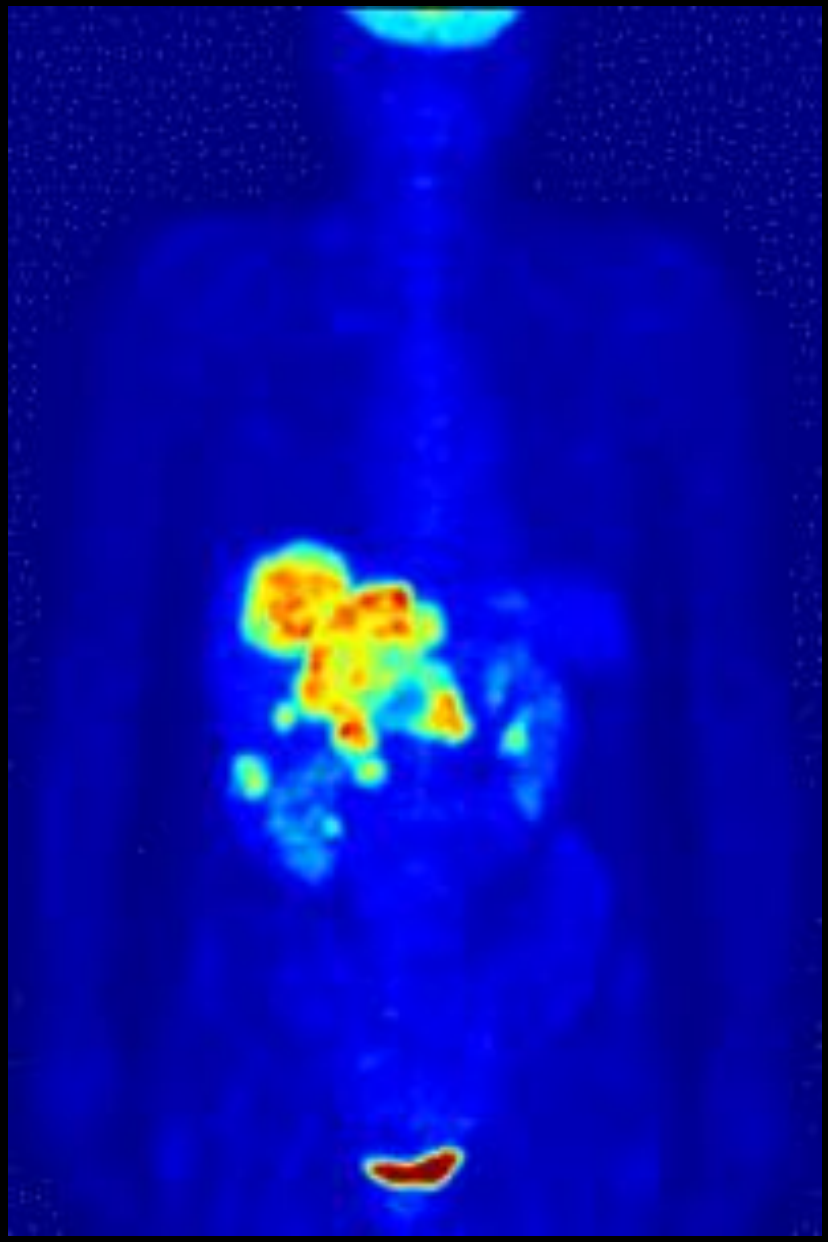
Dammit Jim,
I'm a DOCTOR,
not a PARTICLE
PHYSICIST!!

MEDICINE

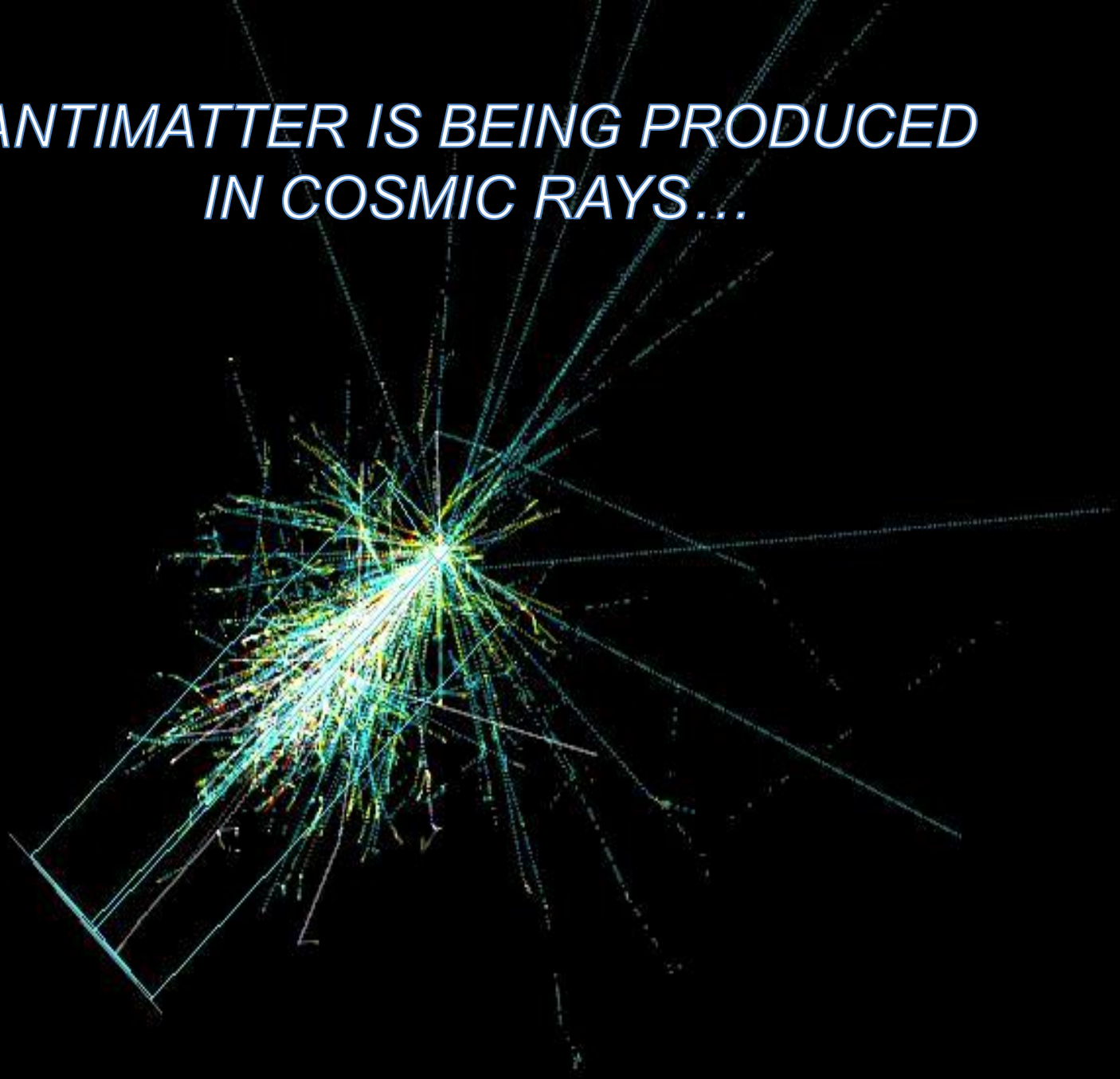
THE NEXT GENERATION




MATTER DOMINATES IN OUR UNIVERSE.


MATTER DOMINATES IN OUR UNIVERSE.
IT WON OUT OVER ANTIMATTER
A LONG TIME AGO.

ANTIMATTER IS BEING PRODUCED IN COSMIC RAYS…



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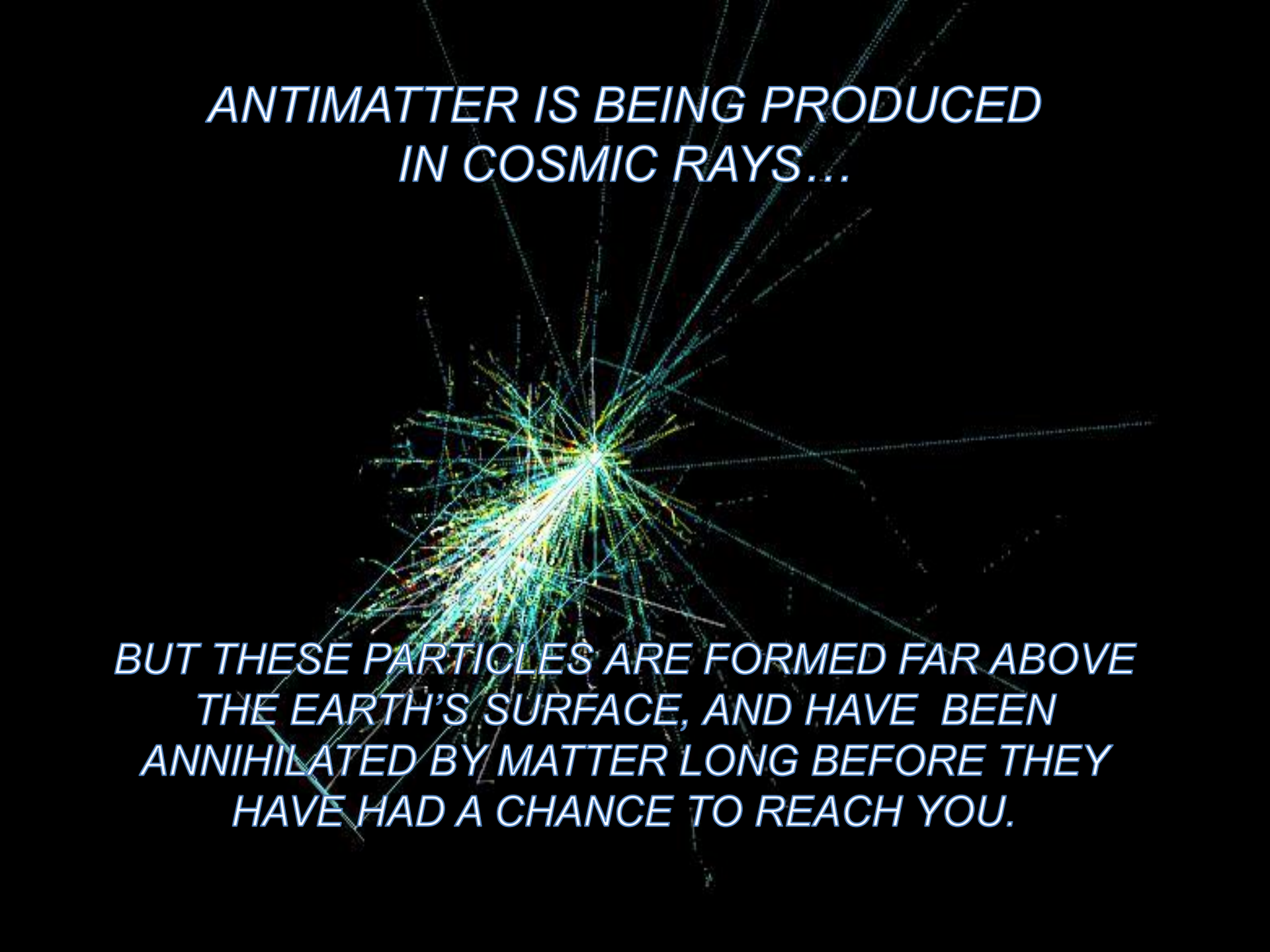

BUT THESE PARTICLES ARE FORMED FAR ABOVE THE EARTH'S SURFACE, AND HAVE BEEN ANNIHILATED BY MATTER LONG BEFORE THEY HAVE HAD A CHANCE TO REACH YOU.

ANTIMATTER HAS BEEN MADE AT PLACES LIKE CERN…

The image depicts the detection of the products formed in a real event of an antihydrogen annihilation (from the CERN ATHENA experiment). The antiproton annihilates producing four charged pions (in yellow), and the positron produces two gamma ray photons (in red).

ANTIMATTER HAS BEEN MADE AT PLACES LIKE CERN…

BUT AS WE HAVE SEEN, IT IS AN EXTREMELY EXPENSIVE PROCESS,
AND THE YEARLY OUTPUT OF ANTIMATTER
(FOR EXAMPLE, IN THE FORM OF ANTIPROTONS)
IS RELATIVELY SMALL.

GIVEN ALL OF THIS,
ANSWER THE FOLLOWING QUESTION:

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ANSWER THE FOLLOWING QUESTION:

ARE YOU AWARE OF ANYONE EVER HAVING BEING EXPOSED TO ANTIMATTER?

