	7 ± 1

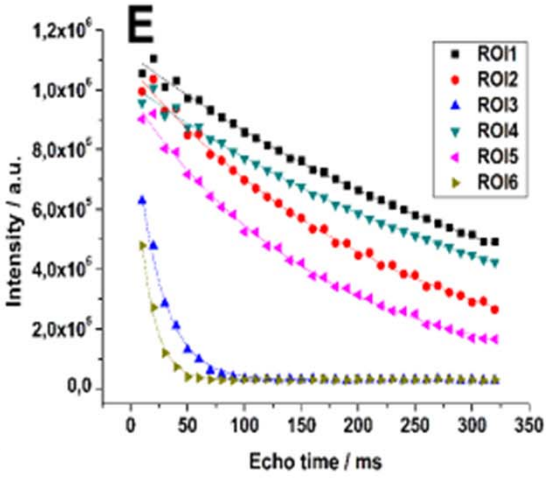
Blood + anti-CD235a GNPs

Leukocytes

anti-CD45







F

ROI	T_2/ms
1	388 ± 48
2	238 ± 18
3	24 ± 1
4	364 ± 45
5	164 ± 8
6	14 ± 1

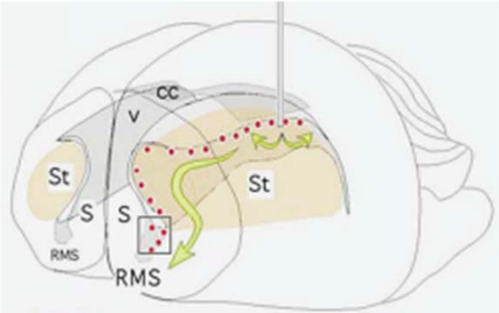
Blood + anti-CD45 GNPs

ciber-bbn

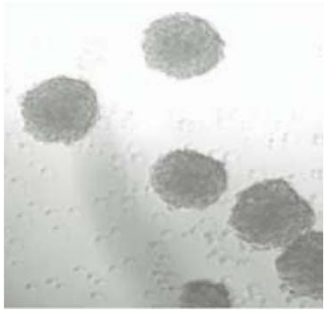
J. Gallo et al., *Biomaterials, 2011*

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

In vivo labeling neural stem cells with Nilo2-GNPs



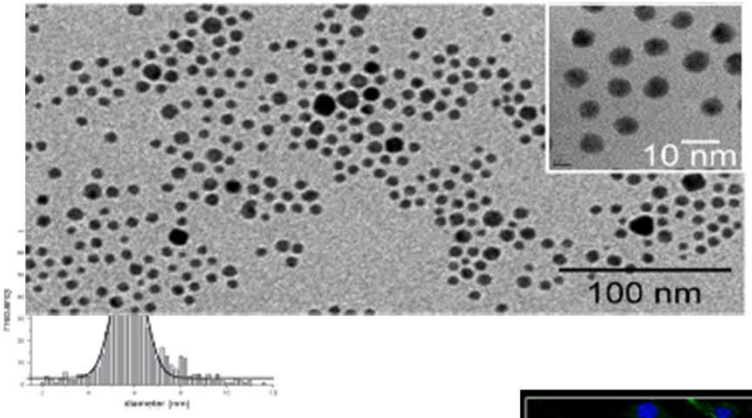
Subventricular Zone (SVZ)
Rostral Migratory Stream (RMS)

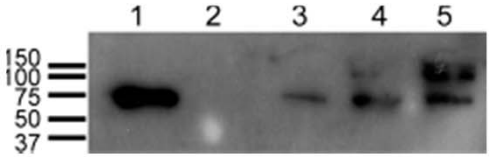


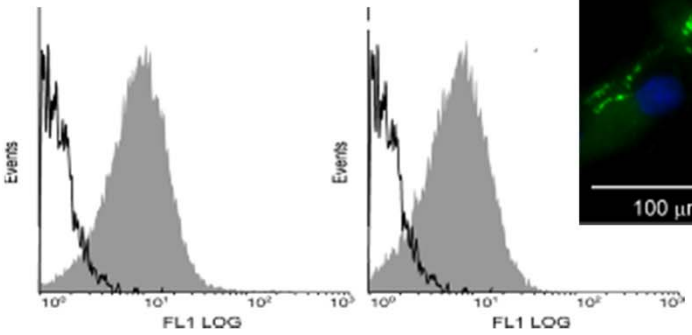
NSCs expanded "in vitro" to neurospheres

