



# Antimatter Mysteries

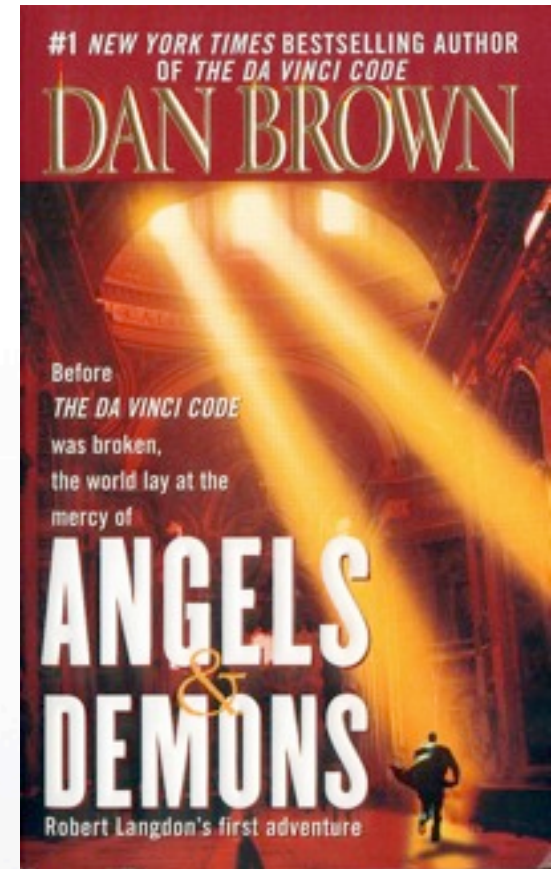
Rolf Landua

Research physicist

CERN

# Angels + Demons: The Book

The story line of ...



What's true ?  
What's false ?

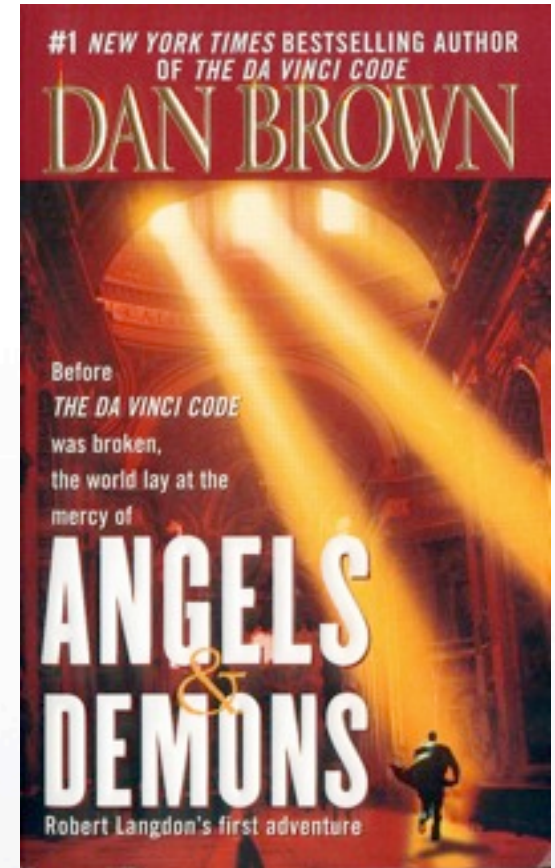
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**Illuminati**

Detective story about a secret society which ...



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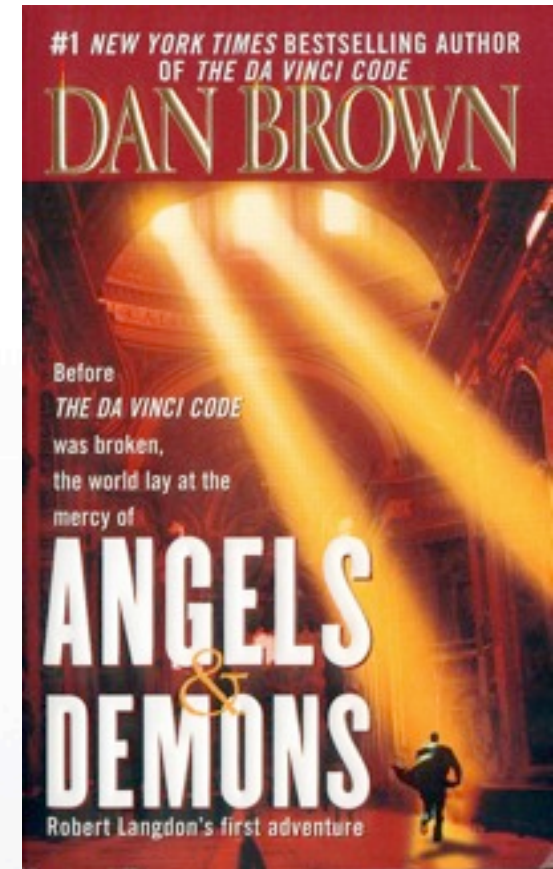


**Illuminati**

Detective story about a secret society which ...



... steals 1 g of antimatter from a physicist at the 'LHC' in a place called "CERN" ...



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Antimatter Mysteries



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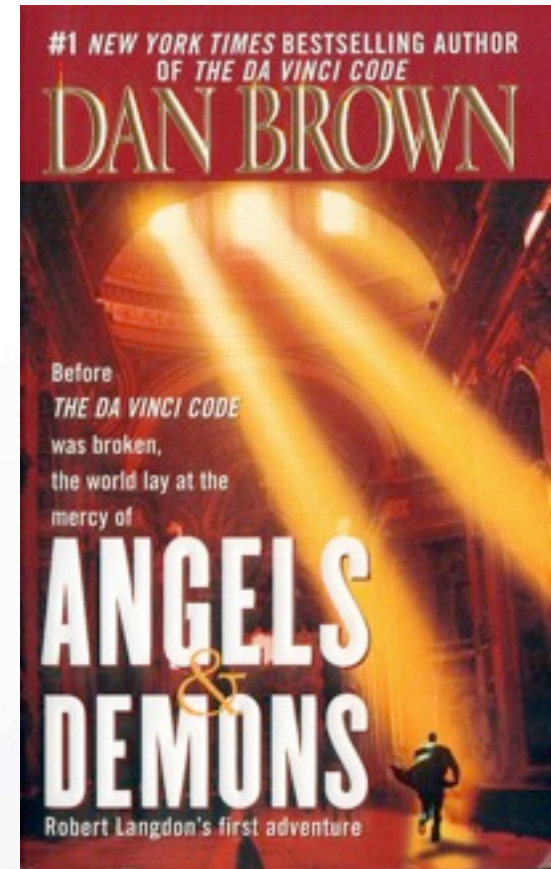
Detective story about a secret society which ...



... steals 1 g of antimatter from a physicist at the 'LHC' in a place called "CERN" ...



... to blow up the Vatican, an old "enemy of science and CERN".



What's true ?  
What's false ?

Antimatter Mysteries

# Angels + Demons: The Movie

TOM HANKS  
**ANGELS & DEMONS**  
A RON HOWARD FILM  
IN THEATERS MAY 15

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COLUMBIA PICTURES AND IMAGINE ENTERTAINMENT PRESENT A BRIAN GRAZER/JOHN CALLEY PRODUCTION  
A RON HOWARD FILM "ANGELS & DEMONS" EWAN MCGREGOR AYELET ZURER STELLAN SKARSGÅRD PIERFRANCESCO FAVINO NIKOLAJ LIE KAAS AND ARMIN MUELLER-STAHL  
MUSIC BY HANS ZIMMER ASSOCIATE PRODUCERS KATHLEEN MCGILL LOUISA VELIS WILLIAM M. CONNOR EXECUTIVE PRODUCERS TODD HALLOWELL DAN BROWN BASED UPON THE NOVEL BY DAN BROWN  
PRODUCED BY BRIAN GRAZER RON HOWARD JOHN CALLEY SCREENPLAY BY DAVID KOEPP AND AKIVA GOLDSMAN DIRECTED BY RON HOWARD  
IMAGINE ENTERTAINMENT COLUMBIA PICTURES  
AngelsAndDemons.com

Antimatter Mysteries



# Angels + Demons: The Cast @ CERN

Sergio Bertolucci

Tom Hanks

Rolf Landua

Tara Shears

Aliyet Zurer

Ron Howard



Antimatter Mysteries



# Angels + Demons: The Movie

Before making ‘Angels and Demons’, director Ron Howard came to CERN to take a course on “antimatter” and the “LHC”.



