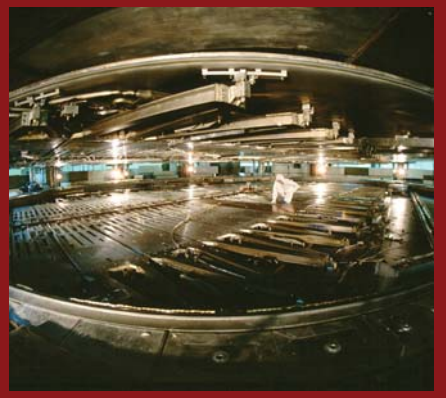
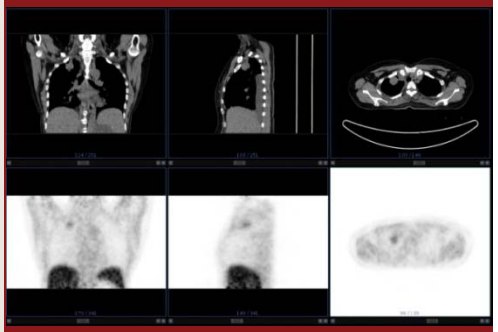
TRIUMF

Canada's National Laboratory for Particle and Nuclear Physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Who Took My Medical Isotope?

What's going on and why people care





T.I. Meyer, Ph.D. | **Head, Strategic Planning & Communications** | **TRIUMF**

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Ripped from the headlines…

Scientists tout alternative to Chalk River isotopes

Intense light beams seen as key to making material for nuclear medicine

BY MARGARET MUNRO

VANCOUVER · Scientists believe they have hit on "a uniquely Canadian solution" to the world's medical isotope woes.

They say intense beams of light should be able to generate isotopes for nuclear medicine, and eliminate the security risks associated with making the medicines with weapons-grade uranium at the aging nuclear reactor in Chalk River, Ont.

A national task force report to be released today says creating isotopes using light beams from "photo-fission" accelerators could also help salvage Canada's reputation in the nuclear world after several misadventures.

The 58-page report, obtained by Canwest News Service, recommends the federal government back a "strong and focused" research program to "support proof-of-principle demonstrations."

See ISOTOPES on PAGE A5

Nov 2008

MSNBC.com

Scans may be able to tell in days if chemo works

Speed of experimental medical imaging could save patients' lives, money

The Associated Press

updated 12:43 p.m. PT, Wed., March. 4, 2009

Mar 2009

NEW YORK - When Mike Stevens learned his lungs were riddled with cancer, it took only a week to start chemotherapy — but six weeks to find out if it was doing any good.

"You're going through all this suffering and stuff and you want to know, am I going to survive? Is this stuff working?" said Stevens, 48, of La Jolla, Calif. "Your whole life is in sort of a limbo."

Doctors typically must wait weeks or months to see if a treatment is shrinking tumors or at least halting their growth. But researchers are exploring a new use for medical imaging that could shorten the stay in purgatory, possibly revealing within a few days whether chemo is working.

Today's talk

- What are medical isotopes?
- Where do they come from?
- Why are they important?

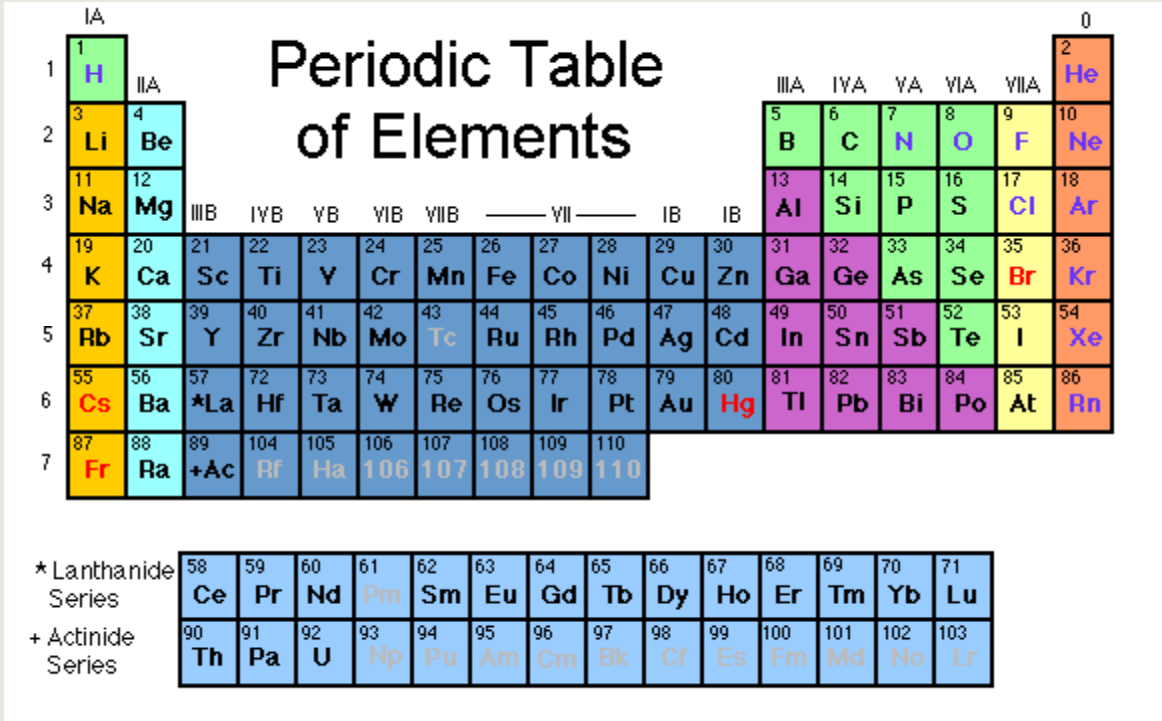
WHAT ARE MEDICAL ISOTOPES?

