

# Research Using Neutrons: from Quantum Computers via Cell Mambranes to Cancer Treatment



*Helmut Schober: Chair of LENS; Director, ILL*

# THE LEAGUE OF ADVANCED EUROPEAN NEUTRON SOURCES



The globally leading neutron infrastructure serving an outstanding research community



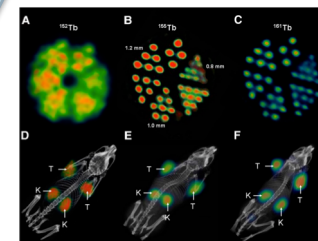
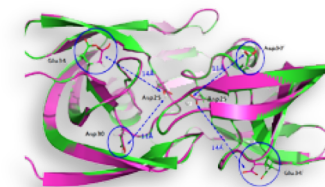
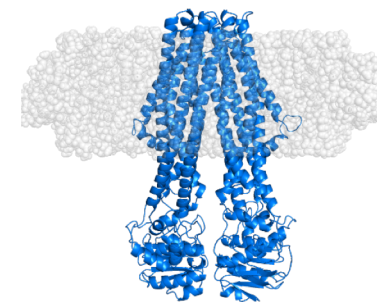
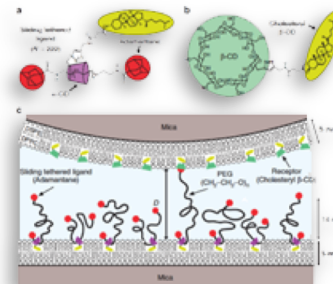
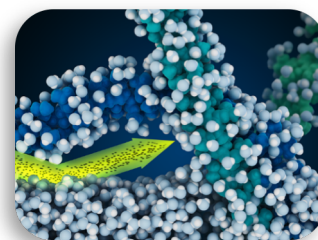
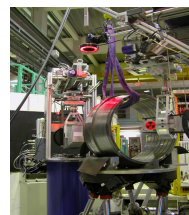
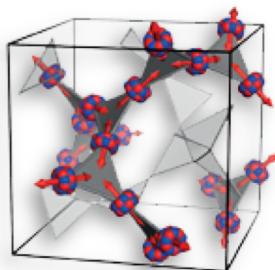
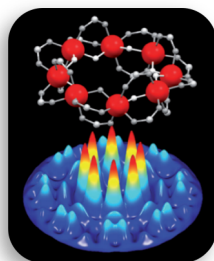
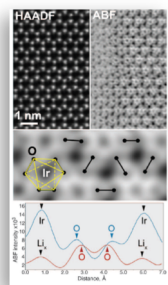
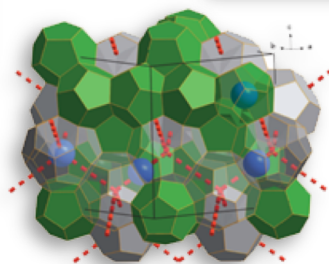
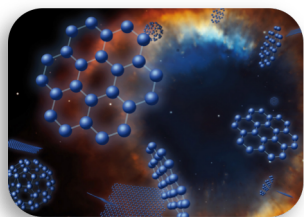
THE EUROPEAN NEUTRON SOURCE



# AT THE SERVICE OF THE TECHNOLOGIES THAT WILL UNDERPIN TOMORROW'S SOCIETY

- Future technology needs ever more complex materials.
- We provide researchers from academia and industry with the sophisticated tools they require for doing their job.

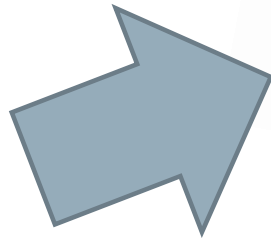
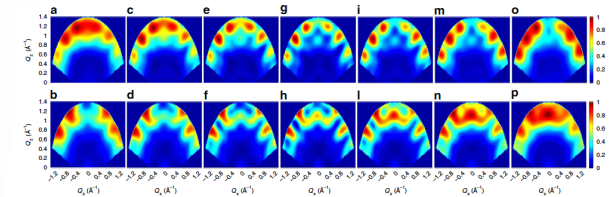
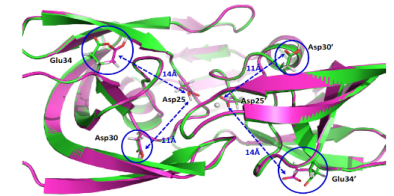
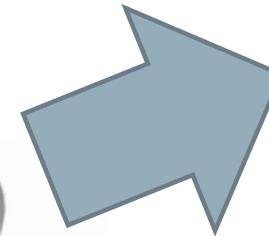
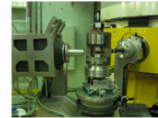
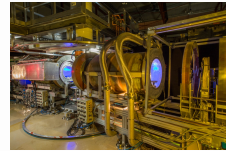
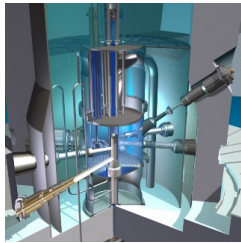
From Quantum Computing to Cancer Treatment