**\*Da Vinci Code, Apollo 13, Beautiful mind, ...**

Antimatter Mysteries

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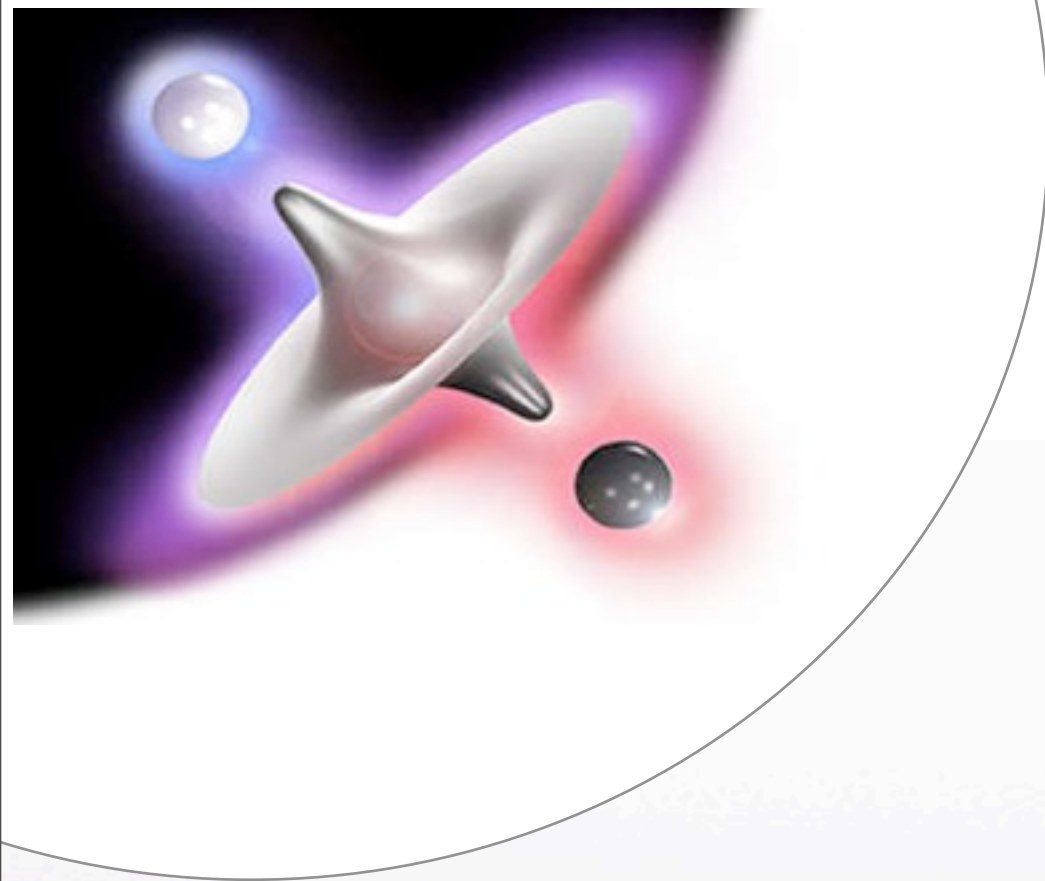
That’s the budget of my new movie “Angels and Demons”

This is what Dan Brown understands about antimatter ....

\*Da Vinci Code, Apollo 13, Beautiful mind, ...



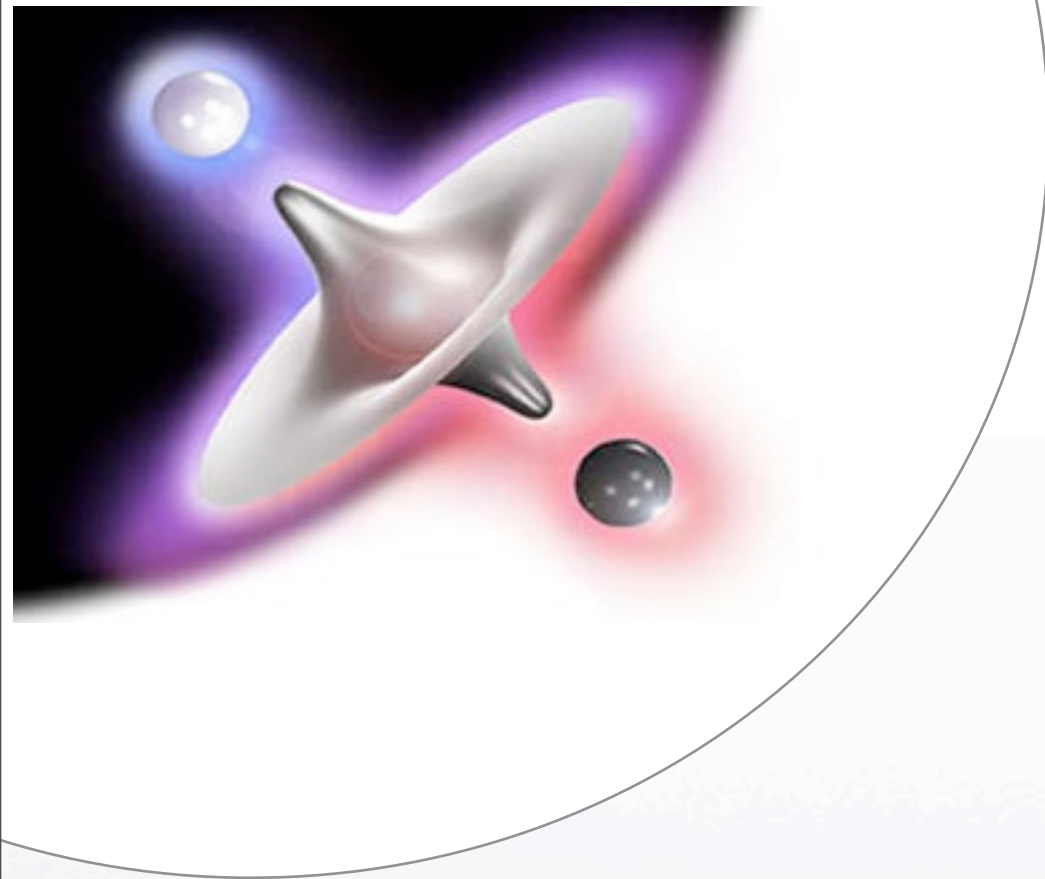
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Antimatter Mysteries

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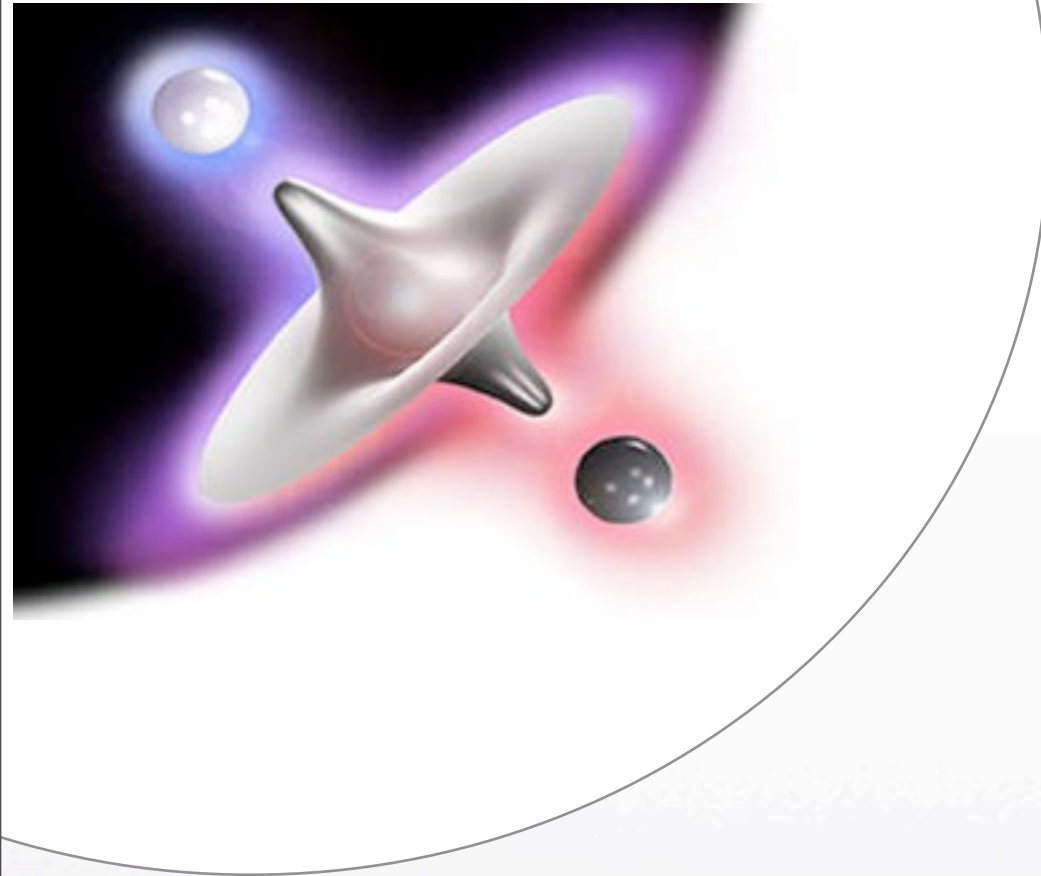
What is antimatter