Scientific Chain of Being

- Remember Shakespeare and the Elizabethan Chain of Being?
- In science, particularly physics, there is a Chain of Being as well
  - The size or length scale of things
- http://www.youtube.com/watch?v=A2cmlhfdxuY
- When do you think this film was originally made?

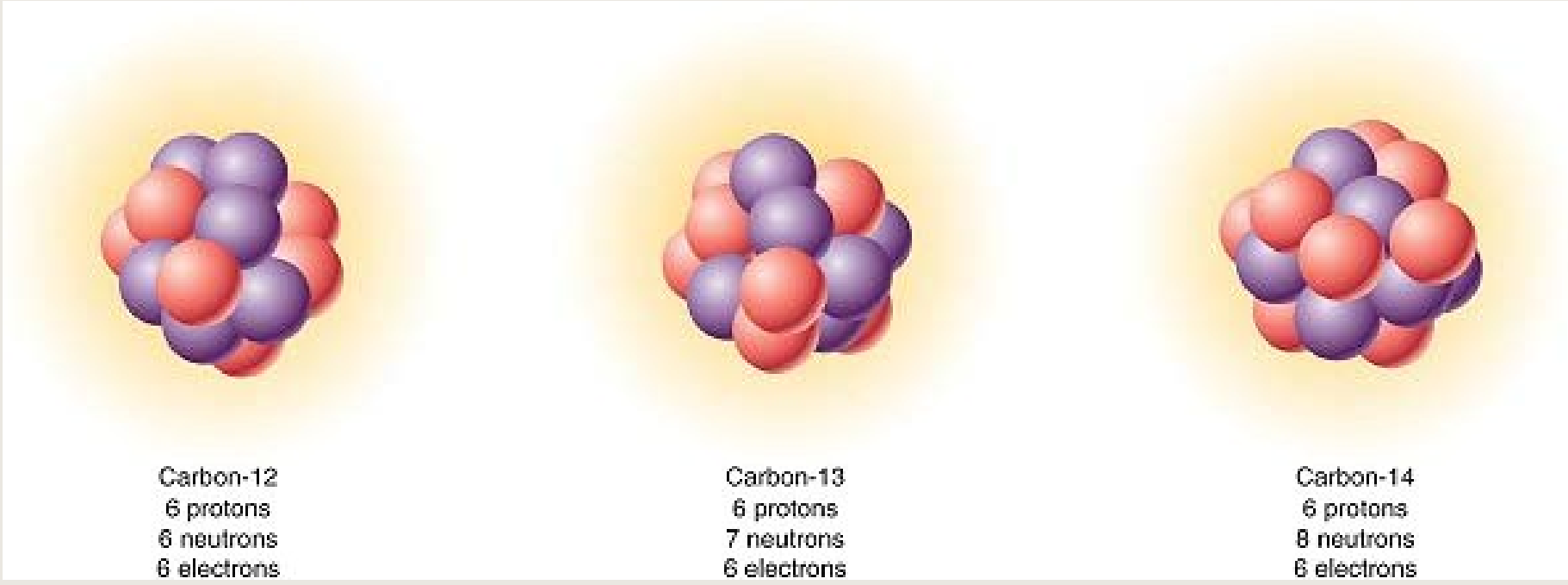
What's an isotope? (1)