# OUR STRATEGY: PROVIDE THE BEST SERVICE TO EUROPE'S BRIGHTEST RESEARCHERS

- Attract brilliant ideas
- Operate powerful neutron sources with the best-in-class instrumentation
- Provide holistic experimental support including scientific expertise, sample environment, laboratories and data analysis



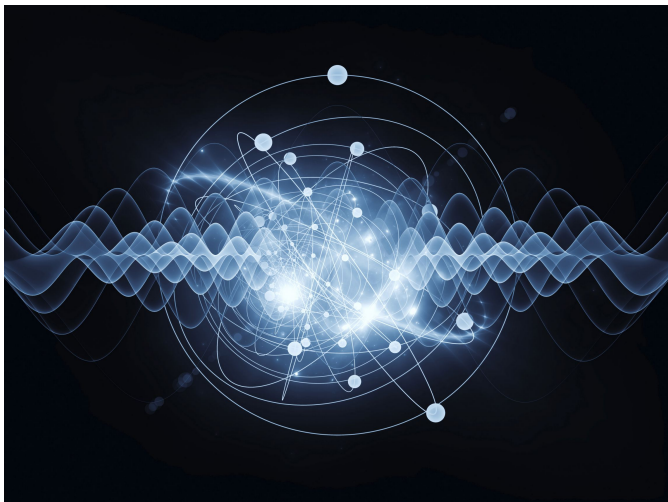
THE EUROPEAN NEUTRON SOURCE





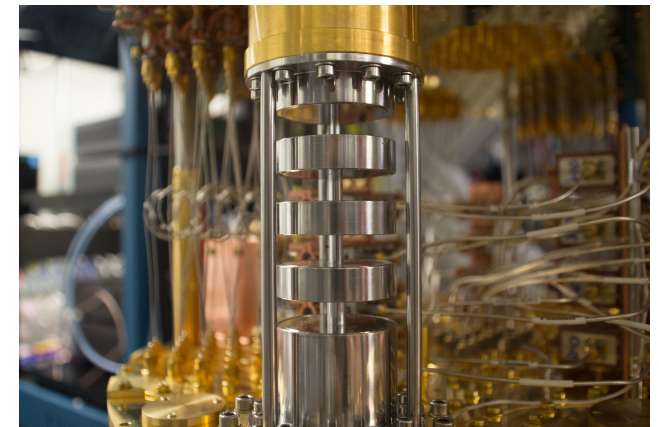
## TOMORROW'S DIGITAL WORLD

- Quantum computers are the ideal tool to simulate all kinds of complex quantum systems.
- They equally will come to grips with other demanding computational tasks.
- The very essence of quantum computers resides in the entanglement of quantum states.



“The Quantum Technologies Flagship aims to place Europe at the forefront of the second quantum revolution, bringing transformative advances to science, industry and society.”

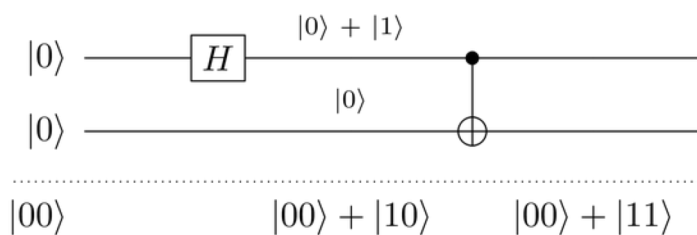
(<https://ec.europa.eu/digital-single-market/en/quantum-technologies>)



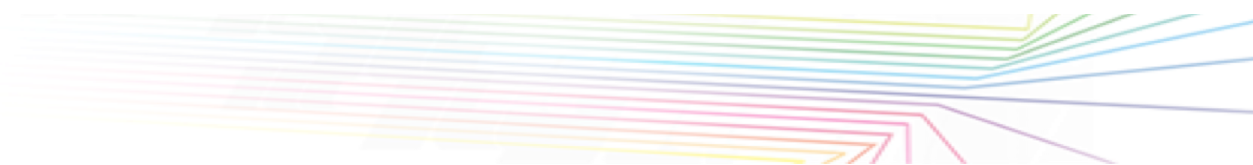
*Image credit - Flickr/ IBM Research, licensed under CC BY-ND 2.0*