# Antimatter Questions

What is antimatter

Where is antimatter made



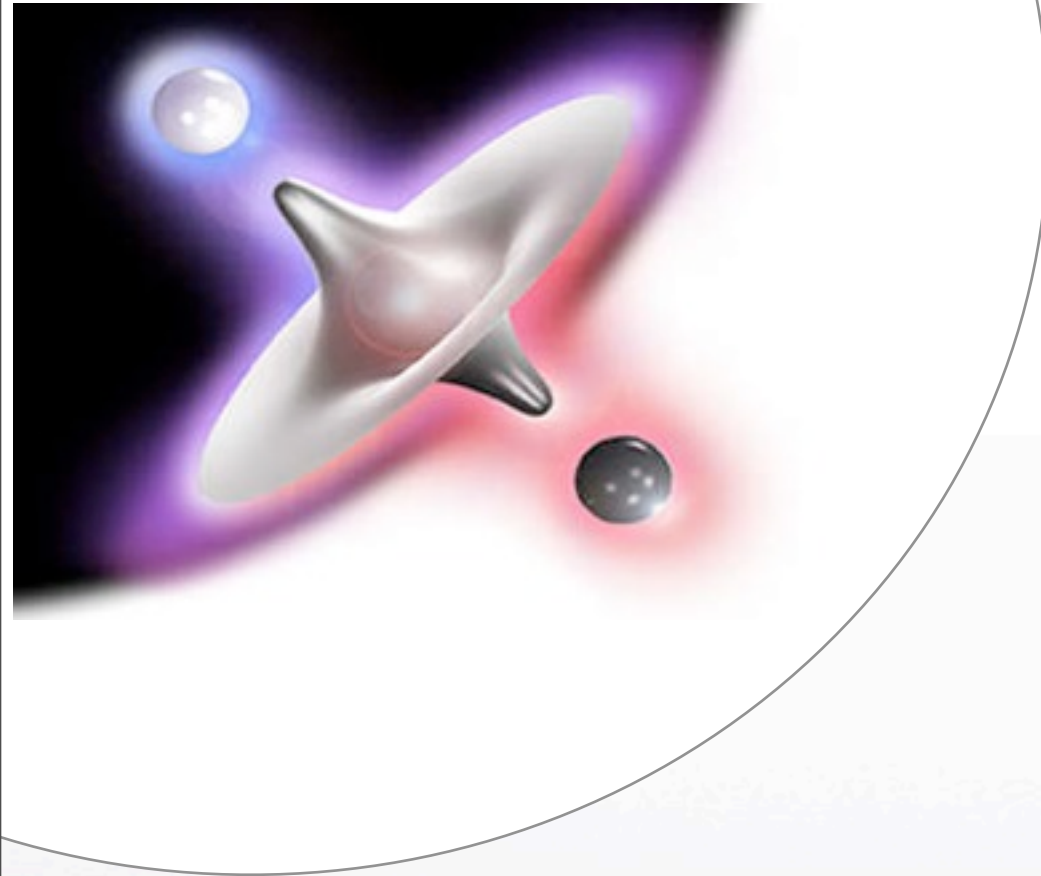


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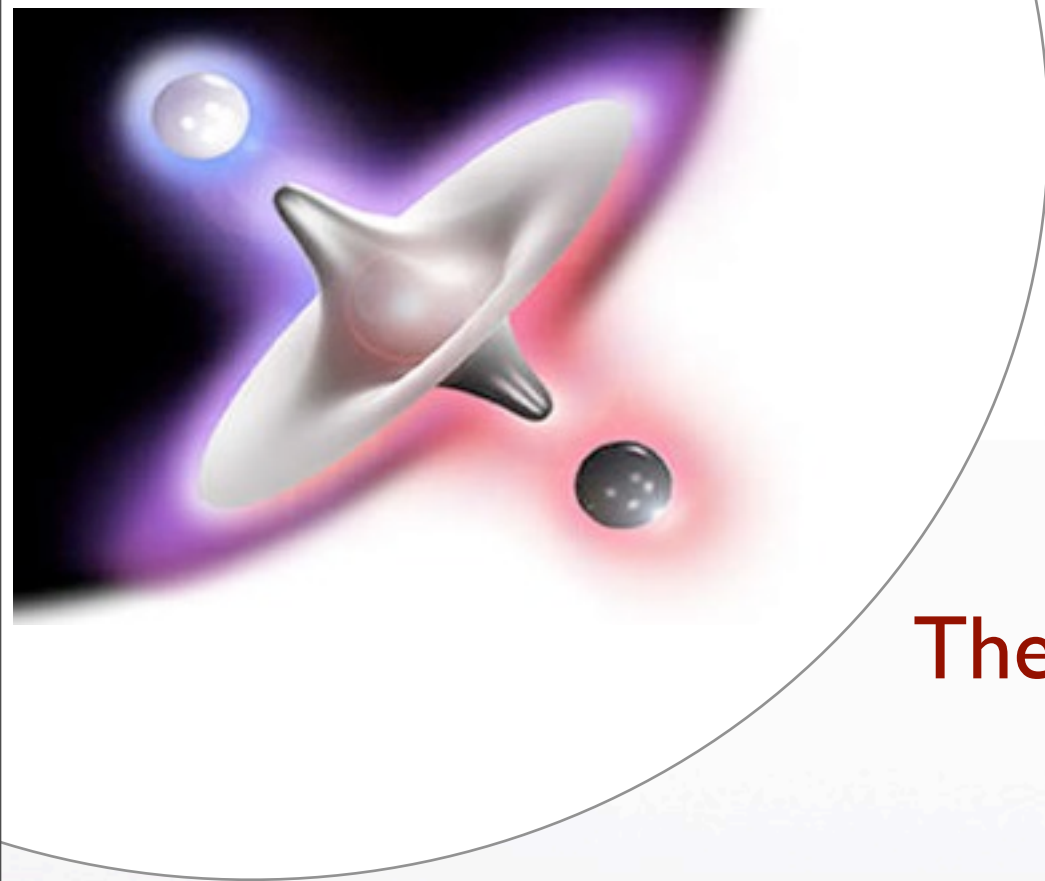
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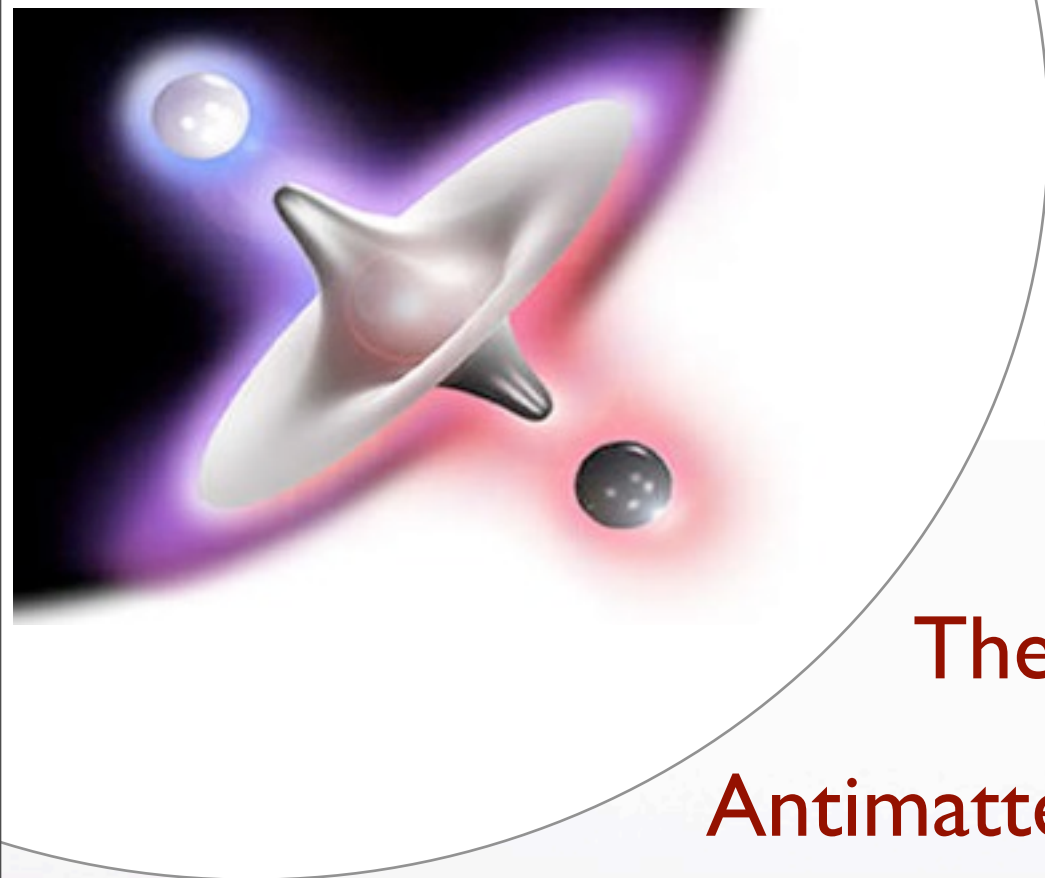
What is antimatter