- Inside every atom is a nucleus
  - The nucleus is made of protons & neutrons
- What makes one atom different from another atom?
  - Number of electrons (they determine the chemistry!)
- And so we have the Periodic Table of the Elements



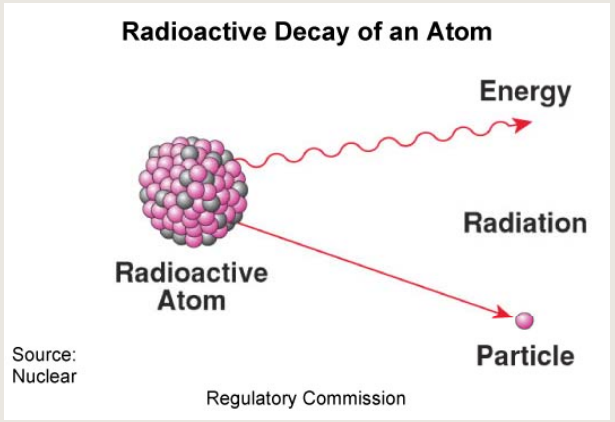
What's an isotope? (2)

- Nuclei are different from one another by the numbers of neutrons and/or protons
  - Carbon = 6 protons
  - How many neutrons?
- Each nucleus with 6 protons is an "isotope" of Carbon
  - The number of neutrons tells you "which" isotope

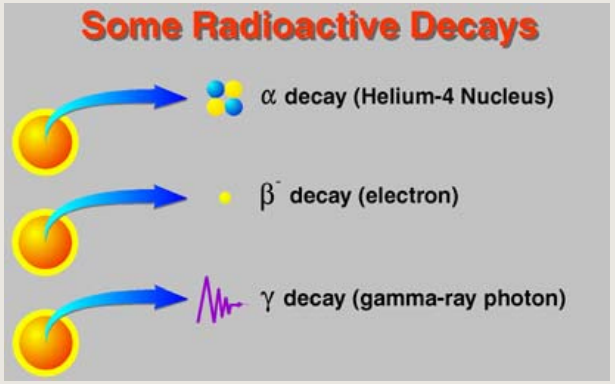


What's an isotope? (3)

- Not all isotopes are stable
  - Configuration of protons & neutrons don't stick together very well
  - We call this radioactive decay



- Probability or "rate" of radioactive decay is known as the half-life
  - How long will it take half the nuclei to decay? Seconds? Days? Years? Millennia?
  - Uranium-238 has a half-life of 4.5 billion years



- Carbon has three primary naturally occurring isotopes (C-12, C-13, C-14)
  - But actually exists all the way from C-8 (2×10^{-21} s) to C-22 (6×10^{-3} s)