## MAPPING OUT ENTANGLEMENT

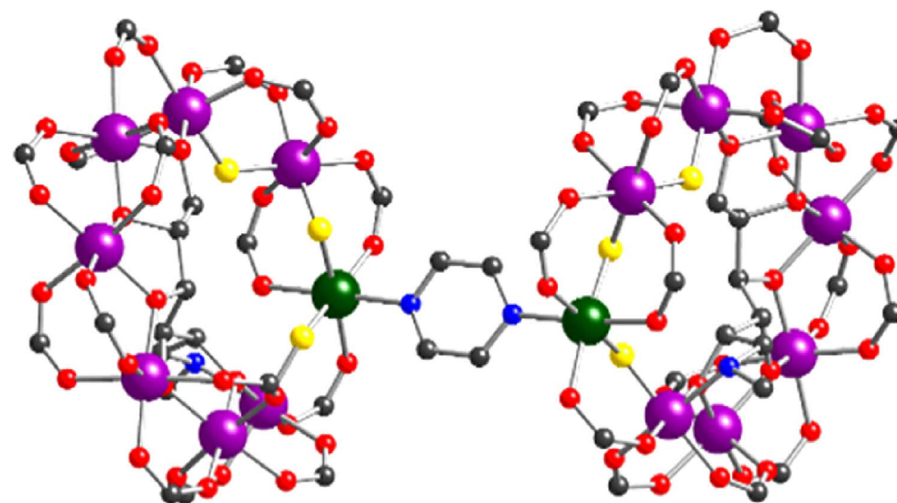
- Quantify entanglement is a sine qua non condition for quantum computing applications.
- Coupled molecular systems are concrete realizations of multiple-bit quantum computing devices.



Hadamard operation as a fundamental step in quantum computing.



$(\text{Cr}_7\text{Ni})_2$  supra-molecular dimer



Two weakly coupled quantum bits ( $S=1/2$ )

# MAPPING OUT ENTANGLEMENT

- Neutrons observe the “molecular quantum computer” while performing a calculation.
- The concurrence  $C=|ad-bc|$  extracted from the data is a perfect measure of the entanglement.

## ARTICLE

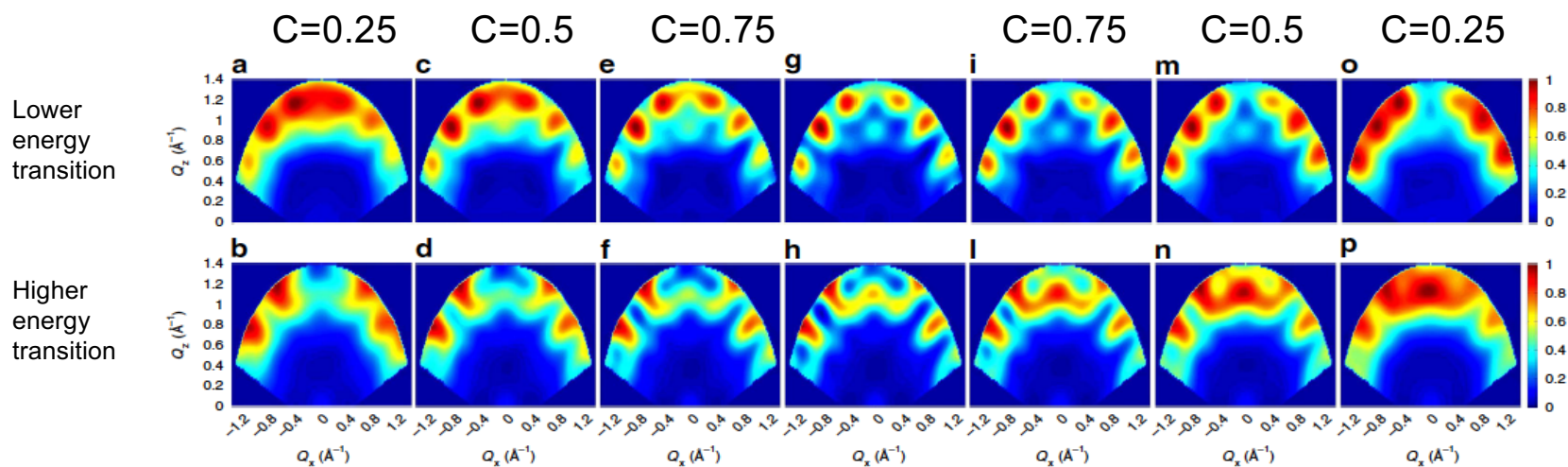
Received 13 Jun 2016 | Accepted 10 Jan 2017 | Published 20 Feb 2017