GIVEN ALL OF THIS,
ANSWER THE FOLLOWING QUESTION:

ARE YOU AWARE OF ANYONE EVER HAVING BEING EXPOSED TO ANTIMATTER?

TAKE A MOMENT AND THINK ABOUT THIS…

WELL, THERE IS A CHANCE THAT SOMEONE YOU KNOW MAY HAVE BEEN EXPOSED TO ANTIMATTER.

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BUT WHERE?
WHEN?
HOW?
WHAT KIND OF ANTIMATTER?

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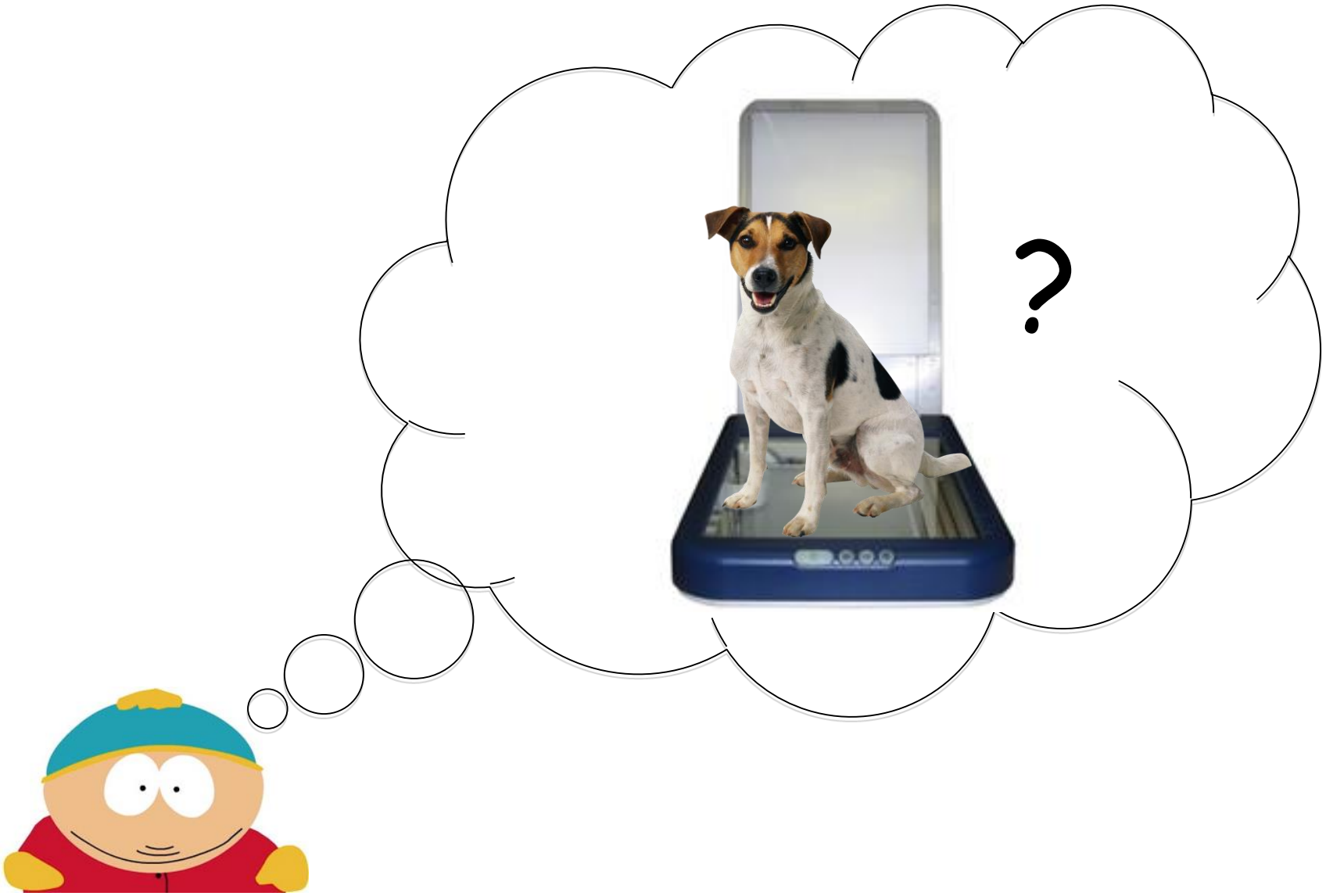

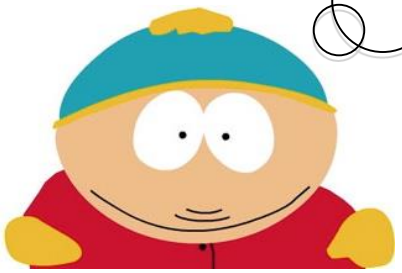

NO. IN THIS CASE THE "PET" HAS NOTHING TO DO WITH A PET ANIMAL…

A PET SCAN IS A TYPE OF MEDICAL IMAGING TECHNIQUE THAT ALLOWS FOR THE STUDY AND VISUALIZATION OF PROCESSES OCCURRING INSIDE THE BODY—AND IT USES THE ANNIHILATION OF MATTER BY ANTIMATTER TO ACHIEVE THIS.

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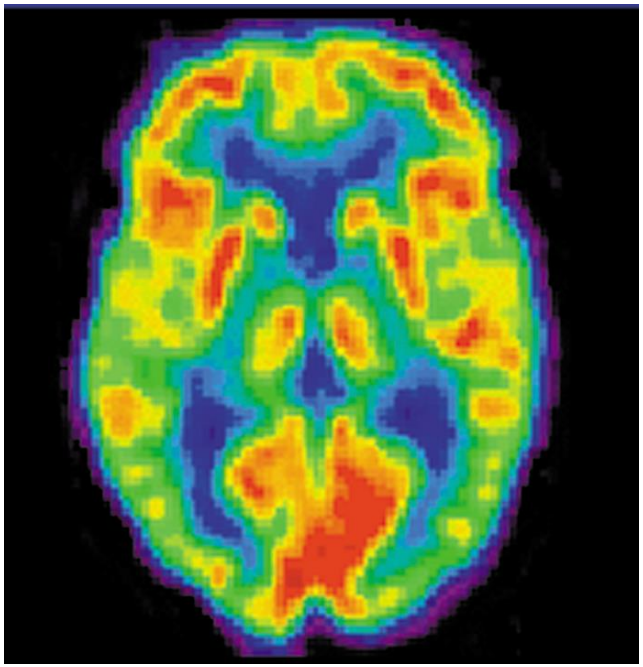

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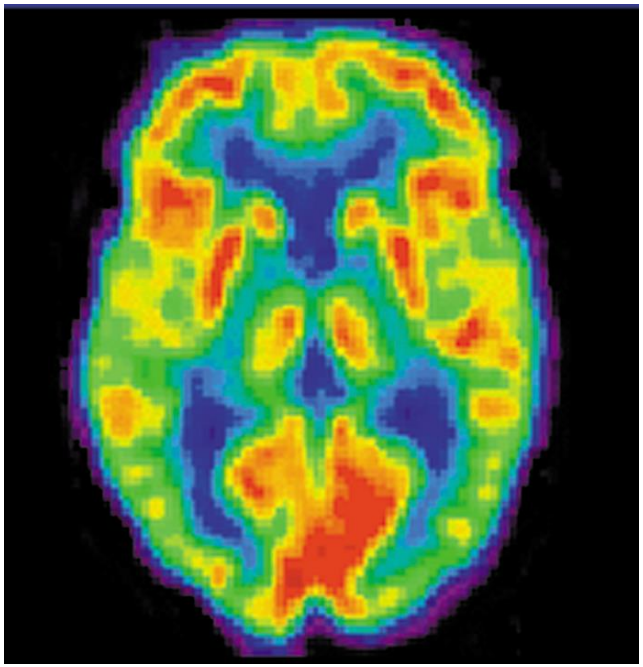

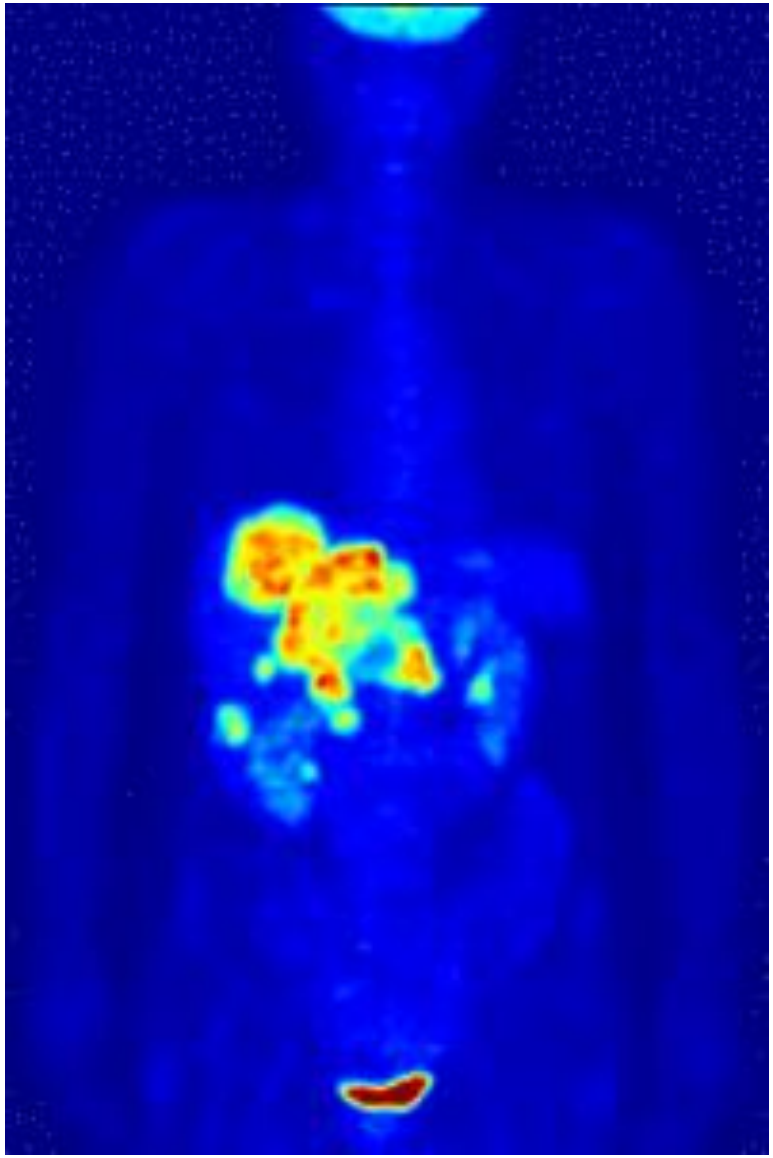

THE "PET" IN
"PET SCAN"
IS AN ABBREVIATION
FOR…


PET


PET
POSITRON


PET
MISSION
POSITRON


PET
TOMOGRAPHY
EMISSION
POSITRON

THE ABILITY OF A POSITRON
TO COMPLETELY ANNIHILATE AN ELECTRON,
AND THE PRODUCTION OF TWO GAMMA RAY PHOTONS IN THE PROCESS,
IS THE UNDERLYING SCIENTIFIC PRINCIPLE BEHIND THE PET SCAN.

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BY FIRST MAKING SOMETHING THAT CAN GENERATE THEM FOR US…

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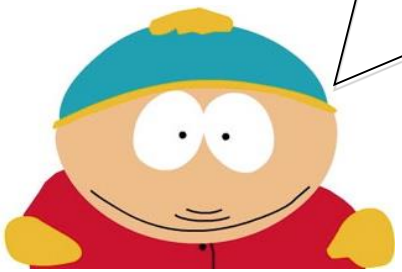
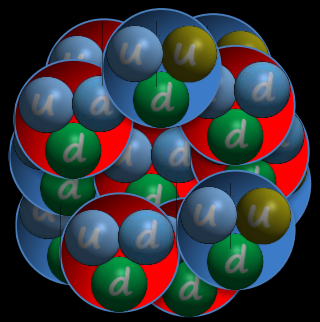
…RADIOACTIVE NUCLEI

RADIOACTIVE NUCLEI, EH? PLEASE, DO TELL.