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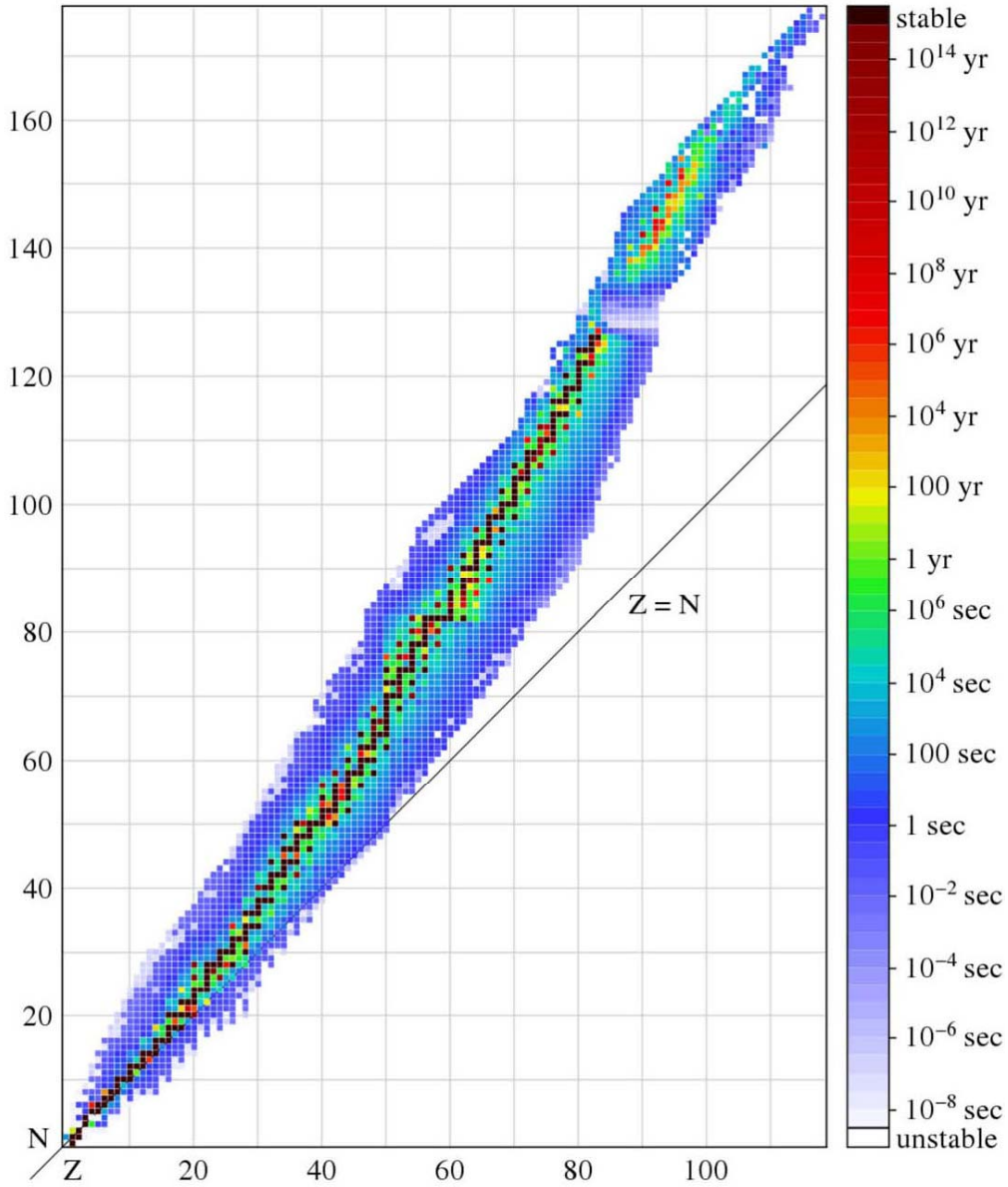
There are many different isotopes

- Isotopes are labelled by the symbol of the chemical element (letters)
- Number Z = #protons
- Number N = #neutrons
- ^{11}C, ^{12}C or sometimes just Carbon-12 or C-12.



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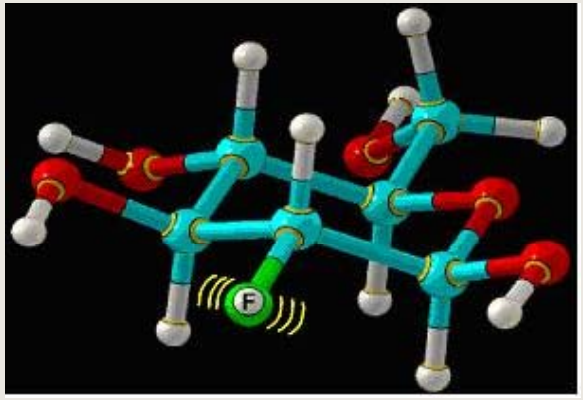
What is a medical isotope? (1)

- Medical isotopes are just isotopes that are good for chemically attaching to biological molecules
  - Adding a medical isotope (i.e., radioactive atom) to a biological molecule is like putting a GPS tracker on the molecule
  - Except it has a time delay and only signals once
  - The GPS signal is the radioactive decay: the decay particle exits the body and is detected by a camera or "scanner"