Where is antimatter made

How is antimatter made

The mystery of antimatter

# Antimatter Questions



What is antimatter

Where is antimatter made

How is antimatter made

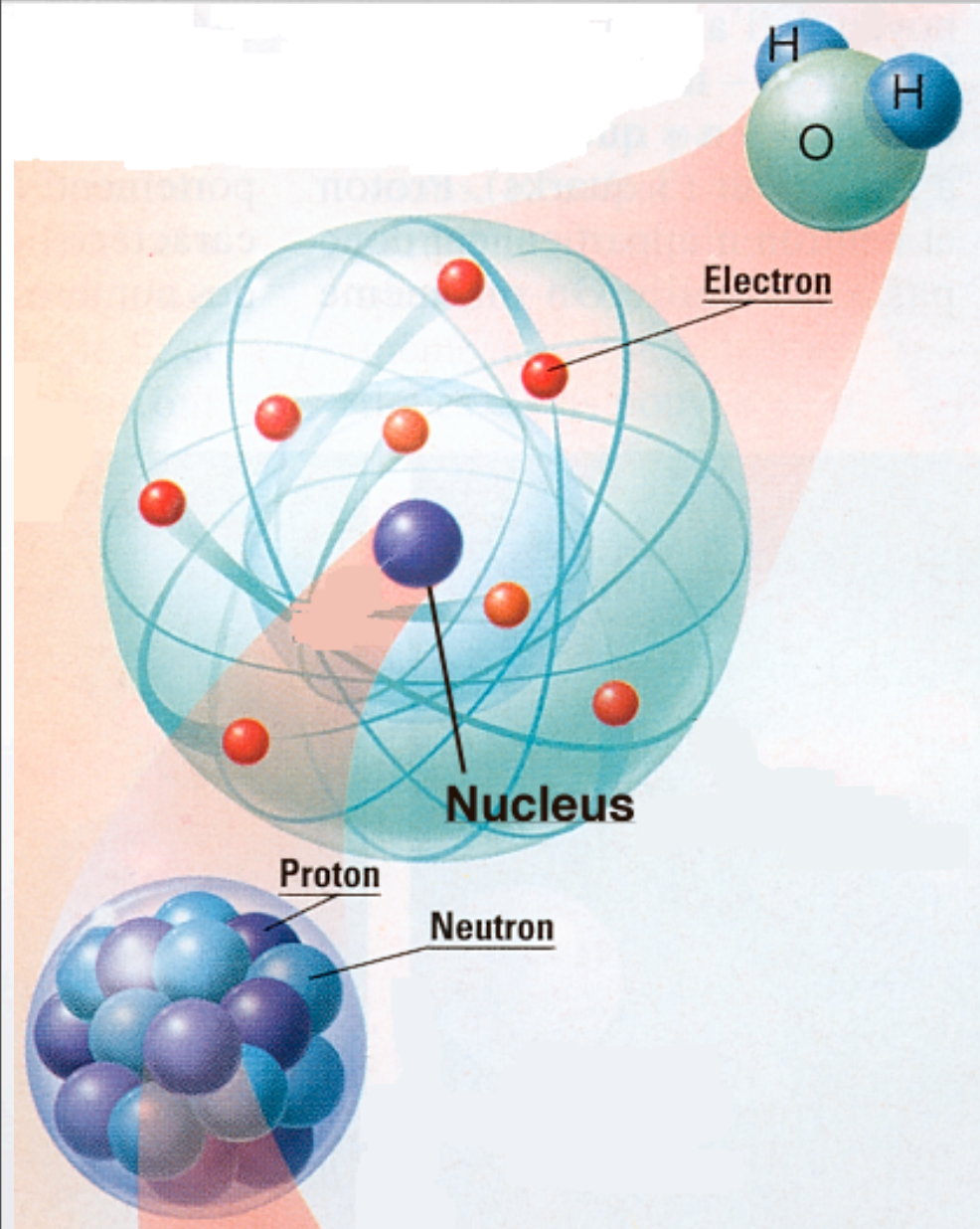
The mystery of antimatter

Antimatter in our daily life ?



# I What is antimatter ?

# I What is antimatter ?



**Everything is made of matter**  
(We, animals, plants, rocks)

**Matter** is made of **particles**

Electrons

Protons

Neutrons

} Quarks

The whole (visible) Universe can be explained with 4 building blocks:

Up-quark, down-quark

Electron, neutrino

# I What is antimatter ?

Particles have specific **masses** and **charges**



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Name	Electric Charge [e]	Mass [GeV*]
Electron	- 1	0.0005
Proton	+ 1	0.938
Neutron	0	0.941

\*GeV = Giga-Electron Volt =  $1.8 \cdot 10^{-27}$  kg

# I What is antimatter ?

Anti-Particles have the **same mass**, but **opposite charge**

Particles



Anti-Particles

Antimatter Mysteries

10

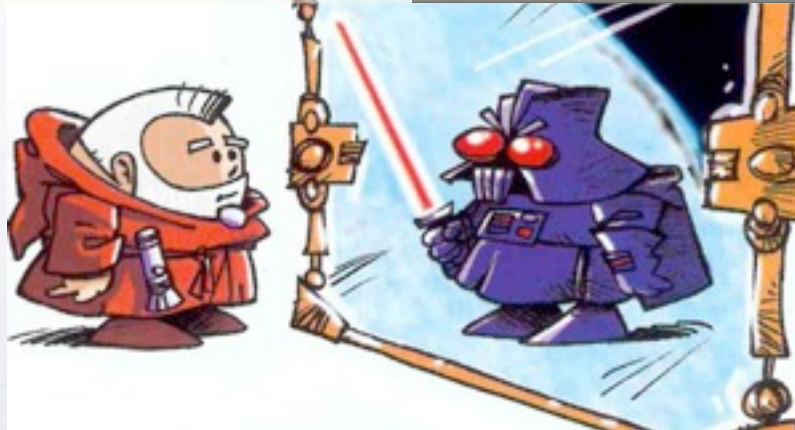
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Name	Electric Charge [e]	Mass [GeV <sup>c</sup> ]	Electric Charge [e]	Name
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Proton	+ 1	0.938	- 1	Antiproton
Neutron	0	0.941	0	Antineutron



Particles



Anti-Particles

Antimatter Mysteries



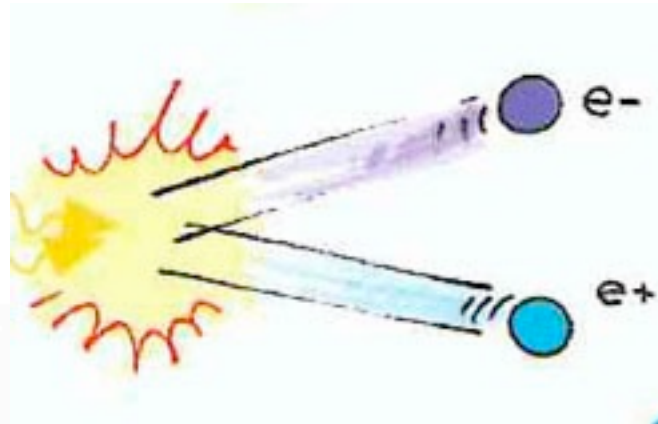
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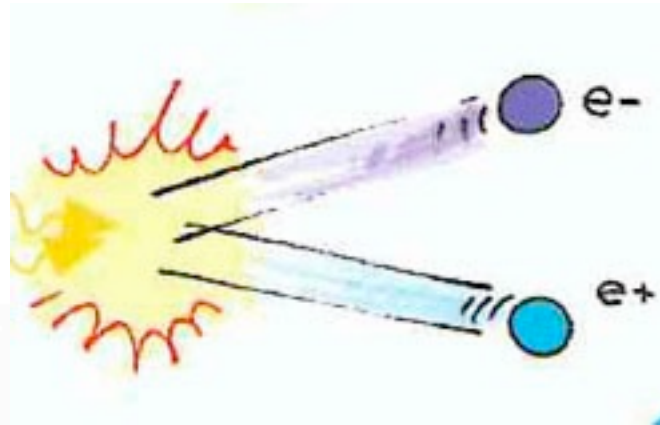
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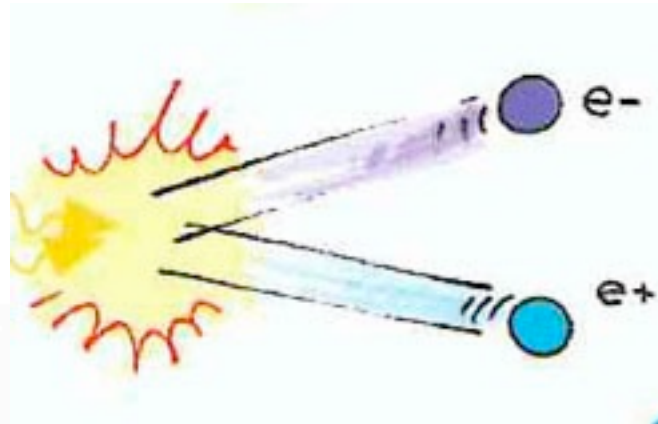
... and they can also **annihilate** each other