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This is a
nitrogen nucleus
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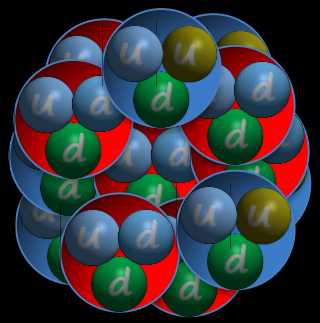

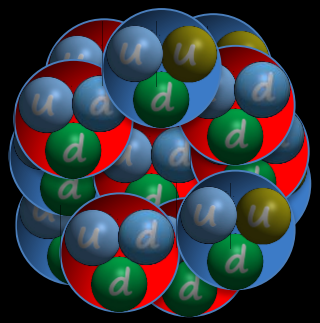

This is a
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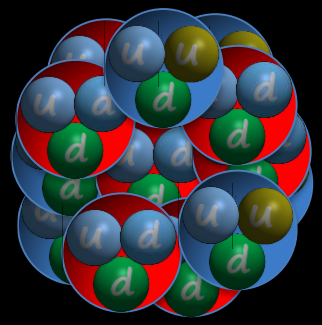
This nucleus contains
7 protons and 7 neutrons
and is called Nitrogen-14.

N-14



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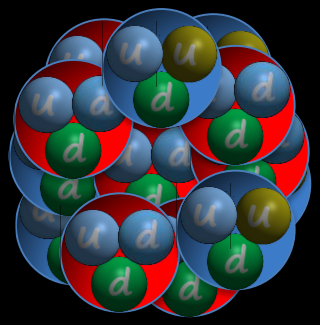
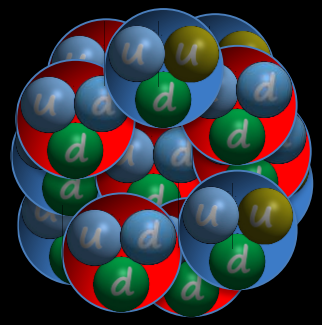
(or N-14 for short, where 14 is equal to the number of protons + the number of neutrons)

These 7 protons and 7 neutrons form a very stable nucleus.

N-14



N-14



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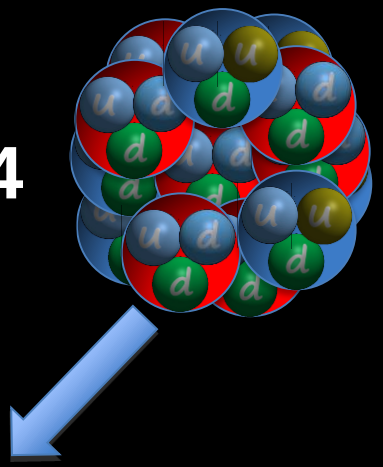
But, if we were to remove one of the neutrons (say, by smashing this nucleus with another particle)…

N-14



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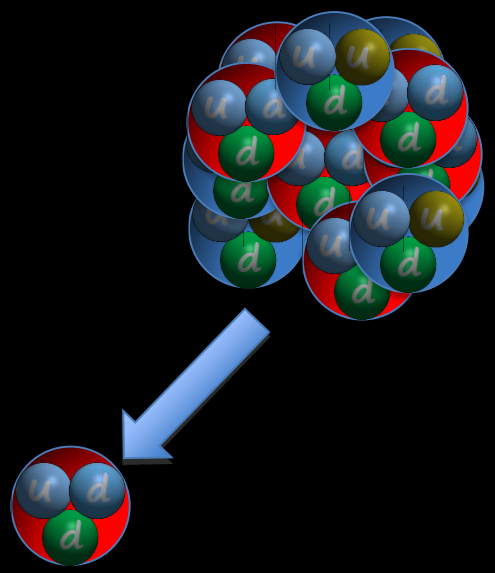

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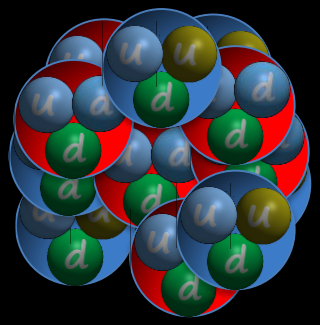

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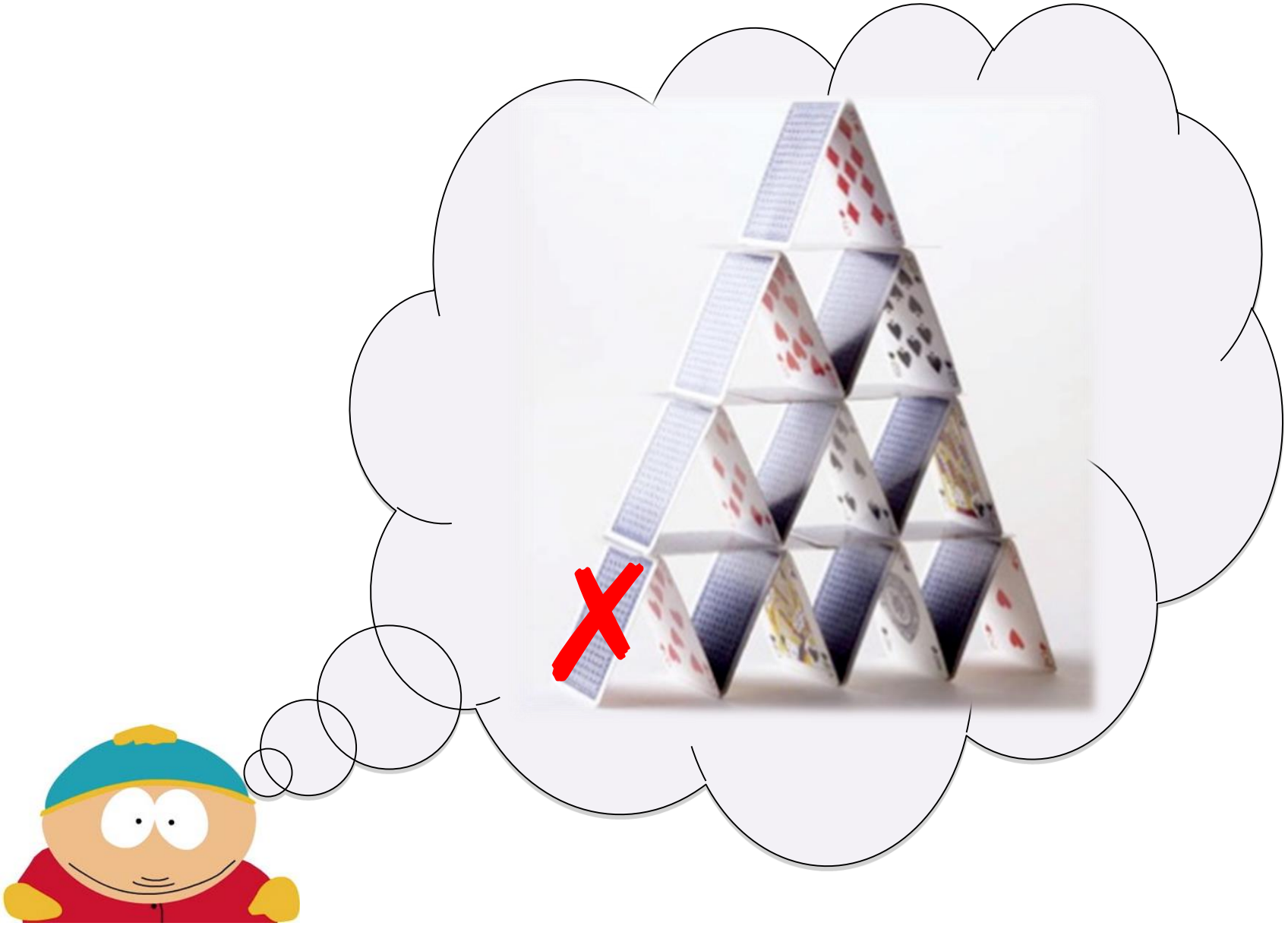
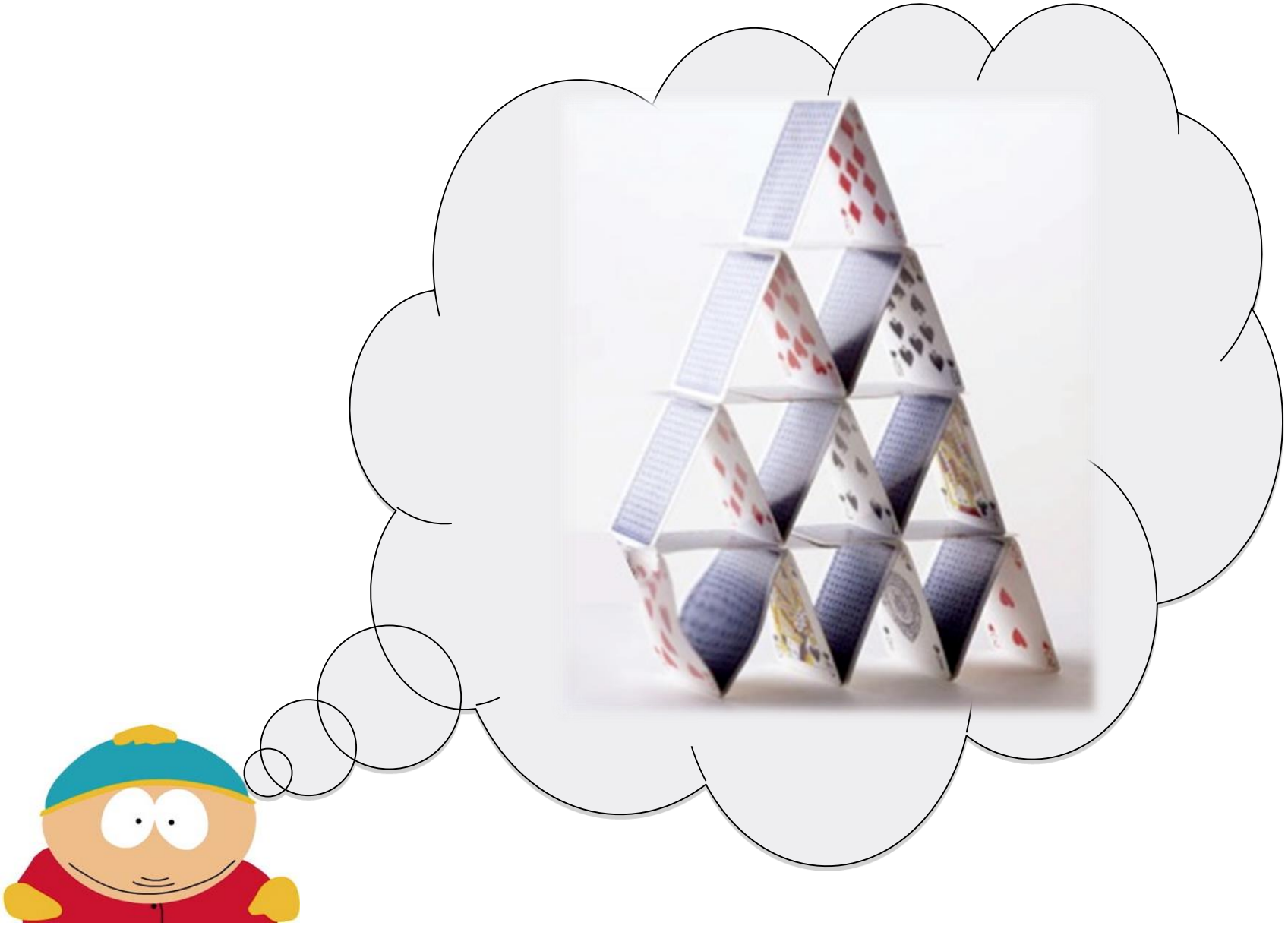
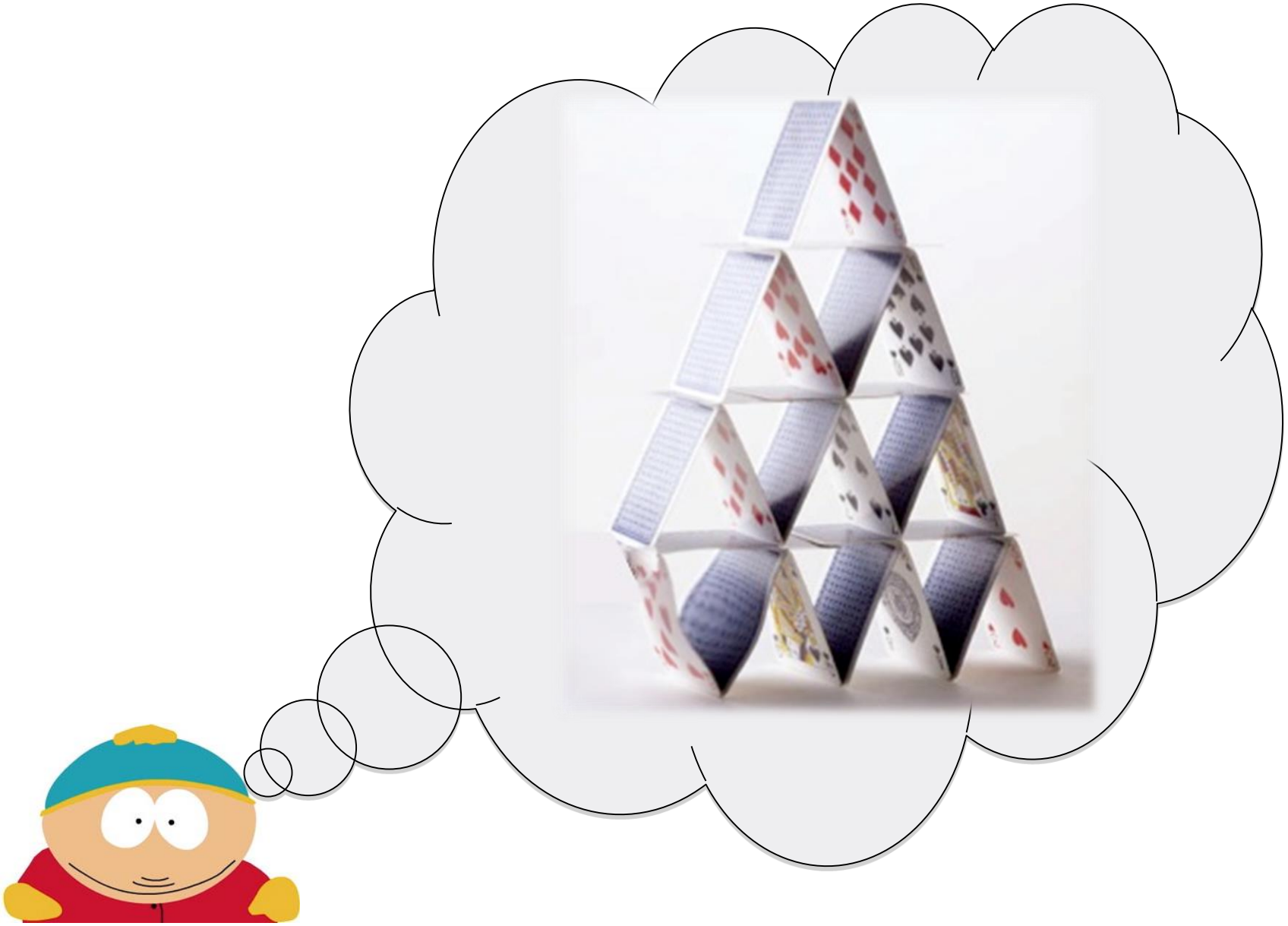
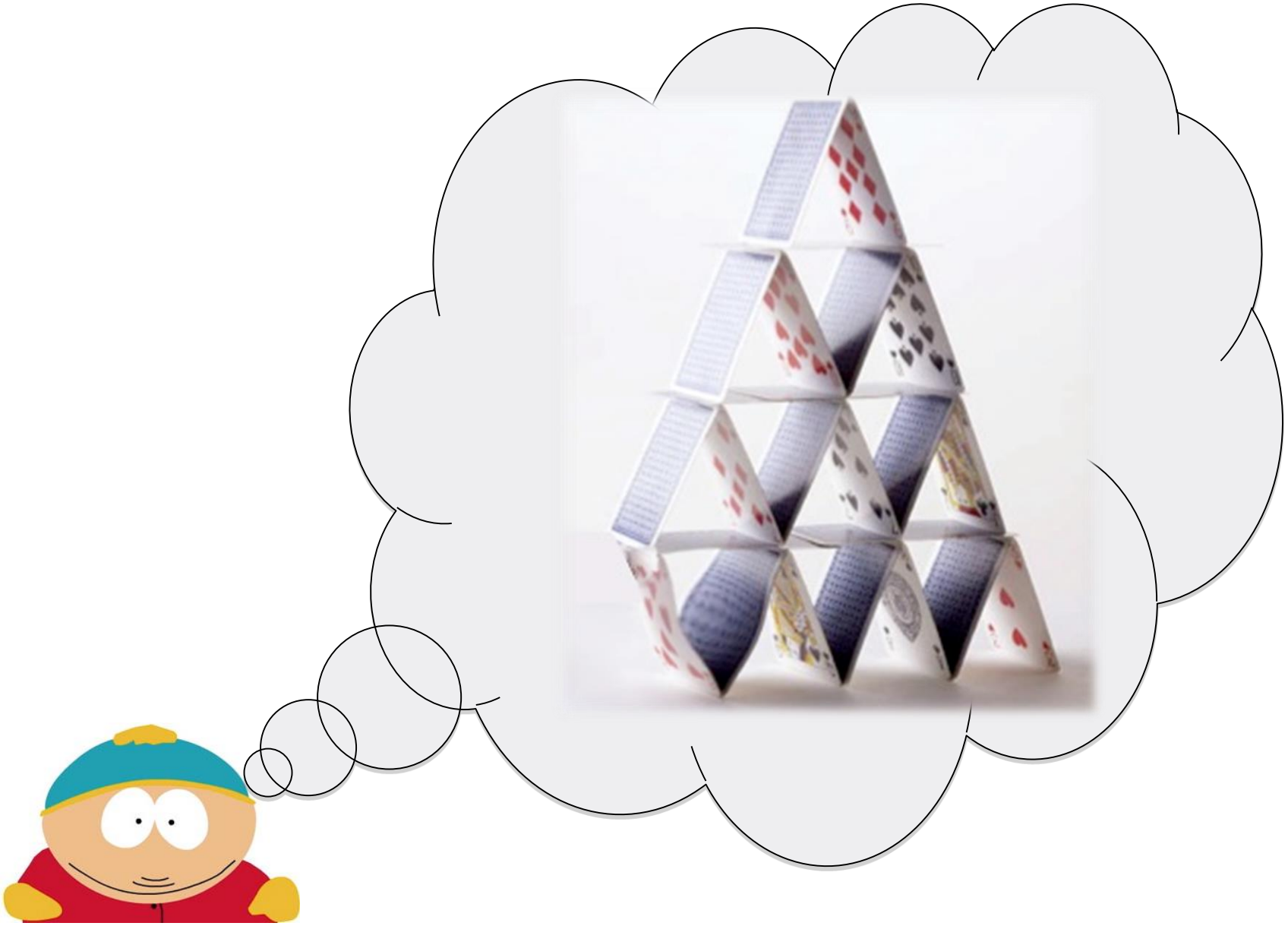
But, if we were to remove one of the neutrons (say, by smashing this nucleus with another particle)…