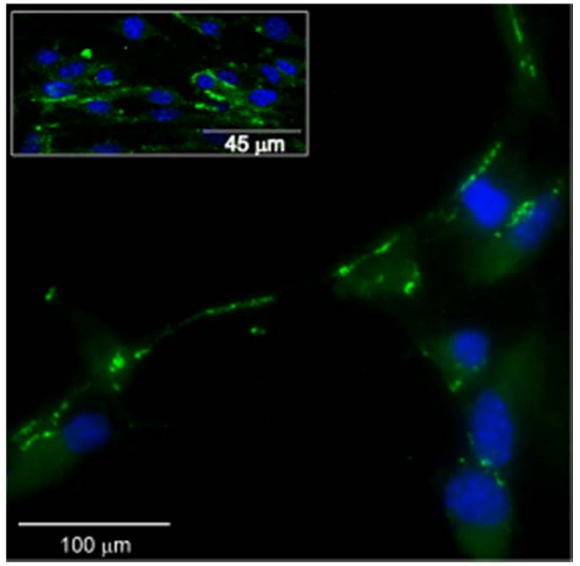
Specific monoclonal antibody against NSC

Nilo1, Nilo2





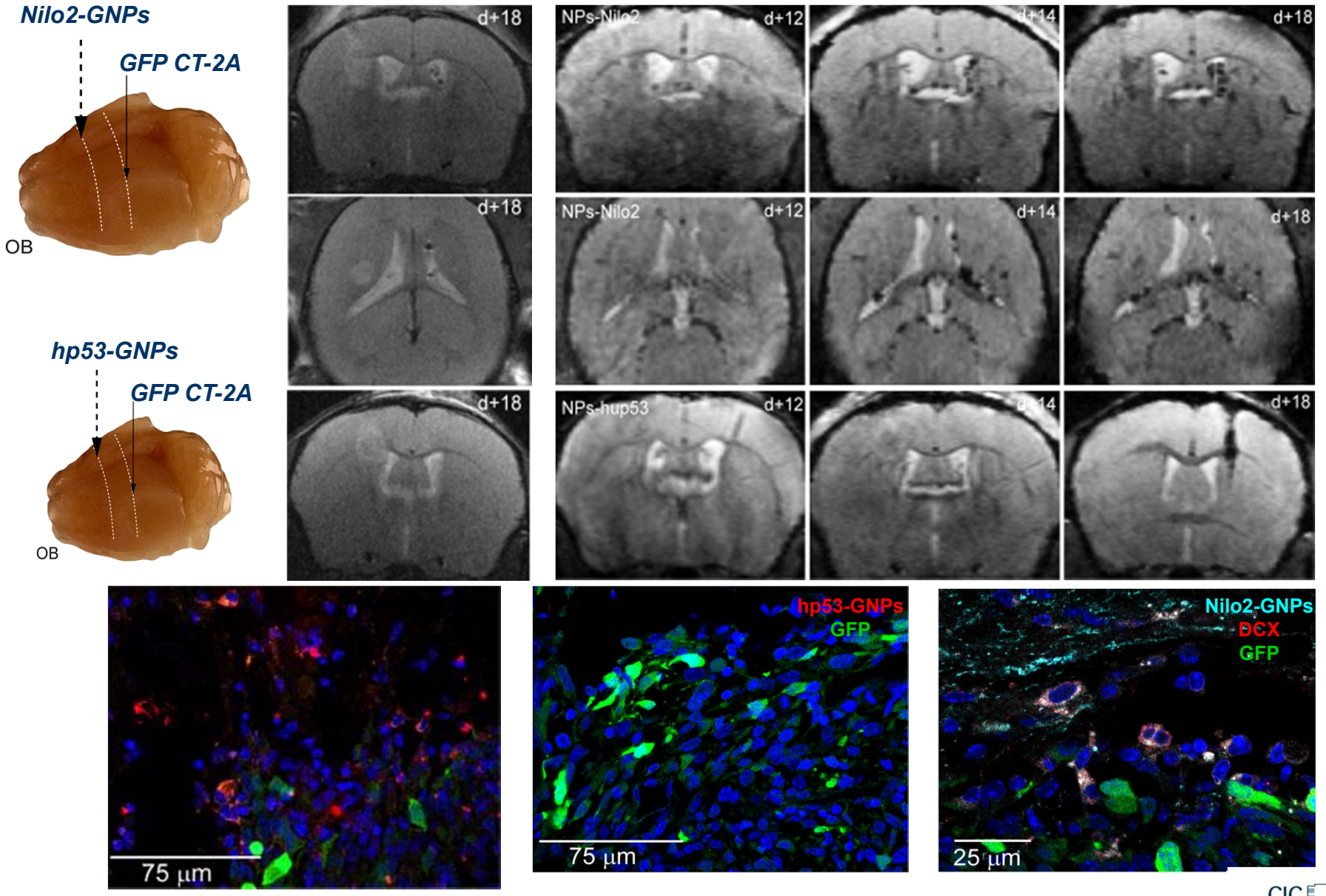




I. del Valle et al., Neuroscience 2010

I. García, J. Gallo
(with G. Elisa, A. Silva, J.A. Sanz, CIB-CSIC; M. Desco, HGM)