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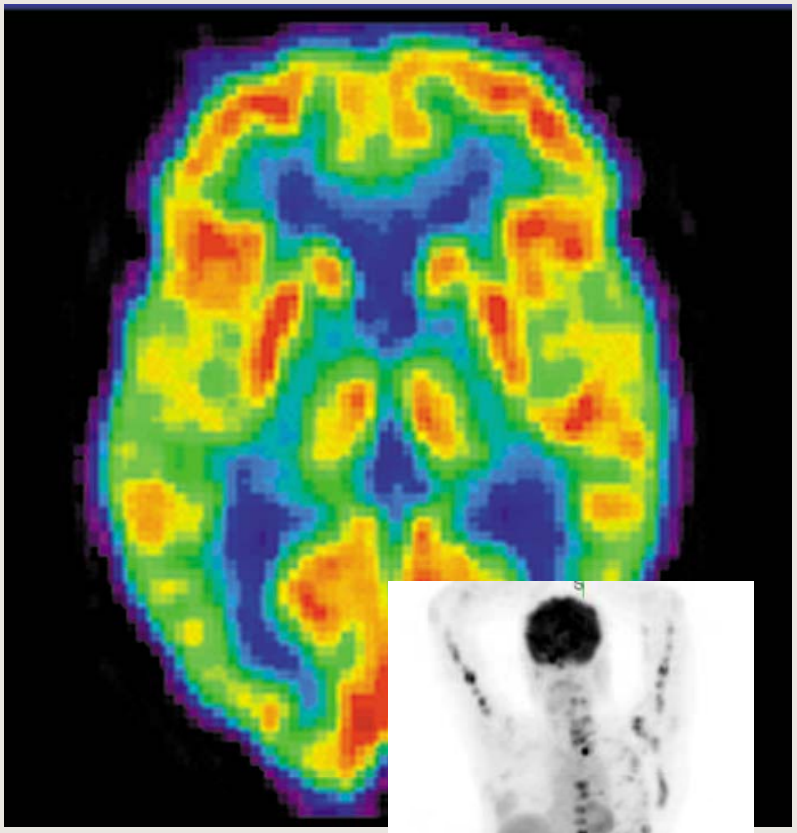
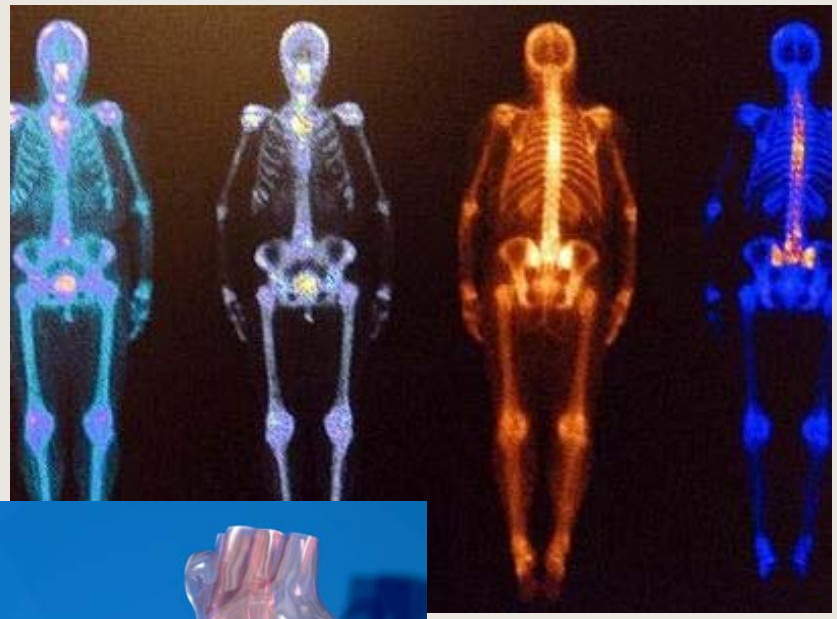
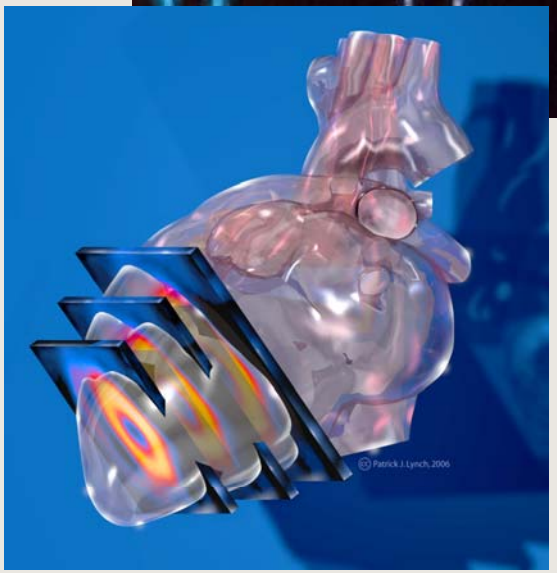
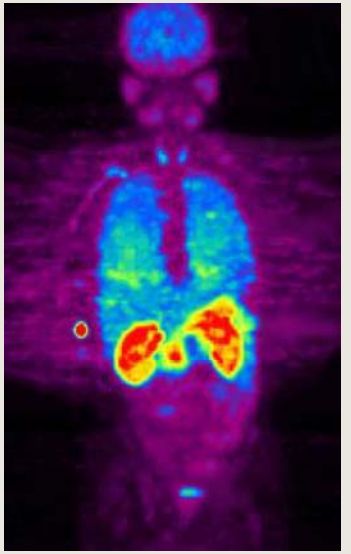
What is a medical isotope? (3)









WHERE DO MEDICAL ISOTOPES COME FROM?