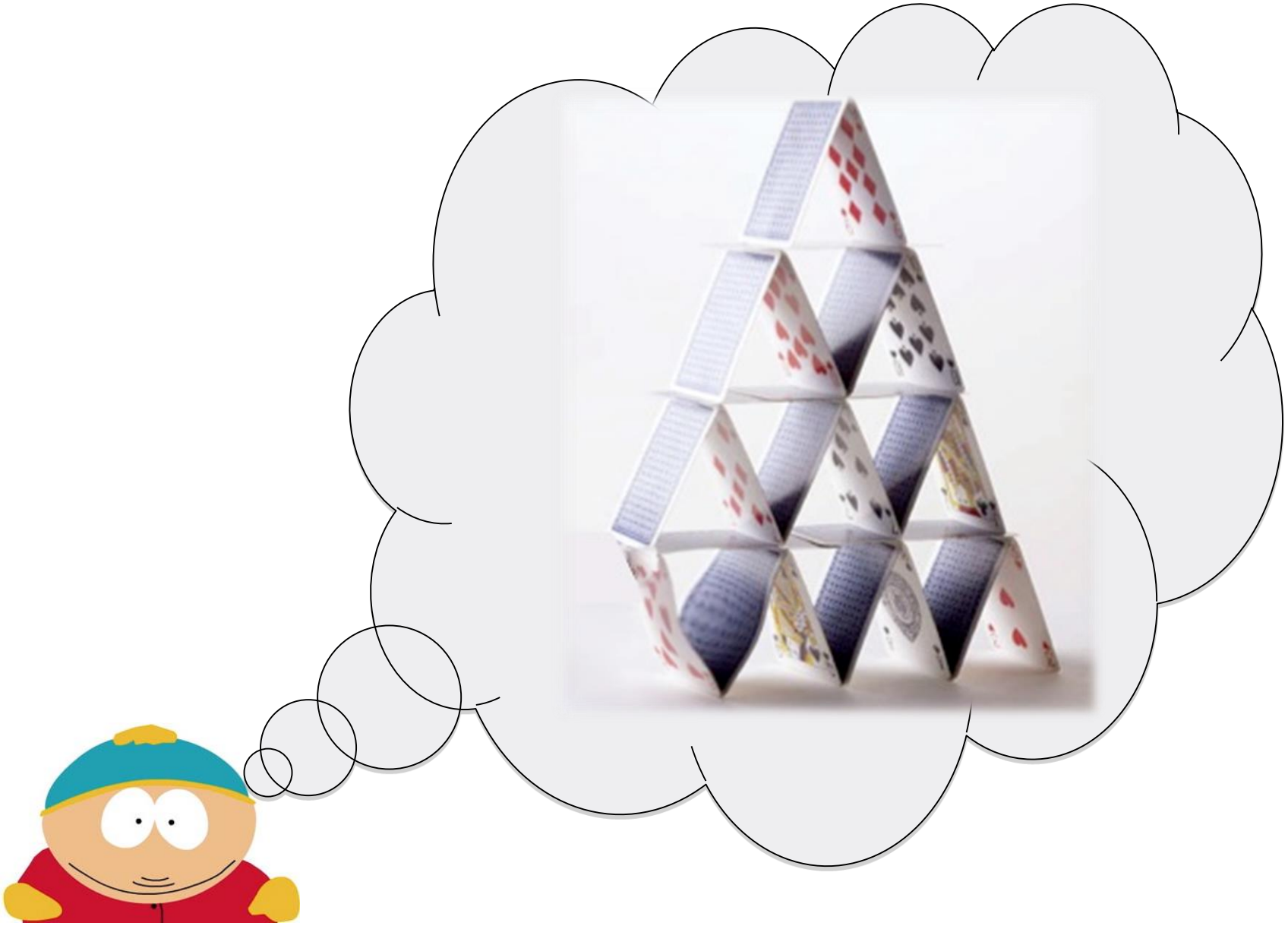
…the nucleus loses its stability.



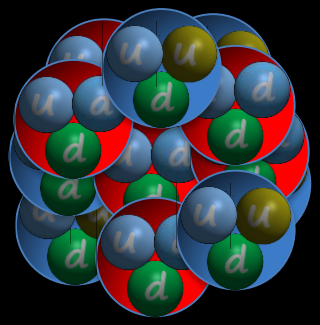






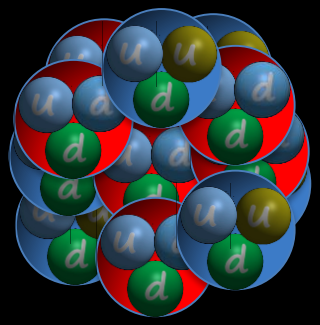


N-13



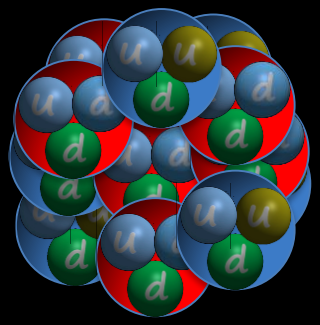
The nucleus that remains contains 7 protons and 6 neutrons and is called Nitrogen-13.

N-13



The nucleus that remains contains 7 protons and 6 neutrons and is called Nitrogen-13.

This nucleus is unstable, which means that it will not remain in its present form for very long.