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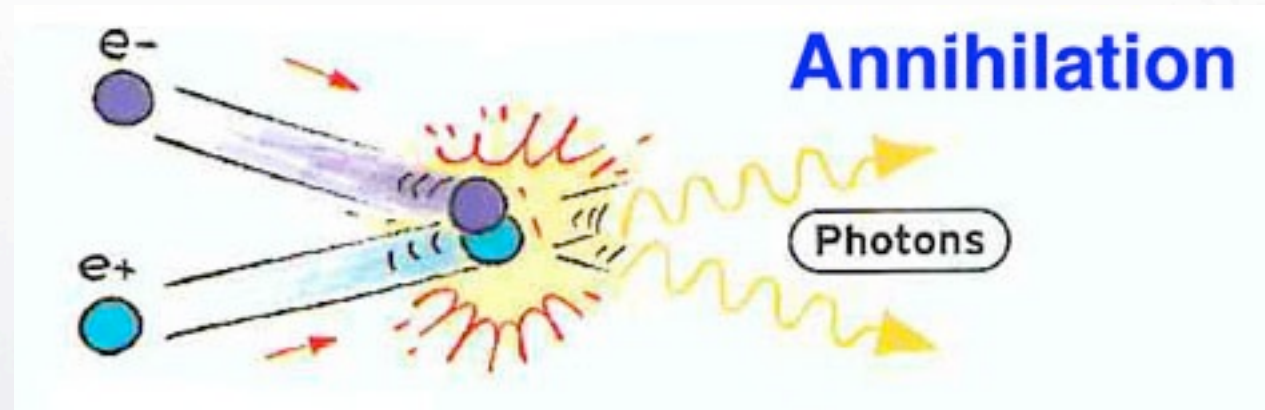
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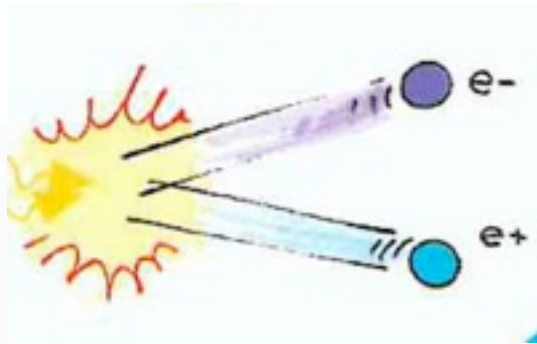
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Mass to energy:

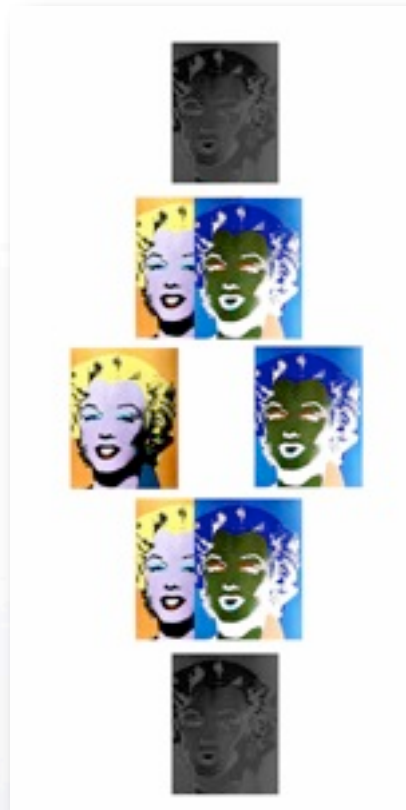


# I What is antimatter ?

What is an anti-particle?



Anti-Particles are **as real as** particles



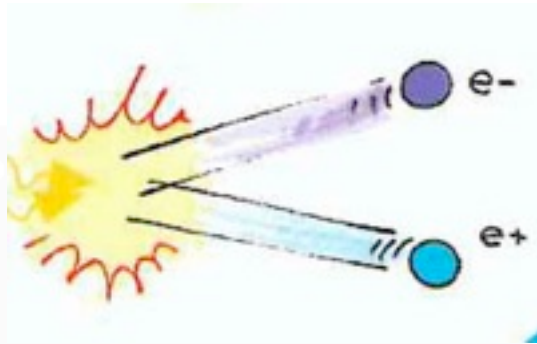
Metaphores



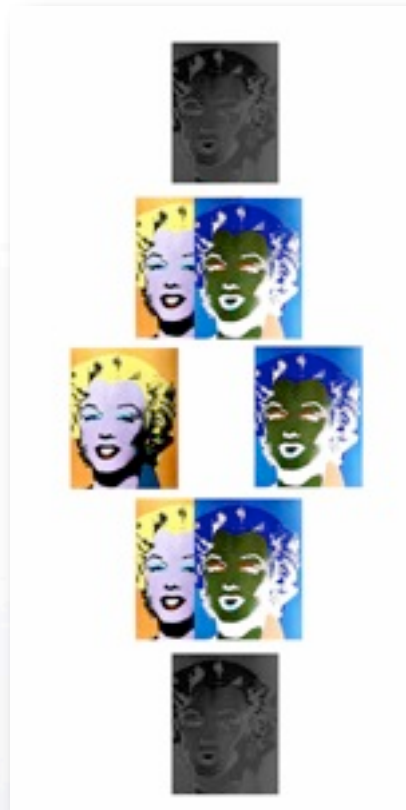


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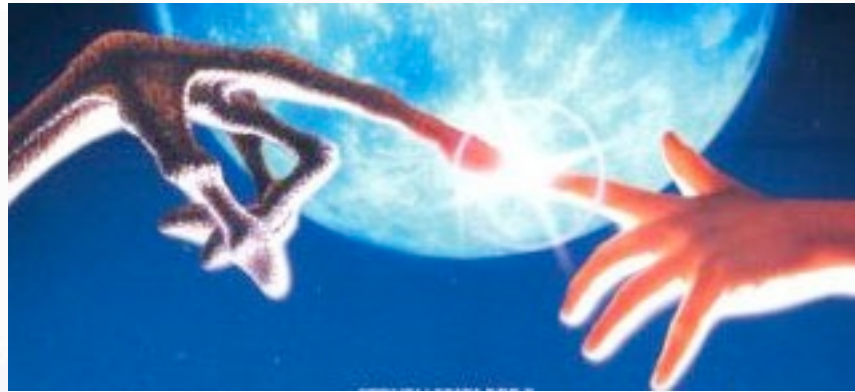


*A world made of antiparticles could exist - and it would look the same as our world.*



# I What is antimatter ?

Careful with “antimatter E.T.” !



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Careful with “antimatter E.T.” !



## 2 Where is antimatter made ?



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Antiparticles are produced using accelerators

The largest accelerator laboratory in the world is CERN in Geneva (CH)

CERN = 'Conseil Européen pour la Recherche Nucléaire'



10,055 physicists from  
105 countries

(1618 physicists from US)



## 2 Where is antimatter made ?



**L**arge  
**H**adron  
**C**ollider

The most powerful  
particle accelerator  
in the world



## 2 Where is antimatter made ?



New particles will be created that only existed shortly after the Big Bang

Dark Matter ?  
The “Higgs” particle ?  
Mini-Black holes ?