In vivo tracking of endogenous neural progenitors in response to tumor

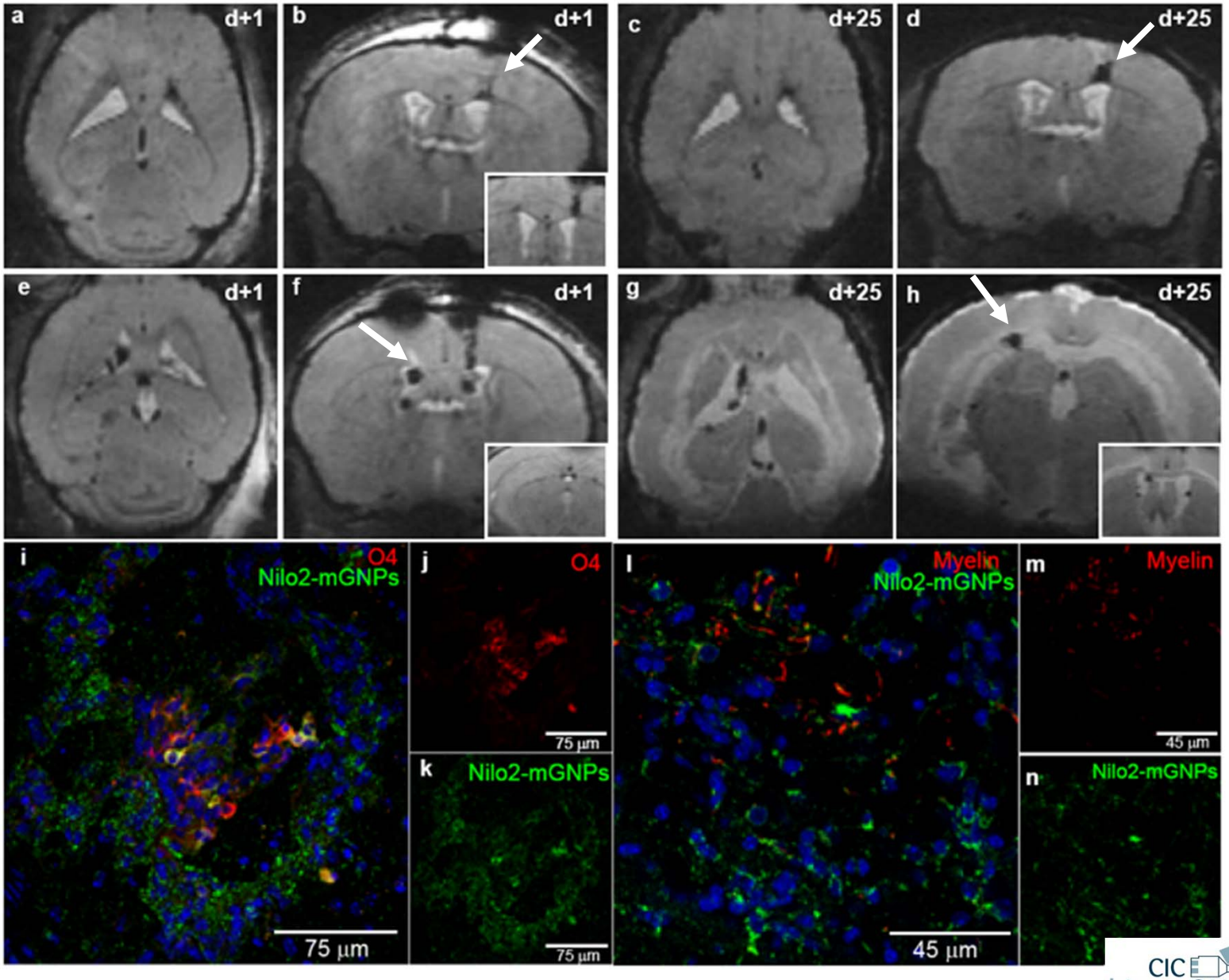


Elvira, G. et al., *submitted*

In vivo tracking of endogenous neural progenitors in response to chemical demyelination