In order to become stable again,
one of its protons
transforms into a neutron…

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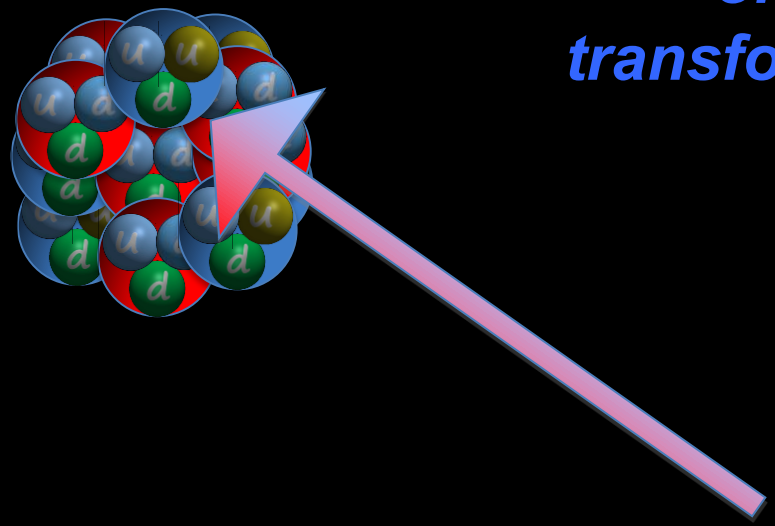

…for example,
this one…

In order to become stable again,
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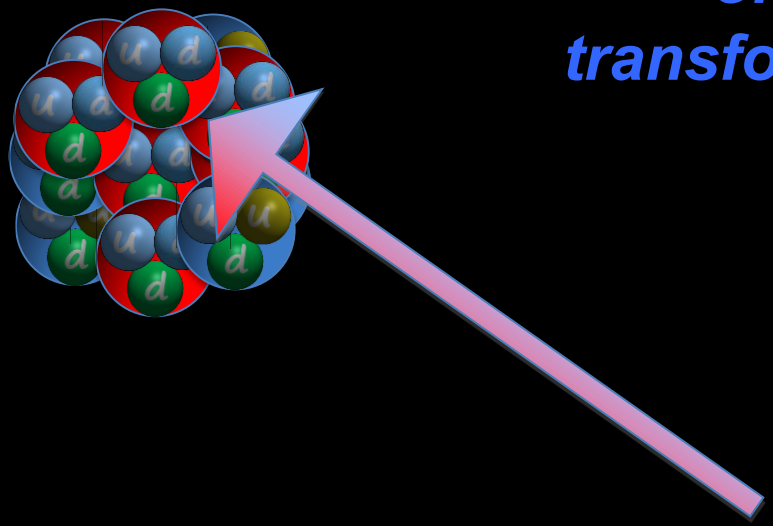

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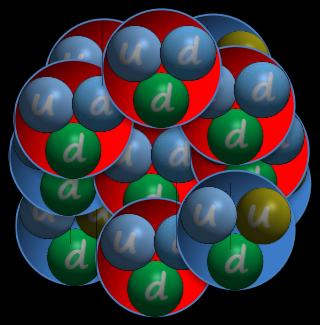
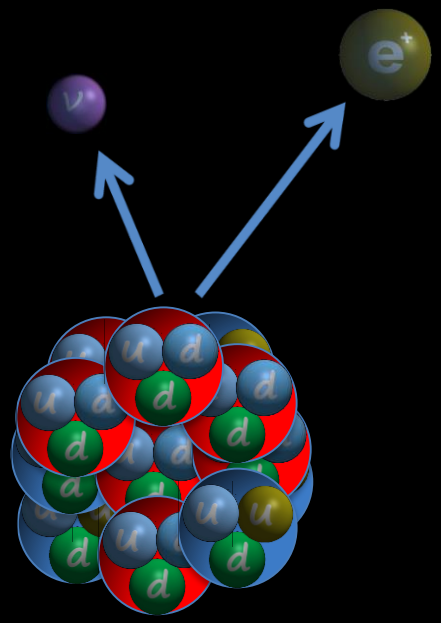


…and the burden of N-13's instability
is carried away by
a positron and a neutrino,
which are emitted from the nucleus.



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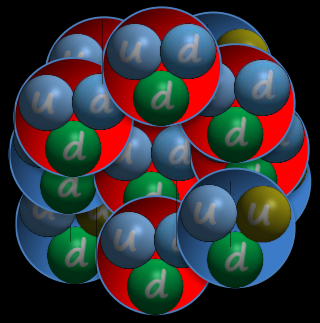
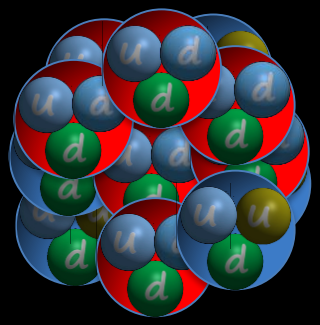
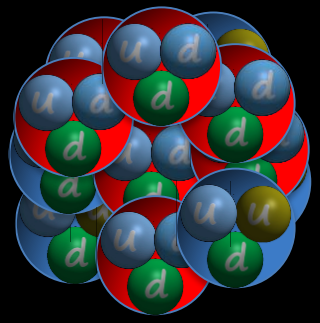


Now, what do we call this remaining nucleus?



We now have a nucleus containing 6 protons and 7 neutrons.

C-13



We now have a nucleus containing
6 protons and 7 neutrons.

It is called Carbon-13 (or C-13),
and this nucleus is STABLE.

Nuclei that are unstable can become stable by giving off energy in the form of particles. Such nuclei are called "radioactive" because of their emissions.

Nitrogen-13 is called a ***positron emitter*** *because its way of dealing with instability is to emit a positron (and a neutrino).*

We say that

Nitrogen-13 decays to Carbon-13, emitting a positron and a neutrino:

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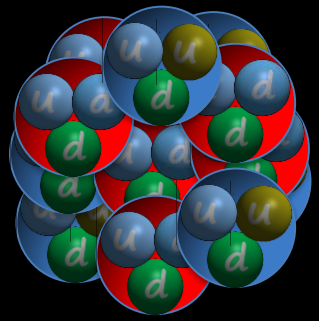

Nitrogen-13

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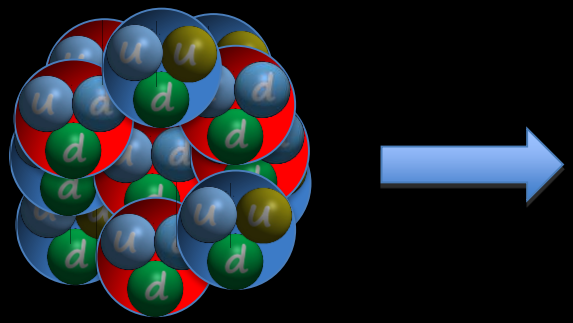

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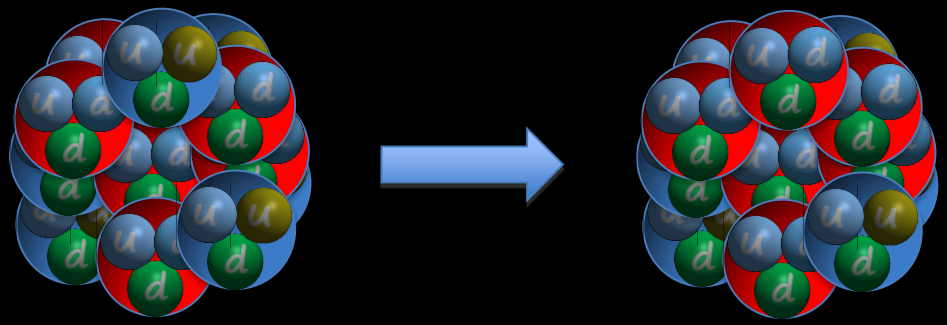

Nitrogen-13 **Carbon-13**

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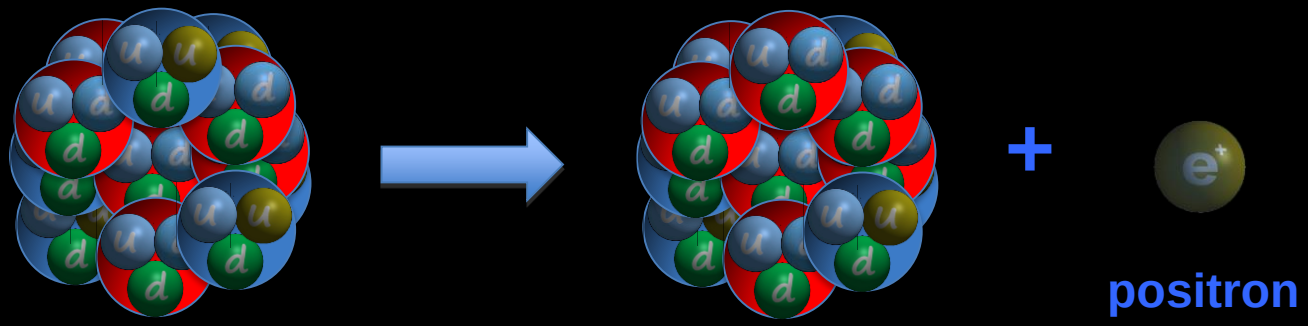

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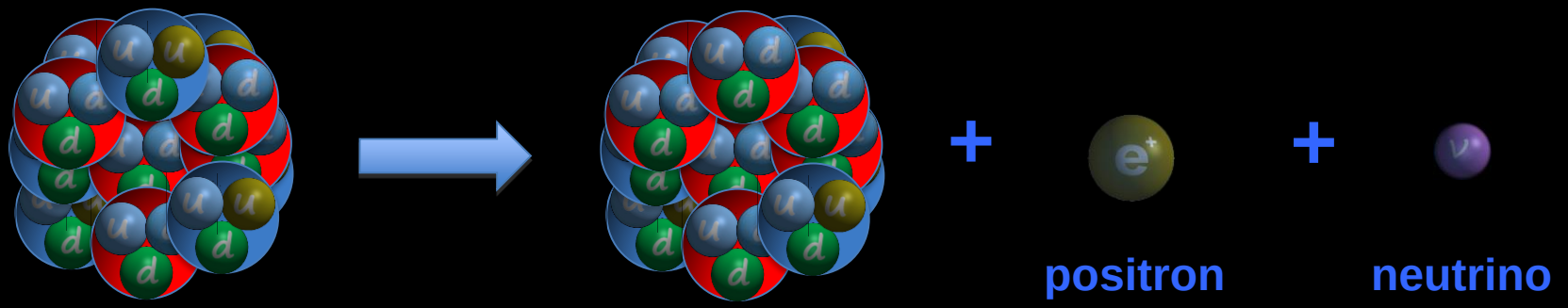

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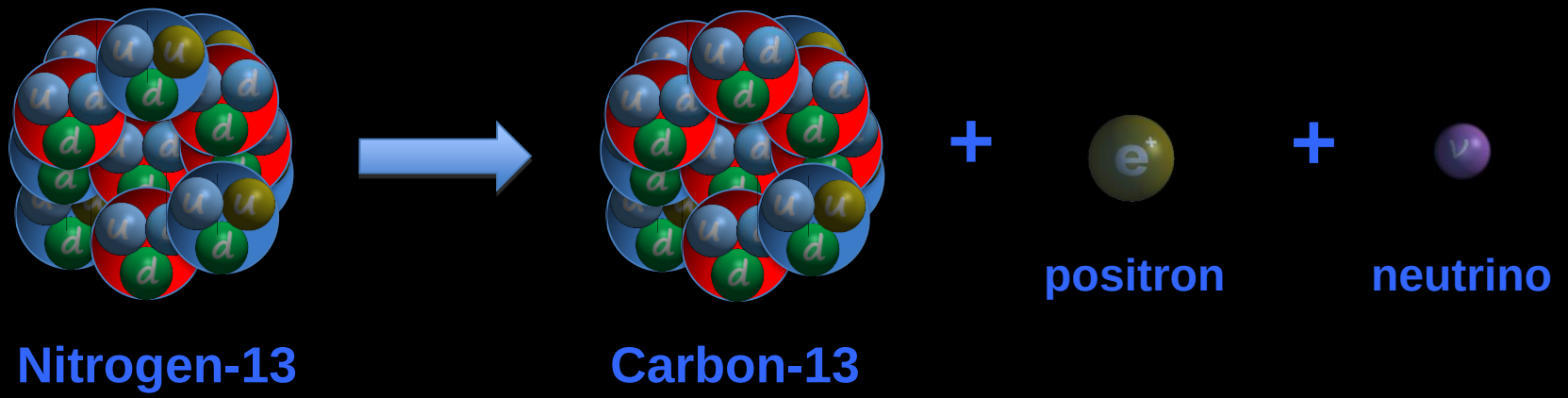
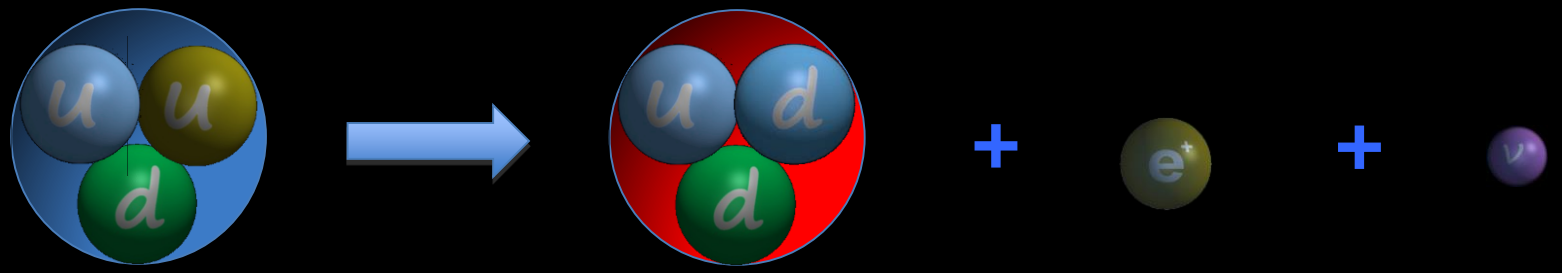


Or, simply…

N-13 → **C-13** + e^+ + ν

We could also say that a proton,
when confined in the nucleus of N-13,
decays into a neutron, a positron and a neutrino:



$$p \longrightarrow n + e^{+} + \nu$$

Or, in terms of just the FUNDAMENTAL particles involved:

up quark → down quark + e^+ + ν

HERE ARE OTHER UNSTABLE (RADIOACTIVE) NUCLEI THAT BECOME STABLE BY EMITTING POSITRONS AND NEUTRINOS:

CARBON-11 **(C-11)**
OXYGEN-15 **(O-15)**
FLUORINE-18 **(F-18)**
SODIUM-22 **(Na-22)**

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AS AN EXERCISE, DETERMINE THE NUMBER OF PROTONS AND NEUTRONS IN THE NUCLEUS THAT REMAINS WHEN EACH OF THESE POSITRON EMITTERS DECAYS.