# 3 How is antimatter made ?

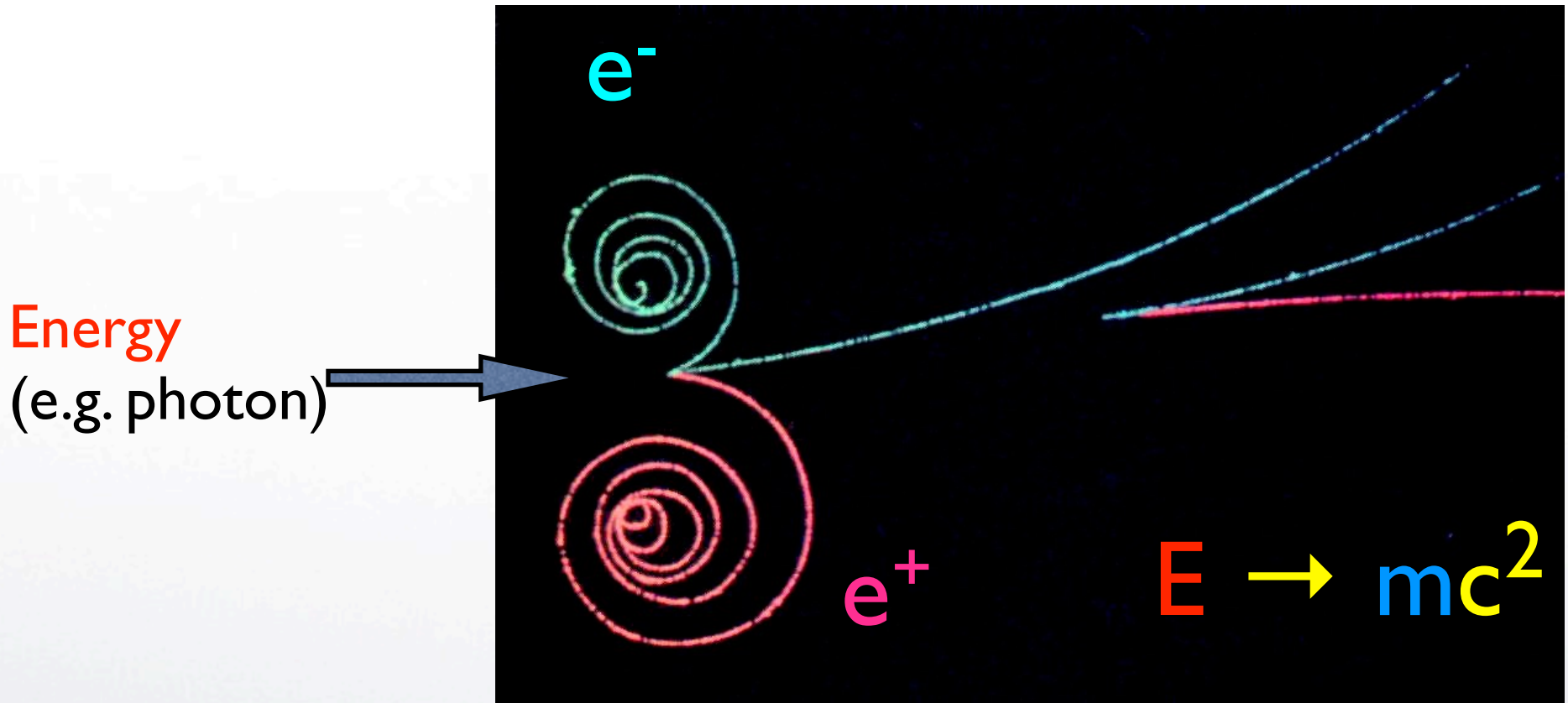
$$E = mc^2$$

# 3 How is antimatter made ?

Energy is converted to mass

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Mass of electron and positron



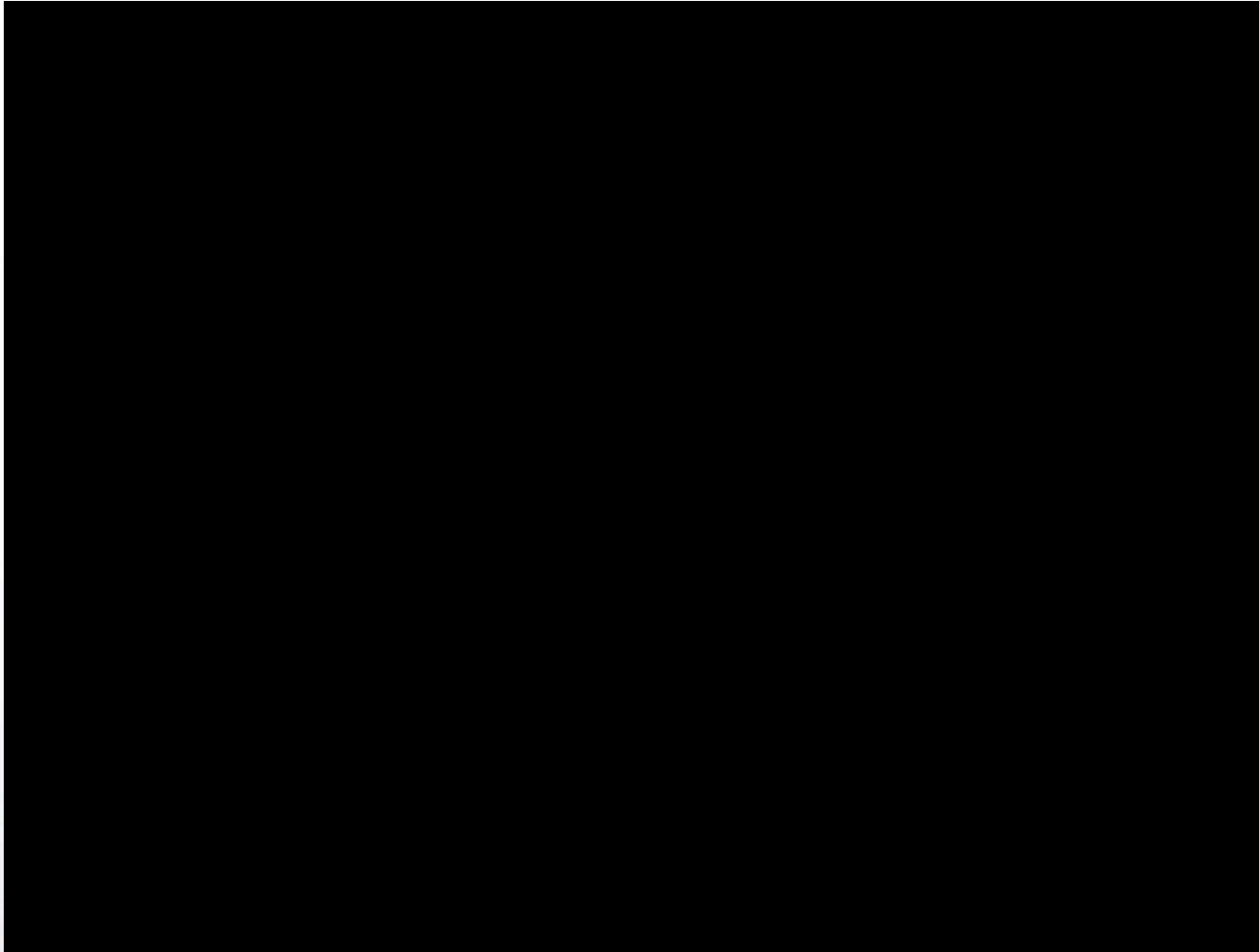
# 3 How is antimatter made ?



**New** particles and antiparticles are created in collisions

# 3 How is antimatter made ?

Antiproton Decelerator at CERN



# 4 The mystery of antimatter



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The Universe started 13 700 million years ago