DOI: 10.1038/ncomms14543

OPEN

## Portraying entanglement between molecular qubits with four-dimensional inelastic neutron scattering

E. Garlatti<sup>1</sup>, T. Guidi<sup>2</sup>, S. Ansbro<sup>3,4</sup>, P. Santini<sup>1</sup>, G. Amoretti<sup>1</sup>, J. Ollivier<sup>3</sup>, H. Mutka<sup>3</sup>, G. Timco<sup>4</sup>, I.J. Vitorica-Yrezabal<sup>4</sup>, G.F.S. Whitehead<sup>4,†</sup>, R.E.P. Winpenny<sup>4</sup> & S. Carretta<sup>1</sup>





# DEVELOPING ENERGY HARVESTING MATERIALS

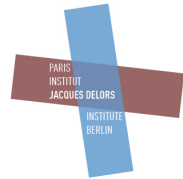
2 SEPTEMBRE 2019

#NEWEU  
#GREENDEAL  
#COMMISSION EUROPE  
#CLIMAT  
#ÉNERGIE

■ THOMAS PELLERIN-CARLIN  
Chef du Jacques Delors Energy Centre

■ EMILIE MAGDALINSKI  
Chercheuse au Jacques Delors Energy Centre

■ JEAN-ARNOLD VINOIS  
Conseiller, Union de l'énergie à l'Institut Jacques Delors, Paris



## NEW BEGINNINGS LE « GREEN DEAL » POUR L'EUROPE COMMENCE PAR LA TRANSITION ÉNERGÉTIQUE !

La présente note résulte d'une coopération entre les Instituts Jacques Delors de Paris et de Berlin et fait des propositions concrètes pour la législature européenne à venir.

**Le dérèglement climatique est là.** La température moyenne mondiale a déjà augmenté de plus de 1°C. Les événements météorologiques extrêmes sont plus fréquents et plus intenses. Comme l'indique la Présidente-élue de la Commission européenne, Ursula von der Leyen, « Que ce soit en Finlande, où les céréalières sont touchés par la sécheresse, ou en France, où a sévi une vague de chaleur mortelle : nous ressentons toute la réalité du changement climatique »<sup>1</sup>.



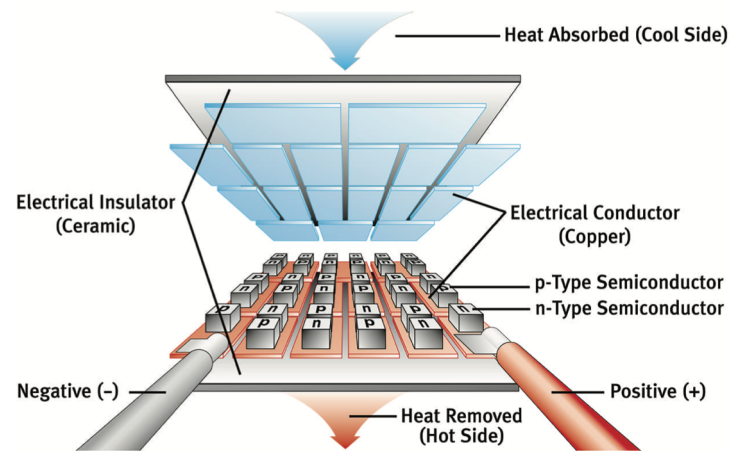
Pendant, nos sociétés n'évoluent pas assez rapidement pour éviter les irréversibles conséquences du dérèglement climatique<sup>2</sup>. L'accord de Paris sur le climat a entériné l'objectif final de « neutralité climatique » (parfois aussi appelé 'neutralité carbone'), c'est à dire réduire les émissions de gaz à effet de serre de manière à ce qu'elles soient suffisamment modestes pour être compensées par des puits de carbone (tels que les forêts ou l'agriculture).

Pour lutter contre le dérèglement climatique en Europe et dans le reste du monde, **l'Europe doit devenir l'archétype d'une transition réussie vers une économie neutre pour le climat, en commençant par une transition énergétique** qui permette à l'Europe de devenir plus prospère, socialement juste et politiquement unie.

Pour atteindre cet objectif, la prochaine Commission européenne doit réaliser la promesse d'Ursula von der Leyen d'un « Green Deal » pour l'Europe. Ce Pacte doit s'articuler autour de trois éléments : ambition climatique, compétitivité basée sur l'innovation et justice sociale. Ils sont essentiels pour parvenir à un large accord politique et pour s'assurer que celui-ci repose sur des politiques permettant d'accélérer la transition énergétique.

<sup>1</sup> Ursula von der Leyen, Discours d'ouverture de la session plénière du Parlement européen, Strasbourg, 16 juillet 2019.  
<sup>2</sup> GIEC, 1,5°C Report, 2018.

- Thermoelectric devices offer the potential of transforming waste heat into electricity.
- They depend on a low thermal conductivity.