GIVE THE NAMES OF THE REMAINING NUCLEI.

TO PREPARE A PATIENT FOR A PET SCAN,
RADIOACTIVE NUCLEI SUCH AS THE ONES MENTIONED ABOVE
ARE INCORPORATED INTO A MOLECULE
THAT THE BODY USES (SUCH AS A SUGAR)

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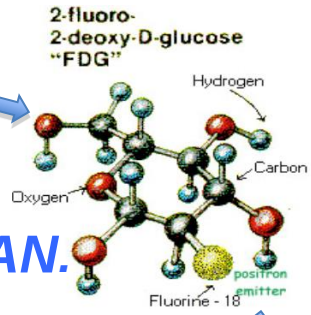
RADIOACTIVE NUCLEI SUCH AS THE ONES MENTIONED ABOVE
ARE INCORPORATED INTO A MOLECULE
THAT THE BODY USES (SUCH AS A SUGAR)

THIS IS THEN INJECTED

INTO THE PATIENT WHO IS TO RECEIVE THE PET SCAN.



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RADIOACTIVE NUCLEI SUCH AS THE ONES MENTIONED ABOVE
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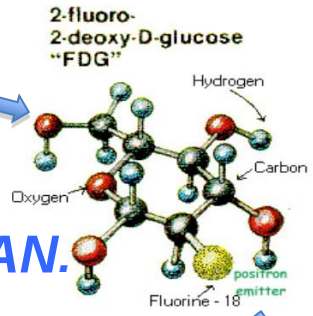

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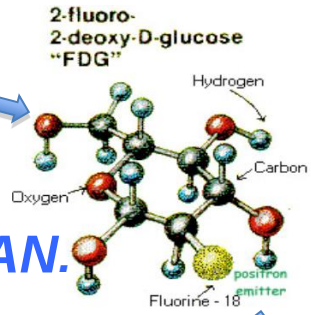

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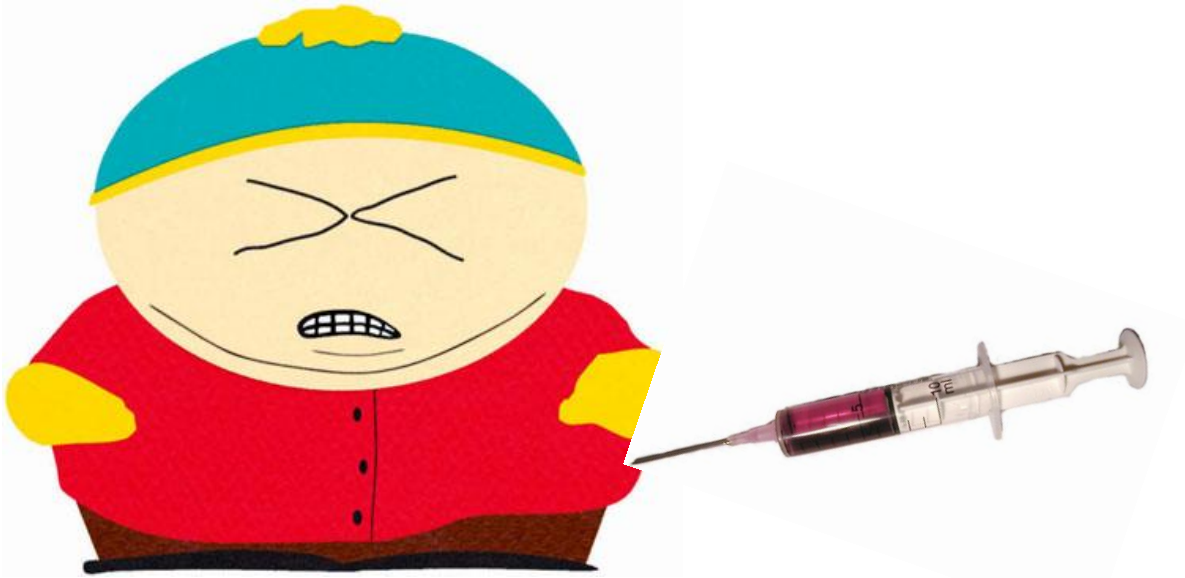

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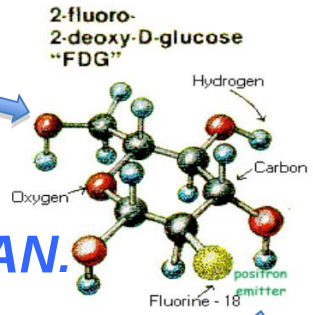

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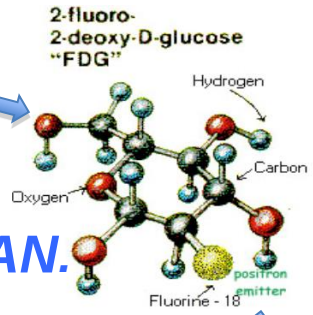

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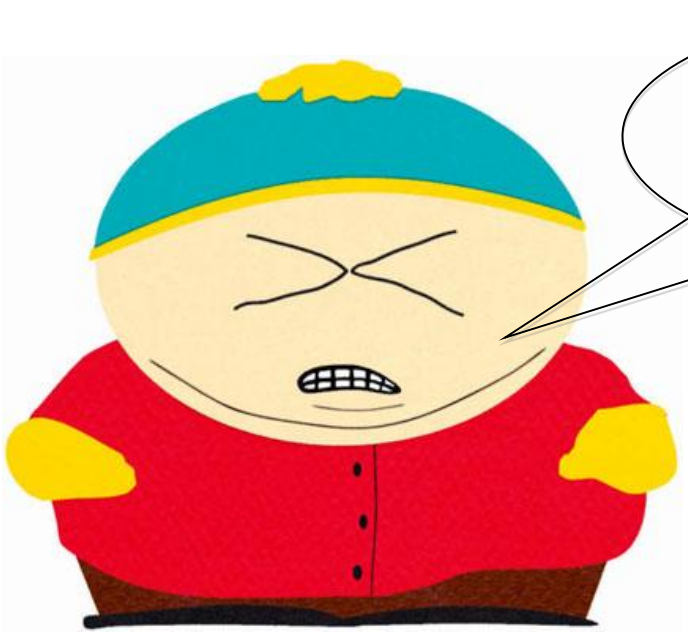

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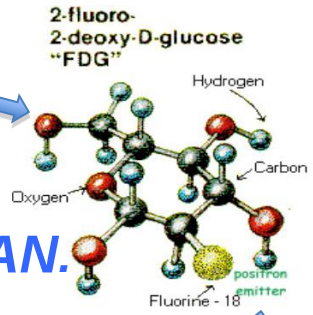

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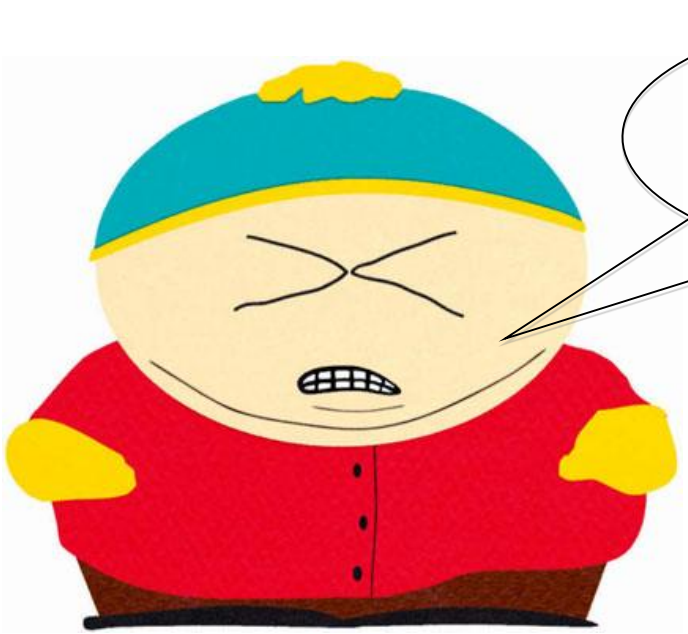

THE MOLECULE IS ABSORBED INTO THE BODY AND WILL EVENTUALLY LOCALIZE IN THE AREA THAT THE DOCTOR IS INTERESTED IN SEEING.

YOU LEARNED IN THE LESSON "OPERATION: ANNIHILATE!" THAT WHEN A POSITRON MEETS AN ELECTRON, THE RESULTING ANNIHILATION PRODUCES 2 GAMMA-RAY PHOTONS:

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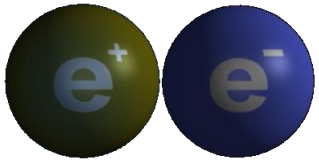

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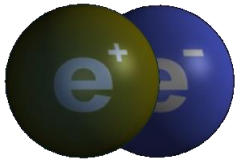

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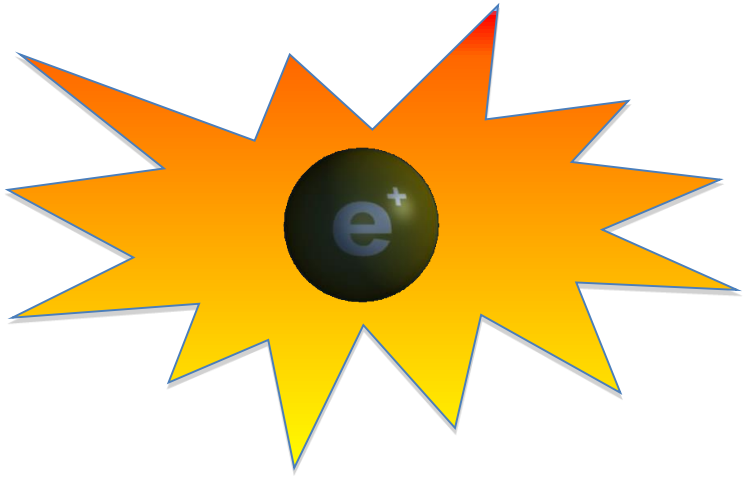