*Immuno*MGNPs

*Immuno*MGNPs + damage



Elvira, G., *et al., submitted*

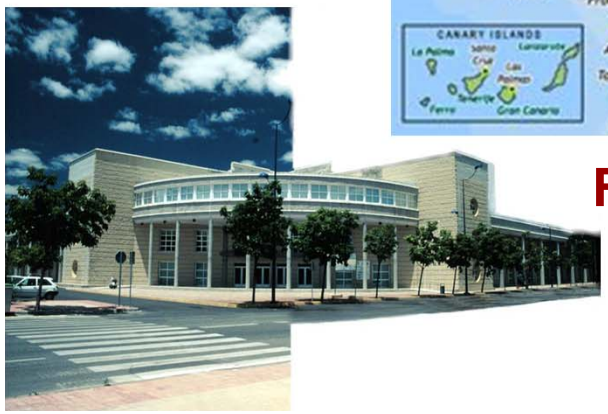
ciber-bbn

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

From Seville to….Donostia-San Sebastian

1997-2006

CSIC



Donostia-San Sebastián

From Sevilla

2007-

CIC biomaGUNE

Biomaterialetako Ikerkuntza Kooperatiboko Zentroa

Centro de Investigación Cooperativa en Biomateriales

CICbiomaGUNE (Biomaterials Cooperative Research Centre) is a non-profit association with the basic aim of **creating, producing, promoting and applying scientific and technological knowledge** in the **biomaterials** field by carrying out systematic research and experimental development work.

Lab of GlycoNanotechnology, CIC biomaGUNE
Donostia-San Sebastián (2011)

Carbohydrate Group, Seville (2006)

F. Chiodo
G. Pourceau
M. Marradi
J. Gallo
P.M. Enriquez
A. Irure
I. Garcia
B. Arnaiz
N. Genicio
M. Carril
P. di Gianvincenzo

CIC biomaGUNE

Centro de Investigaciones Científicas Isla de la Cartuja-CSIC

Sevilla

CIC biomaGUNE
Biomaterialetako Ikerkuntza Kooperatiboko Zentroa
Centro de Investigación Cooperativa en Biomateriales

Donosti-San Sebastian

2000-2006
Grupo de Carbohidratos
Laboratorio de Gliconanotecnologia

África G. Barrientos
Jesús M. de la Fuente
Christophe Tromas
Peter Eaton
Rafael Ojeda
J. Luis de Paz
Isabel Garcia
Caroline Clavel
Andrea Ragusa
Marco Marradi
David Alcántara
Olga Martínez

Collaborations

Metastasis : *A. Bernad (CNB-CSIC)*

HIV: *C. Kelly (King's College London)*
J. Alcamí (ISCIII), E. Yuste (H.Clinic)

MRI: *S. Cerdán, M. L. Garcia (IIB-CSIC)*
C. Arus (UAB)

Vaccines: *H. Snippe, H. Kammerling (Utrecht)*
M. Lehman (U. Bangor)

Neural Stem Cells: *A. Silva (CIB-CSIC)*
M. Desco (H.U. GM)

D. Katinger *(Polymun Scientific, Vienna)* (2G12)
I. M. Jones (*BioSci, University Reading) and*
EVA Centre for AIDS Reagents (gp120)

Laboratory of GlycoNanotechnology
Biofunctional Nanomaterials Unit

Isabel Garcia
Marco Marradi
Blanca Arnaiz
Elena Martines
Olga Martínez-Ávila
Paolo di Gianvincenzo
Nuria Genicio
Juan Gallo
Pedro M. Enríquez
Ainhoa Irure
Fabrizio Chiodo

Prof. M. Martin-Lomas

Financial support:

CSIC; MICINN; ISCIII (CIBER-BBN); Departament of Industry and Innovation (B. Country)

EU (TMR-GlycoGold,IP-EMPRO, CHAARM); Fundation Dormeur