Lauda-Noah

# DEVELOPING ENERGY HARVESTING MATERIALS

Neutrons provide quantitative information on the thermal conductivity of even the most complex thermoelectric.

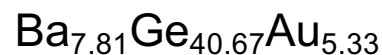
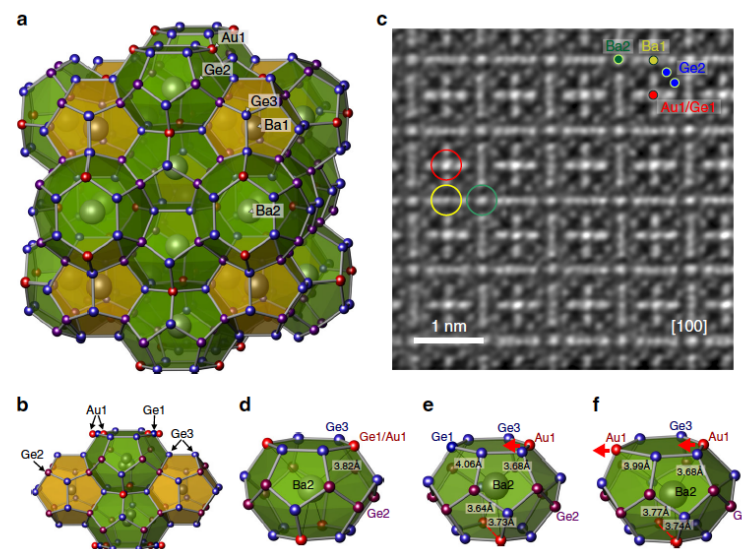
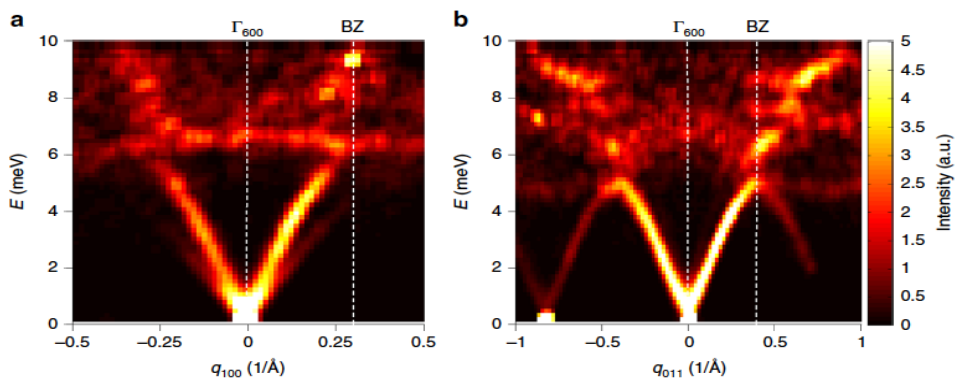


ARTICLE

DOI: 10.1038/s41467-017-00584-7 OPEN

## Direct measurement of individual phonon lifetimes in the clathrate compound $\text{Ba}_{7.81}\text{Ge}_{40.67}\text{Au}_{5.33}$

Pierre-François Lory<sup>1,2</sup>, Stéphane Pailhès<sup>3</sup>, Valentina M. Giordano<sup>3</sup>, Holger Euchner<sup>4</sup>, Hong Duong Nguyen<sup>5</sup>, Reiner Ramlau<sup>5</sup>, Horst Borrmann<sup>5</sup>, Marcus Schmidt<sup>5</sup>, Michael Baitinger<sup>5</sup>, Matthias Ikeda<sup>6</sup>, Petr Tomeš<sup>6</sup>, Marek Mihalkovič<sup>7</sup>, Céline Allio<sup>8</sup>, Mark Robert Johnson<sup>1</sup>, Helmut Schober<sup>1,9</sup>, Yvan Sidis<sup>10</sup>, Frédéric Bourdarot<sup>11</sup>, Louis Pierre Regnault<sup>1</sup>, Jacques Ollivier<sup>1</sup>, Silke Paschen<sup>6</sup>, Yuri Grin<sup>5</sup> & Marc de Boissieu<sup>2</sup>



# HEALTHY AGING

## UNRAVELING AMYLOIDOSIS

- Amylin (Islet Amyloid PolyPeptide IAPP) is a 37 residue hormone co-secreted with insulin by the beta-cells of the Langerhans islets in the pancreas.
- Its production is enhanced during disease (Diabetes type II).
- Amyloid formation is observed close to regions of beta-cell depletion.
- What makes IAPP cytotoxic?