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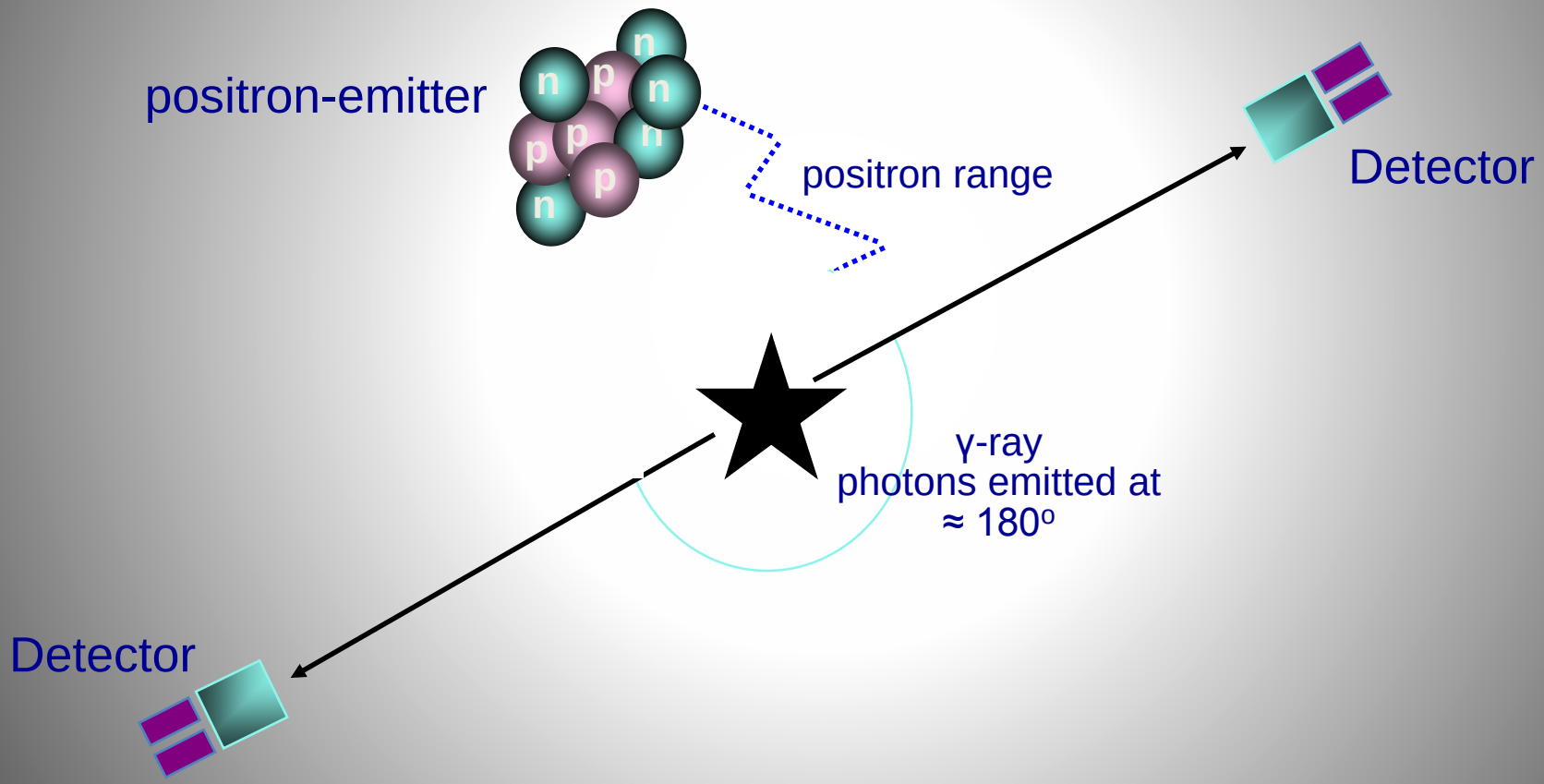
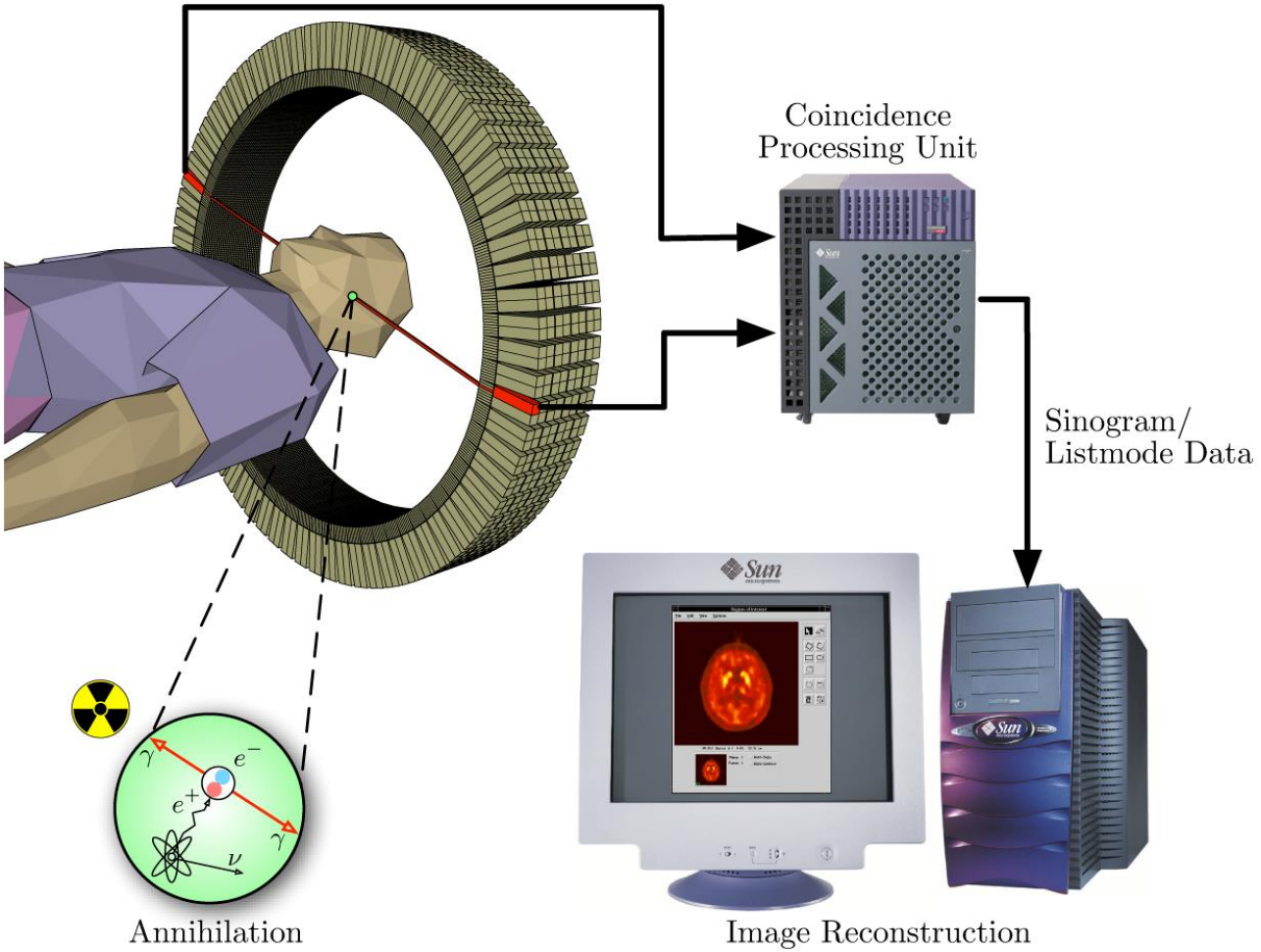
A POSITRON DOES NOT HAVE TO TRAVEL VERY FAR IN YOUR BODY BEFORE IT MEETS AN ELECTRON.

A POSITRON DOES NOT HAVE TO TRAVEL VERY FAR IN YOUR BODY BEFORE IT MEETS AN ELECTRON. WHEN IT DOES, THEY ANNIHILATE AND THE PHOTONS PRODUCED ARE DETECTED.



Images courtesy of Manjit Dosanjh, CERN

UPON DETECTION OF THE GAMMA RAY PHOTONS, A SPECIAL COMPUTER (THE COINCIDENCE PROCESSING UNIT) CONSTRUCTS AN IMAGE BASED UPON THE LENGTH OF TIME IT HAS TAKEN EACH PHOTON TO ARRIVE AT THE DETECTOR.



Images courtesy of Manjit Dosanjh, CERN

THE PET SCAN IS THE ONLY NON-INVASIVE TECHNOLOGY THAT CAN QUANTITATIVELY MEASURE METABOLIC, BIOCHEMICAL AND FUNCTIONAL ACTIVITY IN LIVING TISSUE. IT CAN BE USED TO DETECT CANCER, BRAIN DISORDERS (SUCH AS ALZHEIMER'S AND PARKINSON'S), AND HEART DISEASE (SUCH AS CORONARY ARTERY DISEASE).

THE IDEAS BEHIND USING THE ANNIHILATION OF MATTER BY ANTIMATTER AS A MEDICAL IMAGING TECHNIQUE WERE FIRST DEVELOPED AT CERN IN THE 1970's. THE PET SCAN THUS REPRESENTS A PRACTICAL AND BENEFICIAL APPLICATION OF PURE SCIENTIFIC RESEARCH.

AS AN EXERCISE OR PROJECT, USE YOUR LIBRARY OR THE INTERNET TO FIND MORE INFORMATION ABOUT THE PET SCAN.

HERE ARE SOME QUESTIONS YOU CAN CONSIDER IN YOUR INVESTIGATIONS (YOU ARE ENCOURAGED TO COME UP WITH YOUR OWN, AS WELL):

WHAT ARE SOME OTHER MEDICAL IMAGING TECHNIQUES?
HOW DO THESE DIFFER FROM THE PET SCAN?

WHAT ARE THE REAL ECONOMIC COSTS OF A PET SCAN?

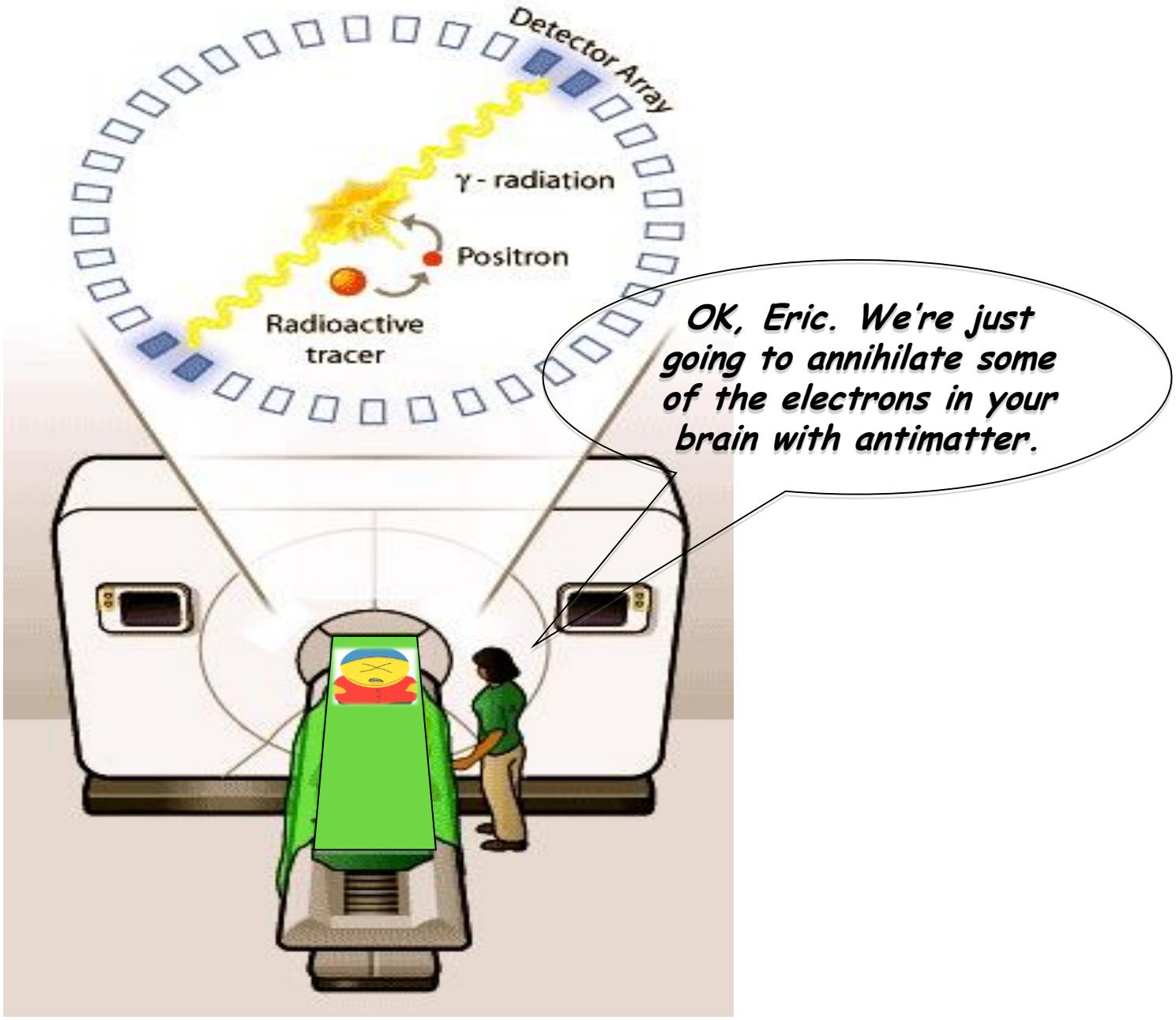
WHO BENEFITS FROM THIS TECHNOLOGY, AND HOW?