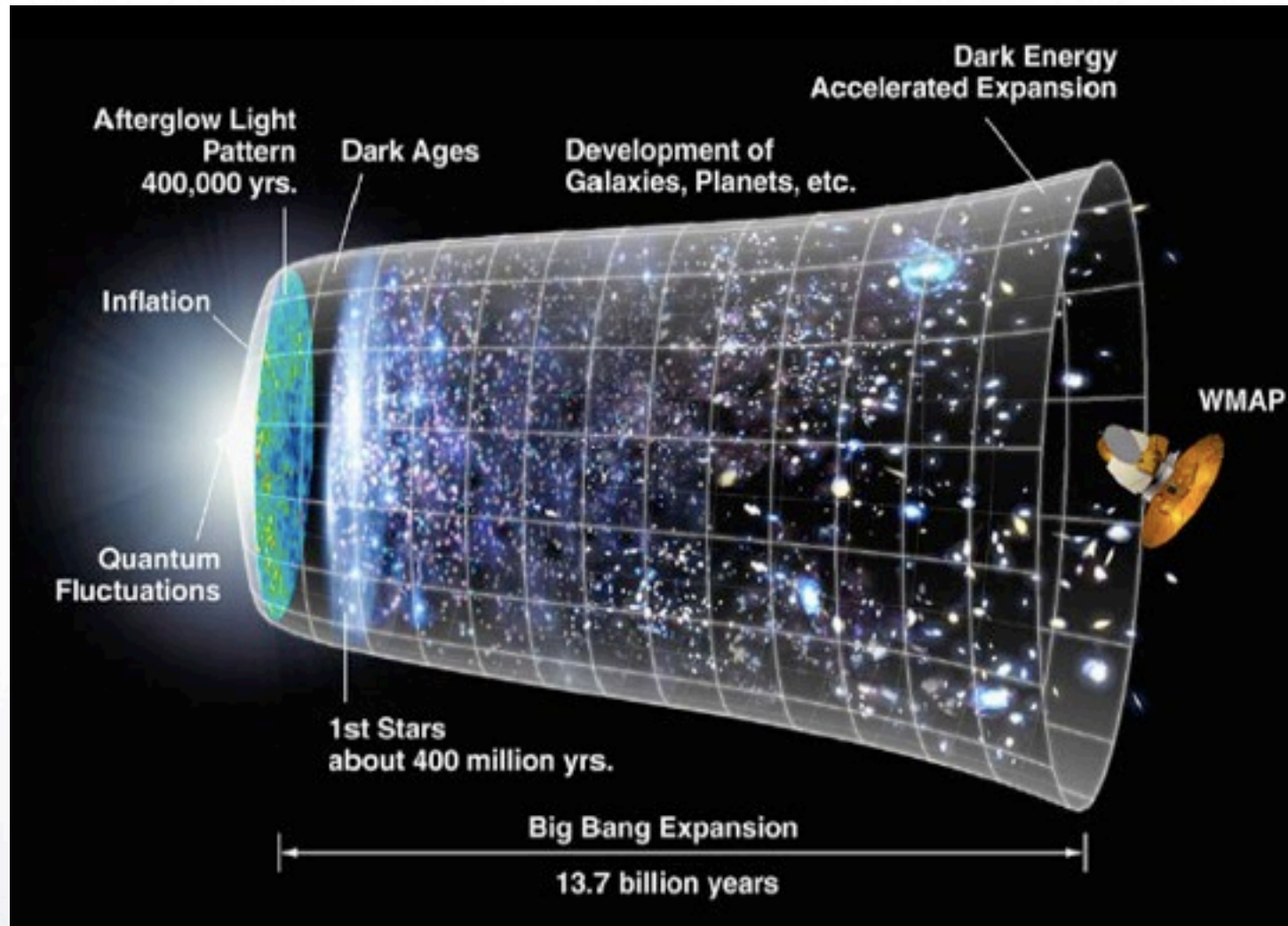
~  $10^{72}$  Joule



Size (x 100) of the visible Universe at the 'Planck' time

Space and time came into existence. The space expanded, while the energy converted into mass (50 % matter, 50 % antimatter)

# 4 The mystery of antimatter



All the antimatter disappeared less than 1 sec after the Big Bang

# 4 The mystery of antimatter

It looks as if there was a giant ‘annihilation battle’ shortly after the Big Bang.

Most of the matter and antimatter disappeared and produced lots of light (still visible).

Only little matter was left = all stars, planets, us!

**Why did ‘our’ matter survive?**

**Why is there ‘something’ and not ‘nothing’?**

Without this tiny asymmetry, we would not exist!  
That is why we study antimatter.

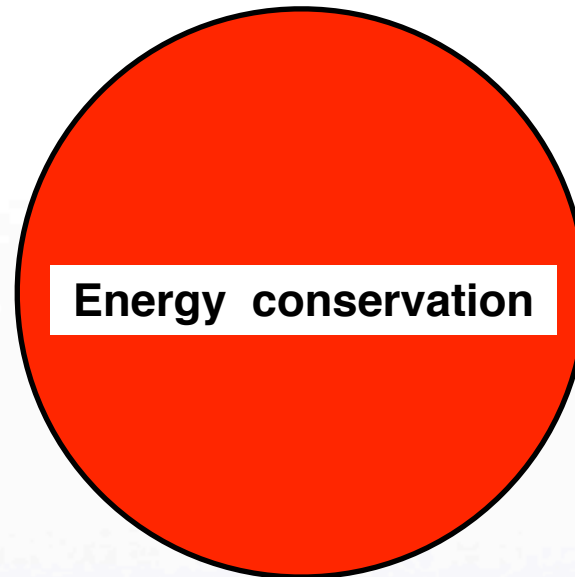


# 5 Energy source? Weapon? Star Trek?



*Dan Brown: Antimatter is the energy source of the future.*

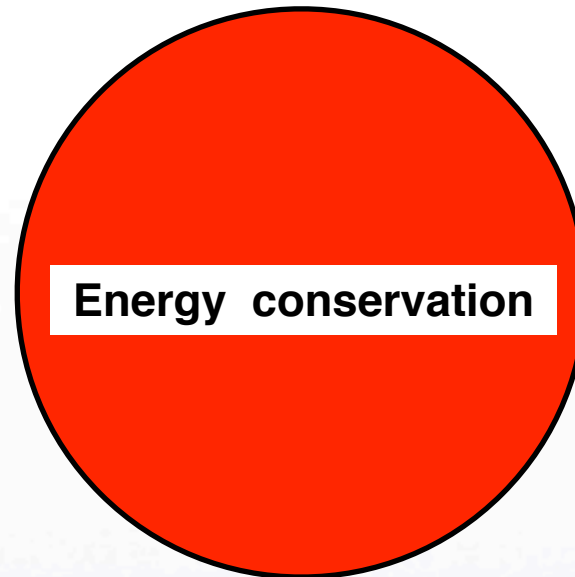
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Antimatter production **requires energy**

**1,000,000,000 times more energy invested  
than released** by annihilation

# Antimatter bombs ?



*Dan Brown is right:  
only 0.5 g antimatter makes an 'anti-atomic bomb'*

**BUT:**

20 kt TNT =  $8.4 \cdot 10^{13}$  J  
0.5 g antimatter + 0.5 g matter

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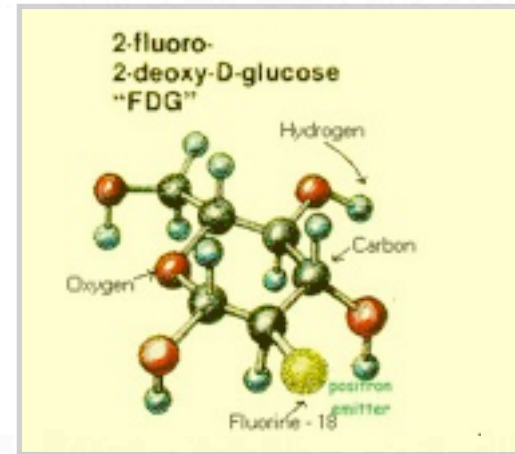
**Delivery time ~ 1 000 000 000 years**

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# Positron Emission Tomography !

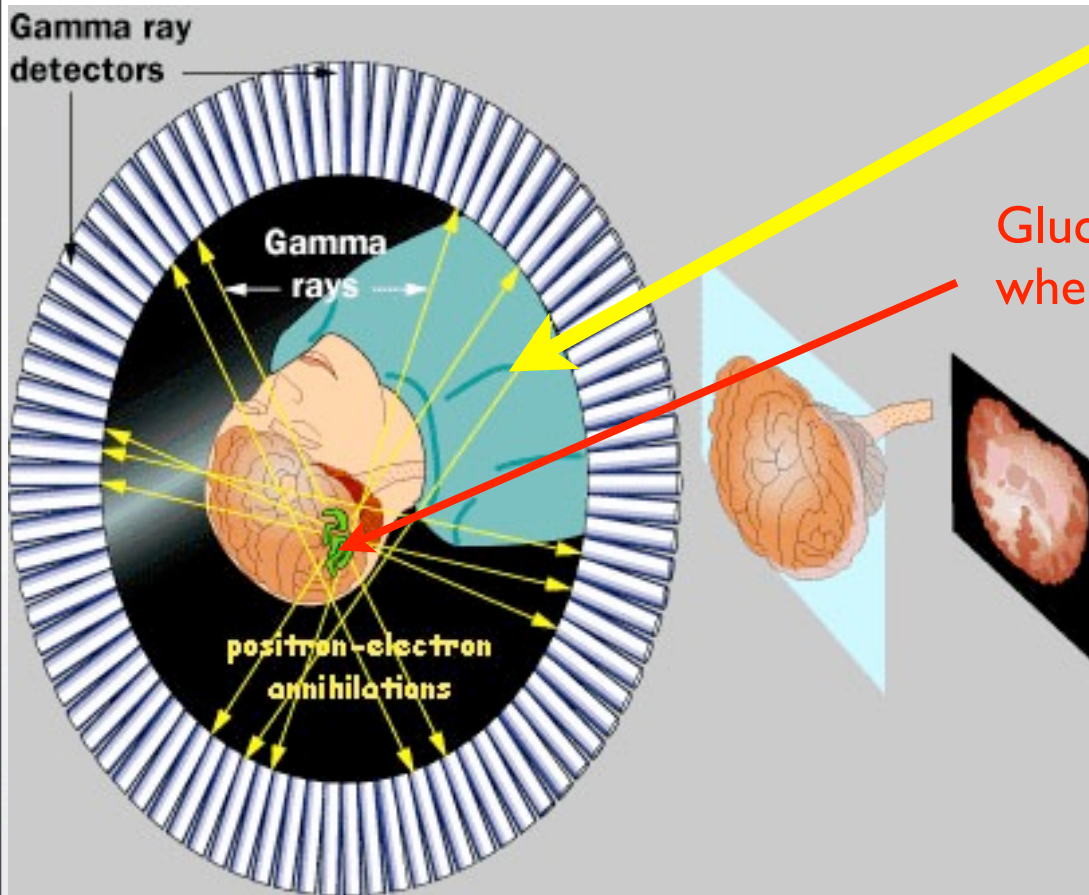
Add **positron** emitting isotopes (e.g. F-18) to glucose molecule and inject into blood stream