Anne Martel, et al, JACS 2017



The screenshot shows the top navigation bar of the European Innovation Partnership website. It includes the European Commission logo, the text 'EUROPEAN INNOVATION PARTNERSHIP on Active and Healthy Ageing', and a breadcrumb trail: 'European Commission > EIP on AHA > Tags > Neurodegenerative disorders'. Below this is a menu with items: 'About the partnership', 'Action Groups', 'Reference Sites', 'I2M', 'Blueprint', 'MAFEIP', 'Library', 'News', and 'Events'.

### Neurodegenerative disorders

Governmental Experts on Dementias gathered together last week in Luxembourg

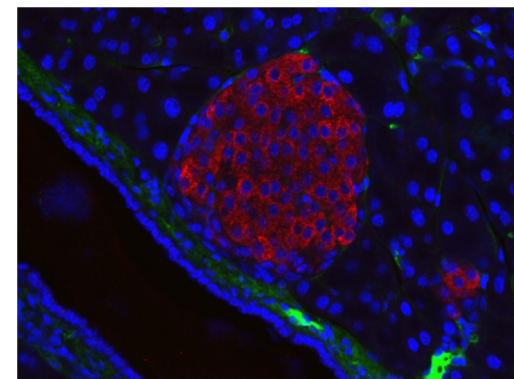