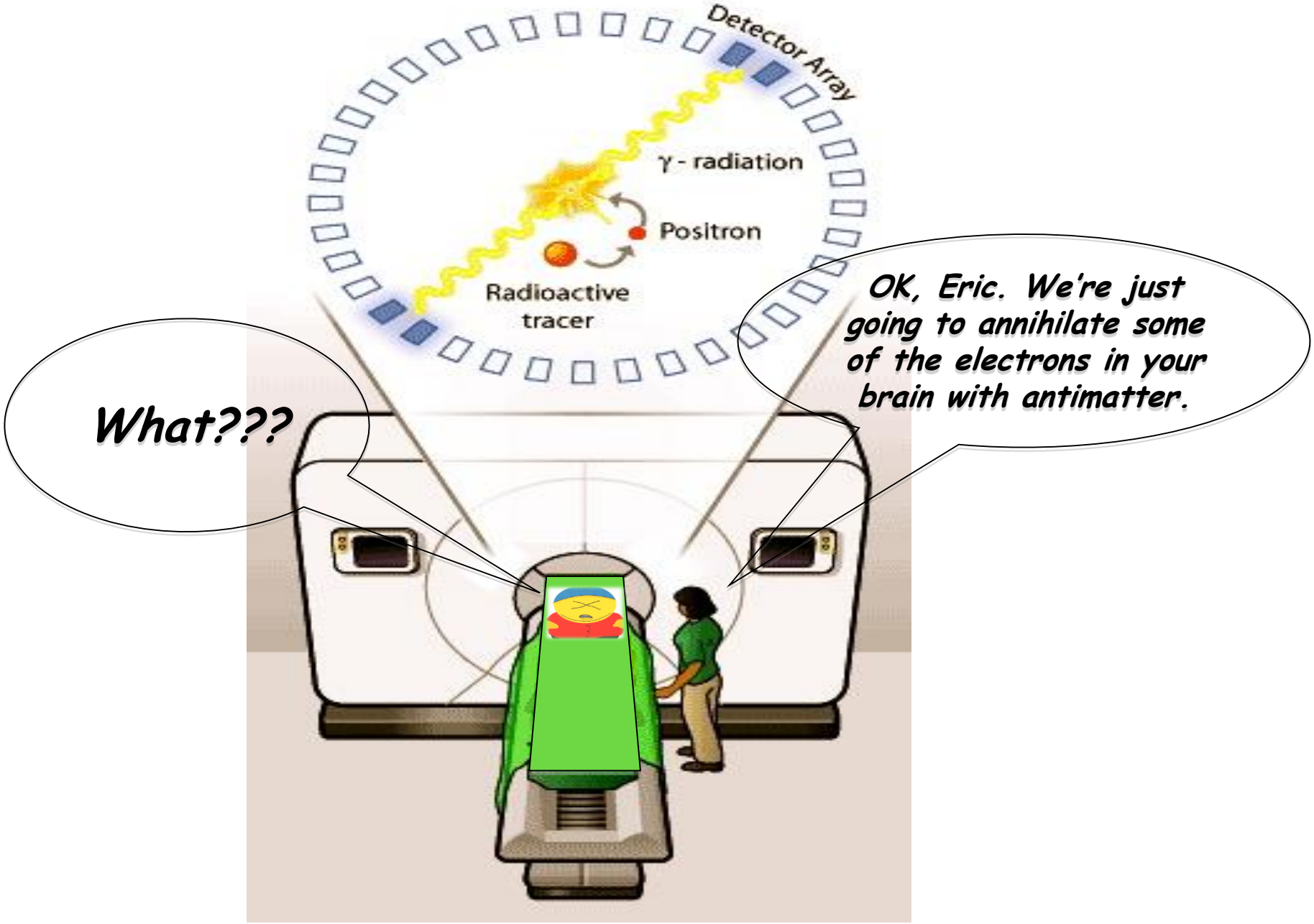
AND ONE FINAL NOTE:

RESEARCH IS NOW UNDERWAY AT CERN TO LOOK INTO THE POSSIBILITY OF USING ANTIMATTER, NOT AS AN IMAGING TECHNIQUE, BUT AS A TREATMENT METHOD FOR CANCER.

ALTHOUGH THE IDEAS INVOLVED GO BEYOND THE SCOPE OF THIS LESSON, SEE THE FOLLOWING LINK IF YOU ARE INTERESTED IN KNOWING MORE:

http://www.phys.au.dk/~hknudsen/introduction.html


Detector Array
γ - radiation
Positron
Radioactive tracer
OK, Eric. We're just going to annihilate some of the electrons in your brain with antimatter.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What???
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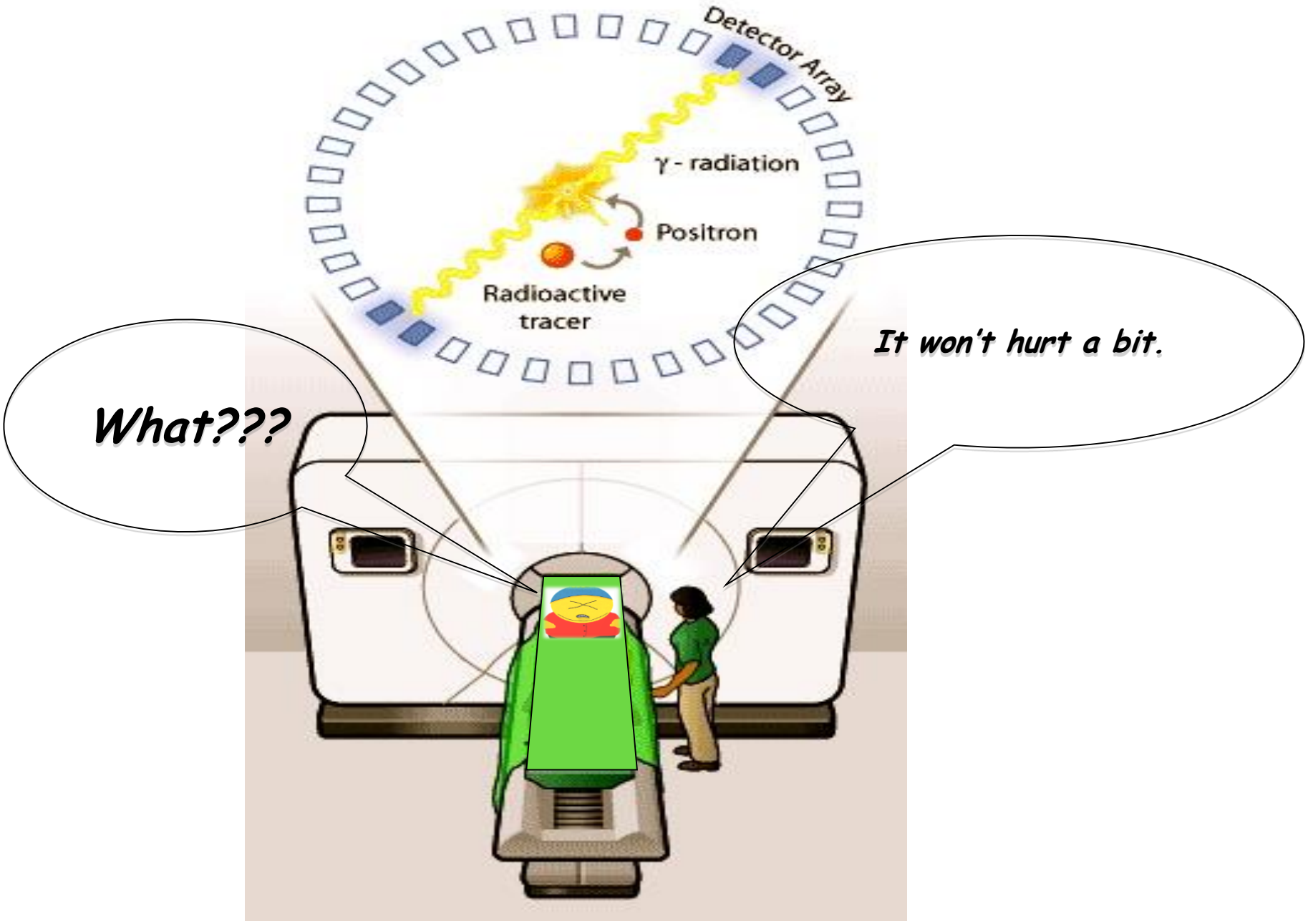
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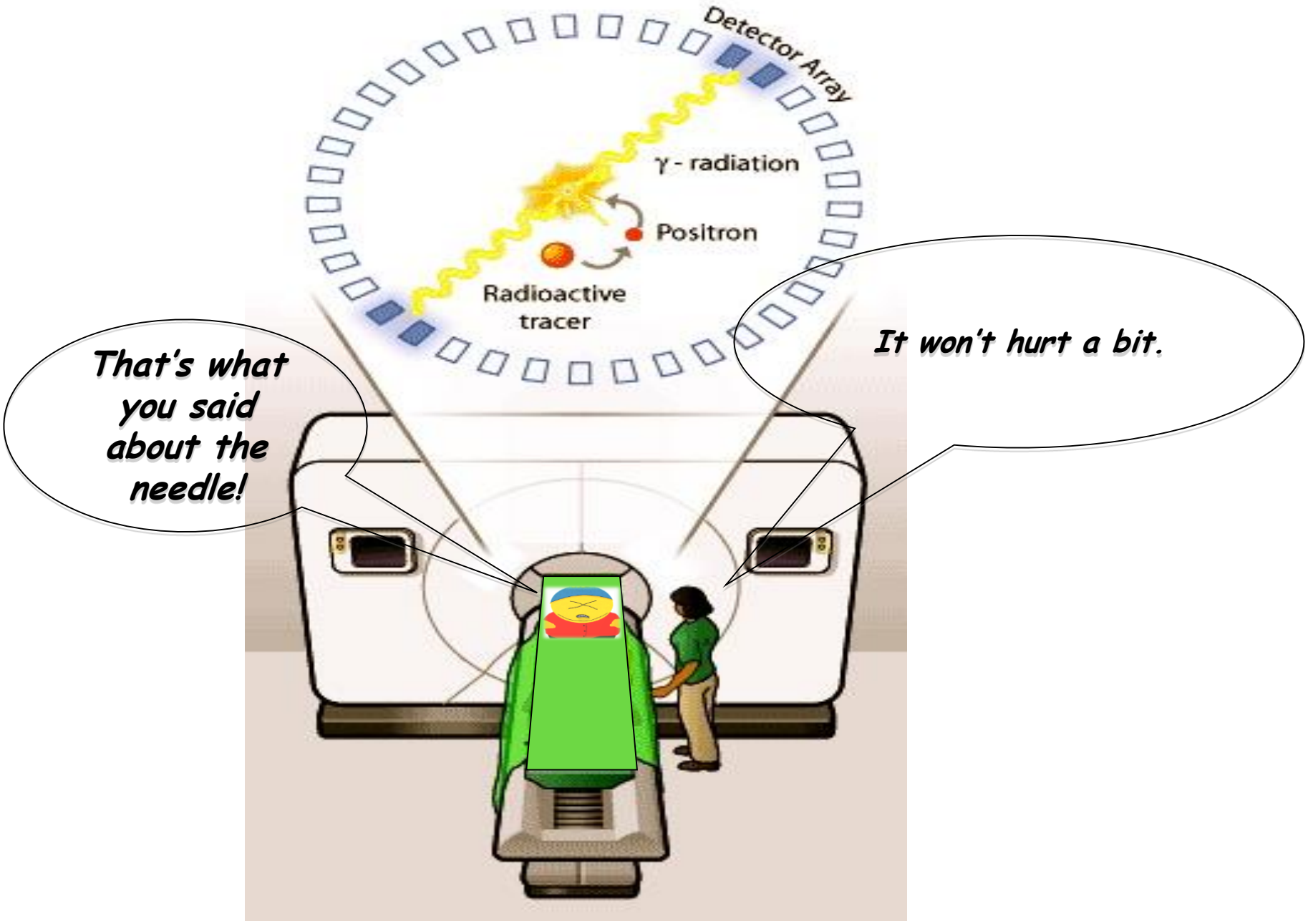
What???
It won't hurt a bit.


Detector Array
γ - radiation
Positron
Radioactive tracer
That's what you said about the needle!
It won't hurt a bit.