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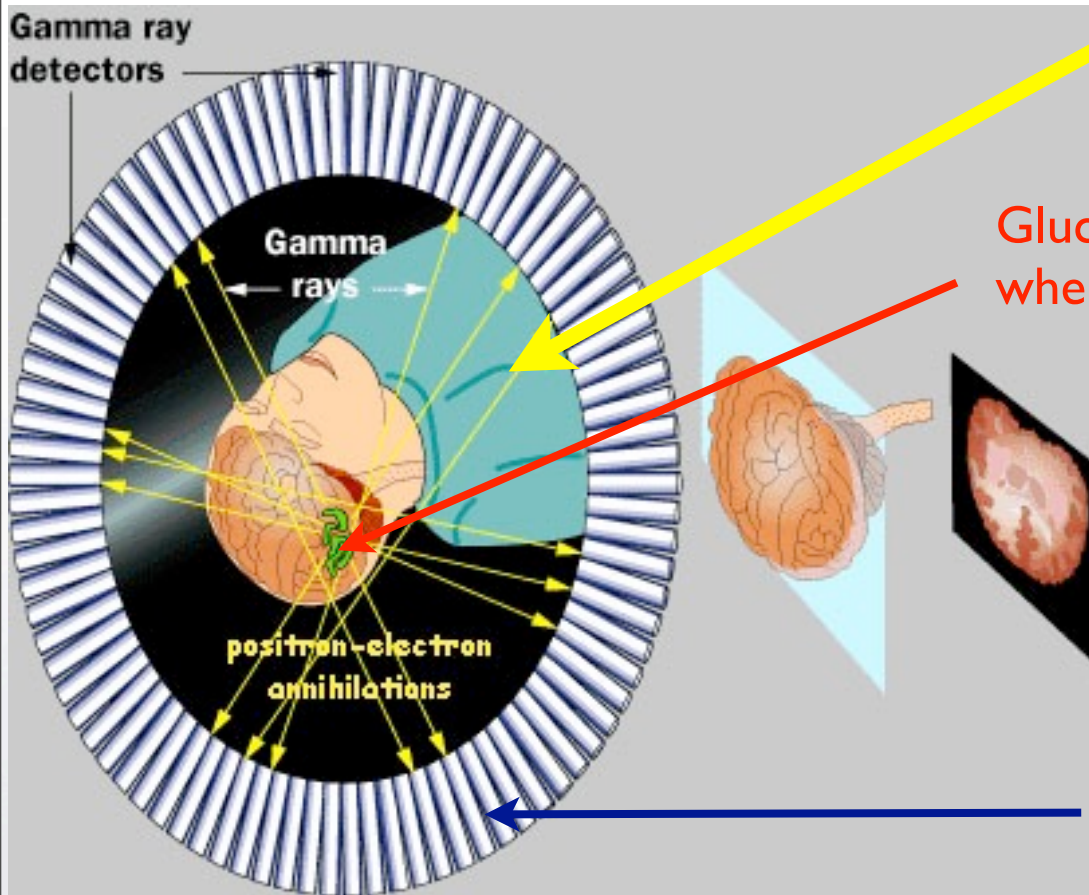
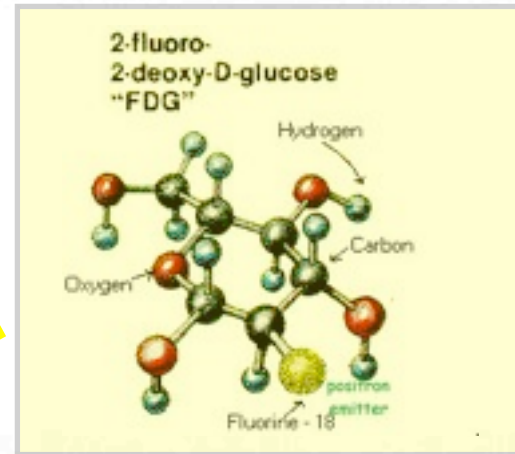
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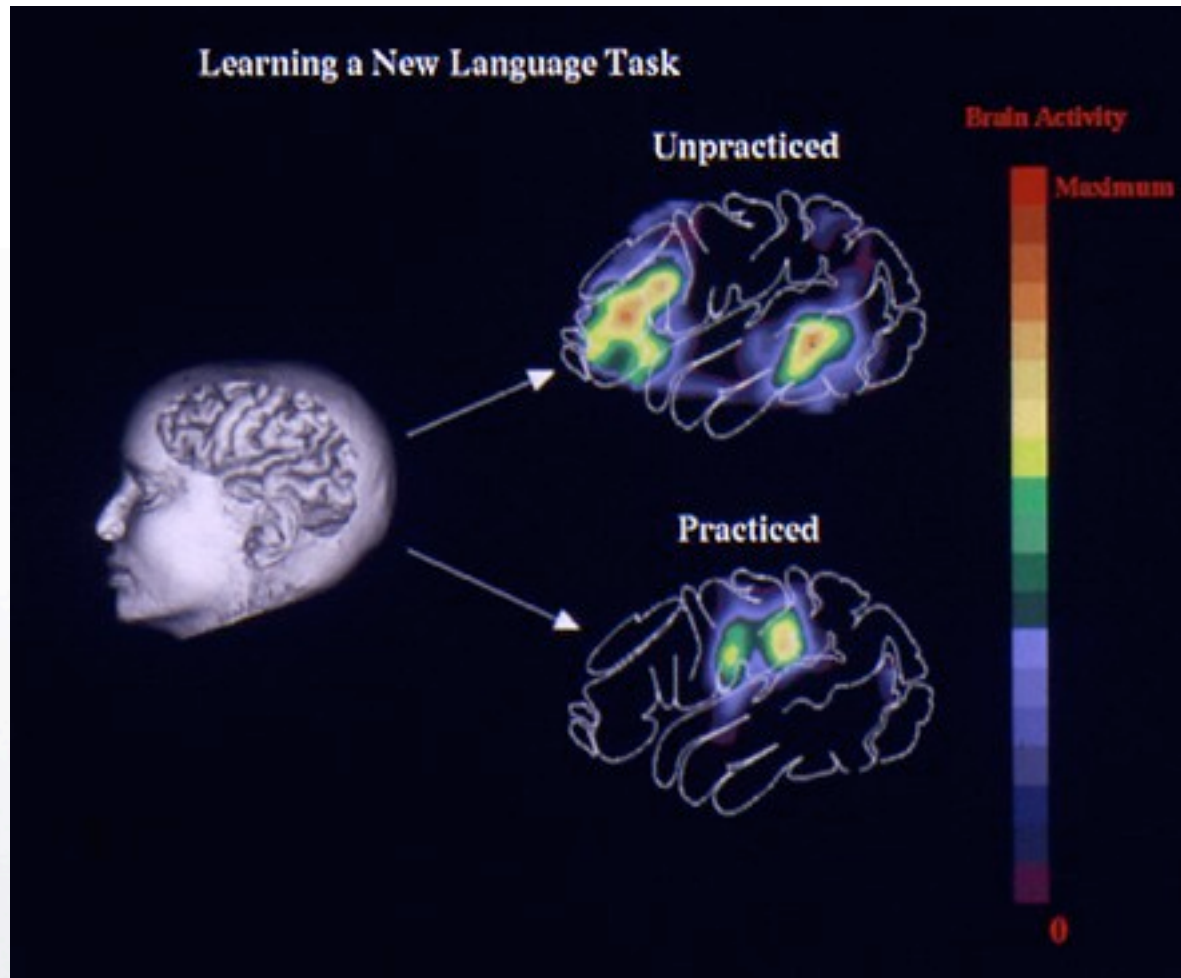
Glucose molecules accumulate (and decay) where energy is needed

Use detector to reconstruct place of positron annihilation



# Positron Emission Tomography

Antimatter annihilations help to understand how the brain works





## Back to Ron Howard ...

What did  
Ron Howard  
say after his  
visit to  
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Thank you for your attention.