14/02/2014

13 Member States along with the Joint Programme on Neurodegenerative Disease (JPND), the Joint Action Alzheimer...



*Human Amylin*

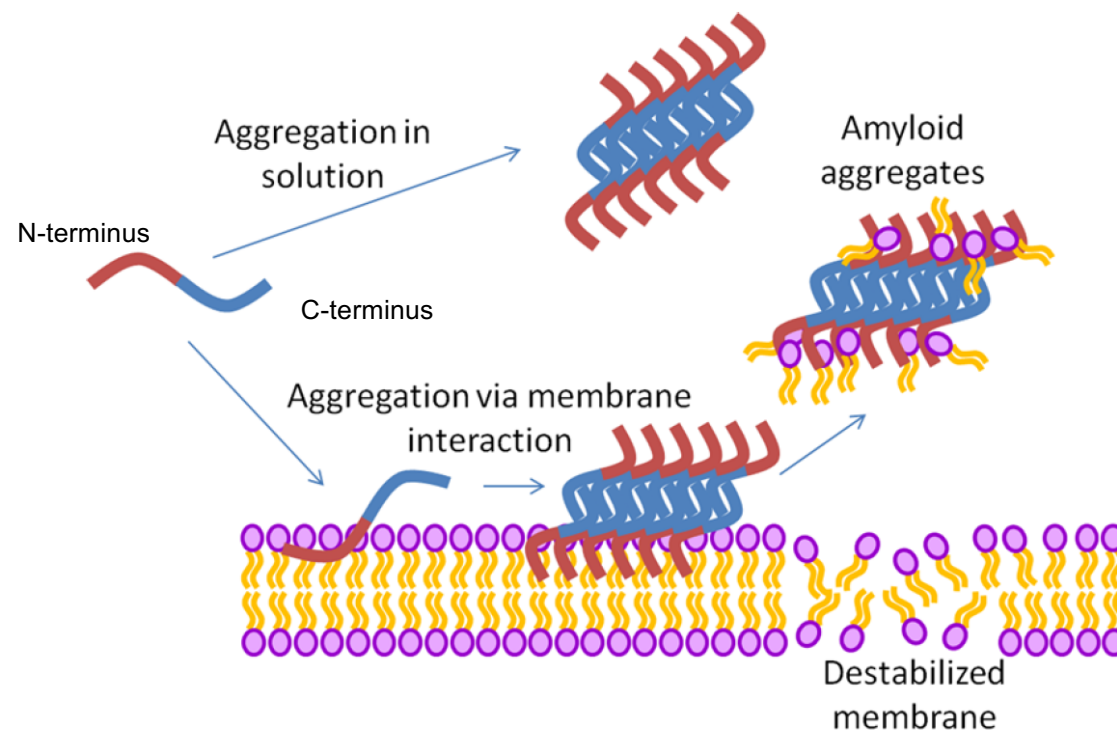
### *Langerhans islets*





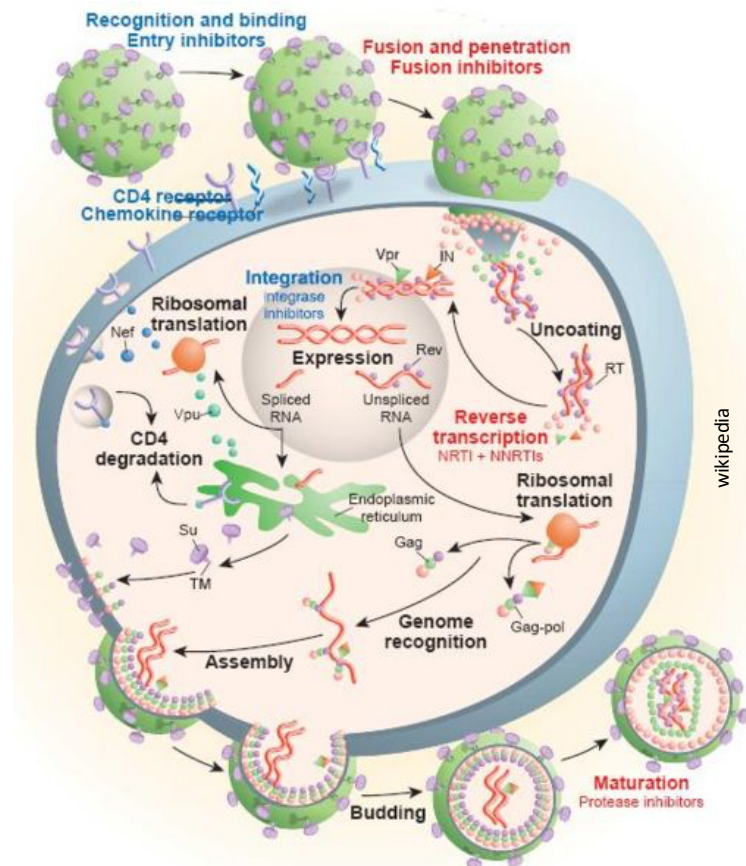
## UNRAVELING AMYLOIDOSIS

- The studies favour the “detergent scenario”.
- The lipids are extracted from the bilayer by the N-terminus of IAPP, and integrated into amyloid aggregates.
- The amyloidogenic aggregation would kinetically compete with the process of membrane permeation and, therefore, inhibit it.

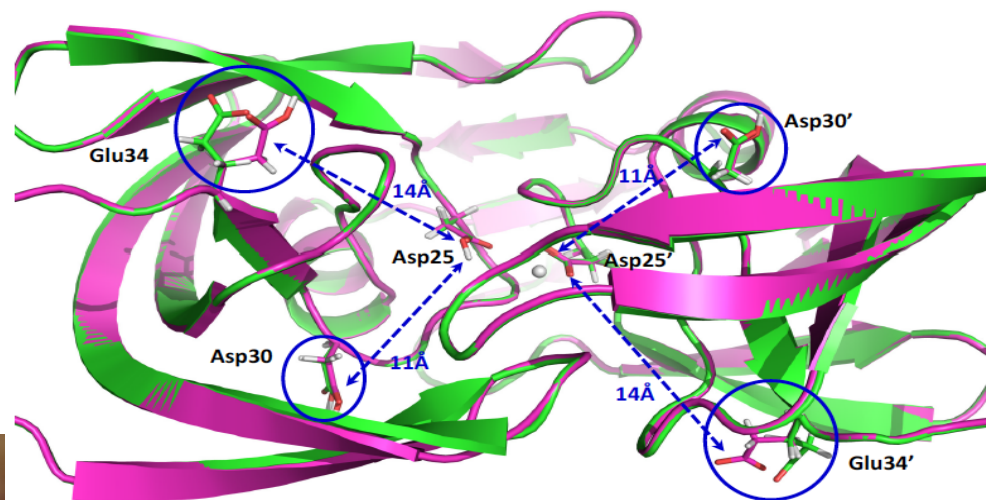
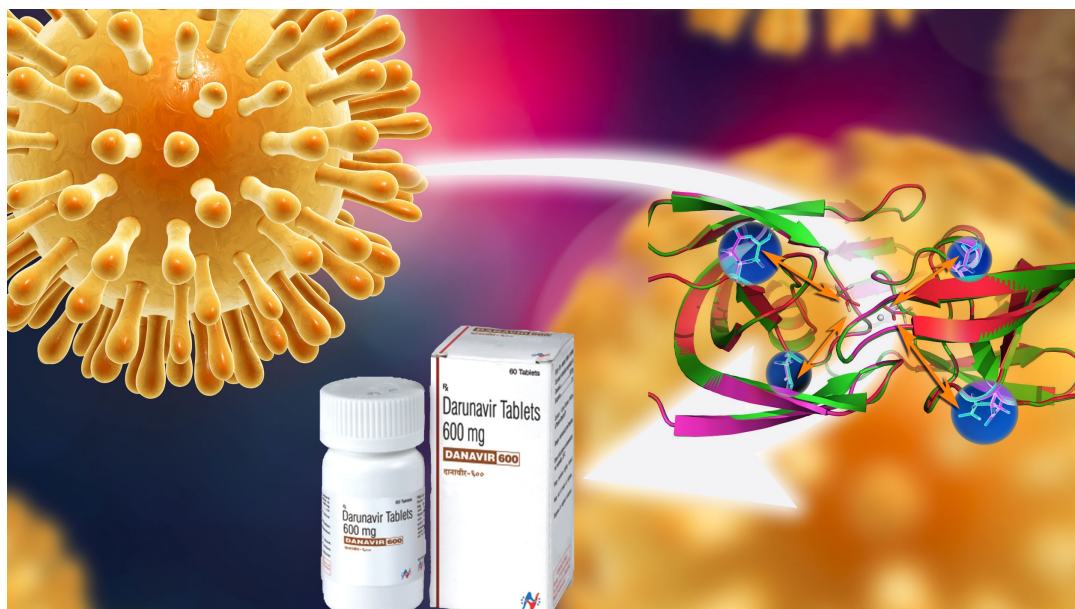


# GETTING TO GRIPS WITH VIRAL DISEASES

- The viral life cycle of HIV can be interrupted by inhibiting the catalytic activity of protease.
- HIV protease is, therefore, one of the therapeutic targets.



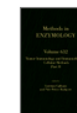
# GETTING TO GRIPS WITH VIRAL DISEASES



Methods in Enzymology

Available online 10 January 2020

In Press, Corrected Proof



Proton transfer and drug binding details revealed in neutron diffraction studies of wild-type and drug resistant HIV-1 protease

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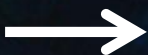
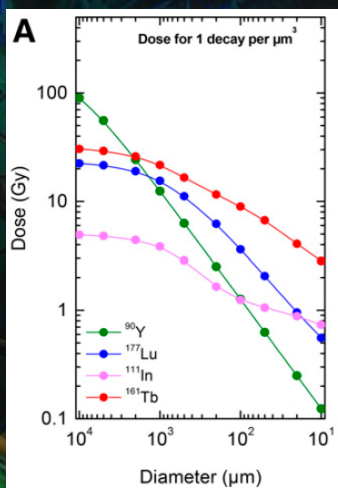




# RADIOISOTOPES FOR CANCER TREATMENT

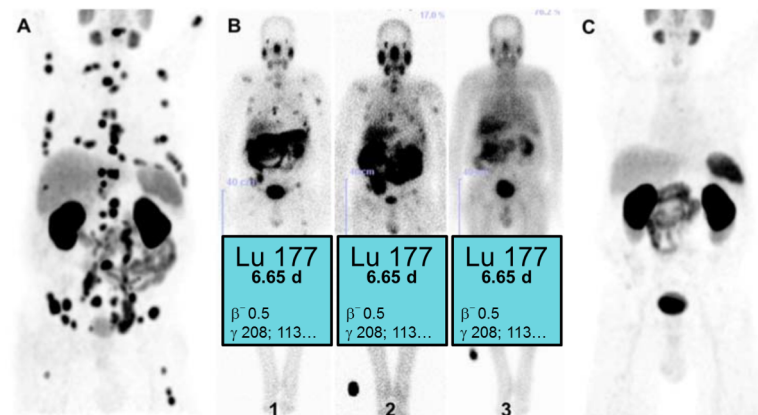
Several thousand cancer patients per year benefit from a treatment with  $^{177}\text{Lu}$  "Made in Grenoble"

In parallel "novel" radioisotopes are produced for preclinical R&D.



## Mission area: Cancer

What this mission area is, how missions will be chosen, mission boards, meetings, news, events.



**Tb 155**  
5.3 d

$\epsilon$   
 $\gamma$  87; 105; 180...  
 $e^-$

**Tb 152**  
17.5 h

$\epsilon$   
 $\beta^+$  3.0; 2.6; 2.0...  
 $\gamma$  344; 271; 586...

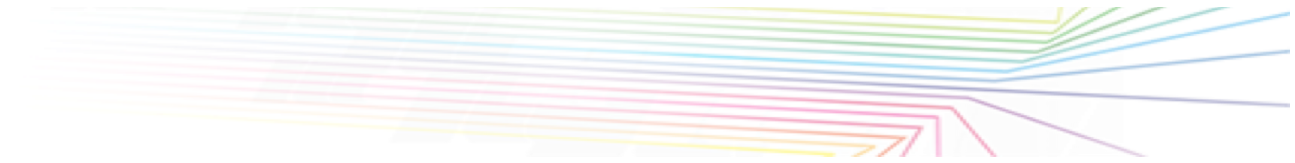


**Tb 161**  
6.9 d

$\beta^-$  0.5; 0.6  
 $\gamma$  26; 49; 75...  
 $e^-$

**Tb 149**  
4.1 h

$\epsilon$   
 $\alpha$  3.97  
 $\beta^+$  1.4...  
 $\gamma$  352; 165...



**I HOPE YOU ENJOYED THIS SHORT EXCURSION INTO THE WORLD OF NEUTRONS**



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