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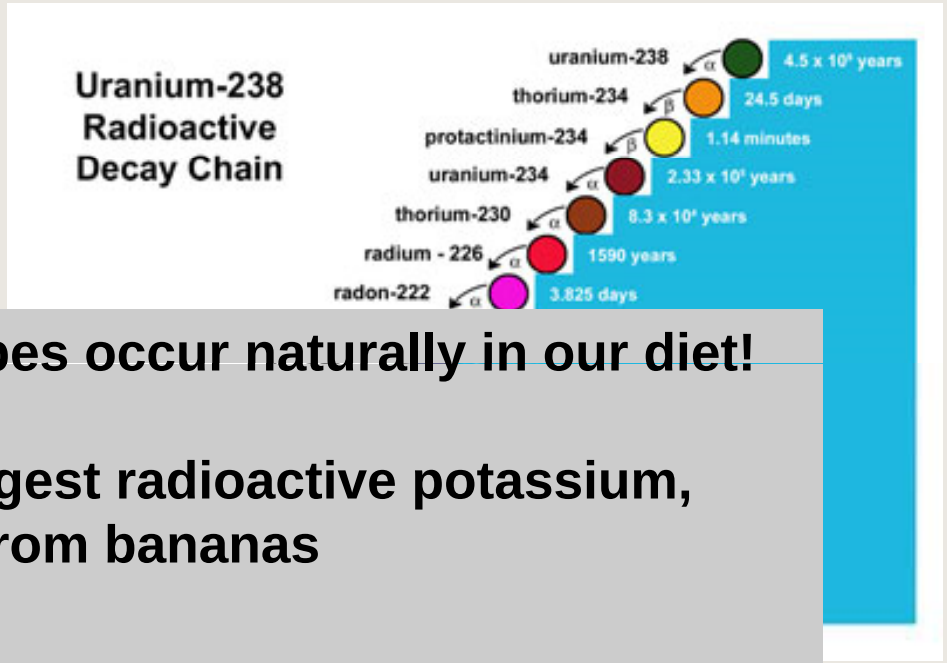
Where do isotopes come from?

- I'll assume you're all old enough for the "birds & the bees" talk

- Isotopes come from
  - Nature
    - Mining (dig them out of the ground)
    - Sorting through stuff (separation)
  - Man-made tools
    - Nuclear reactors
    - Accelerators

“Natural” isotopes

- Isotopes can come from ongoing radioactive-decay “chains” from other isotopes mad… …s, and supe…
- We c… …t isoto… …ll sea w… …
- Trick… …ut” the isotopes



Isotopes occur naturally in our diet!

We ingest radioactive potassium, e.g., from bananas

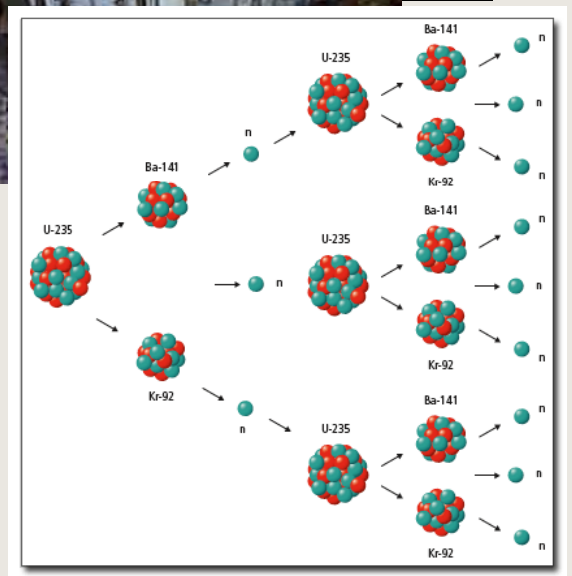
So our bodies emit about 180 positrons per hour!

"Man-made" Isotopes

- If isotopes are just combinations of protons & neutrons, can we build them up from the basic ingredients?
  - Turns out...NO. The cost of isolating protons & neutrons and then "sticking" them together is just too high
- So...why not take existing nuclei and "adjust" them just a bit?

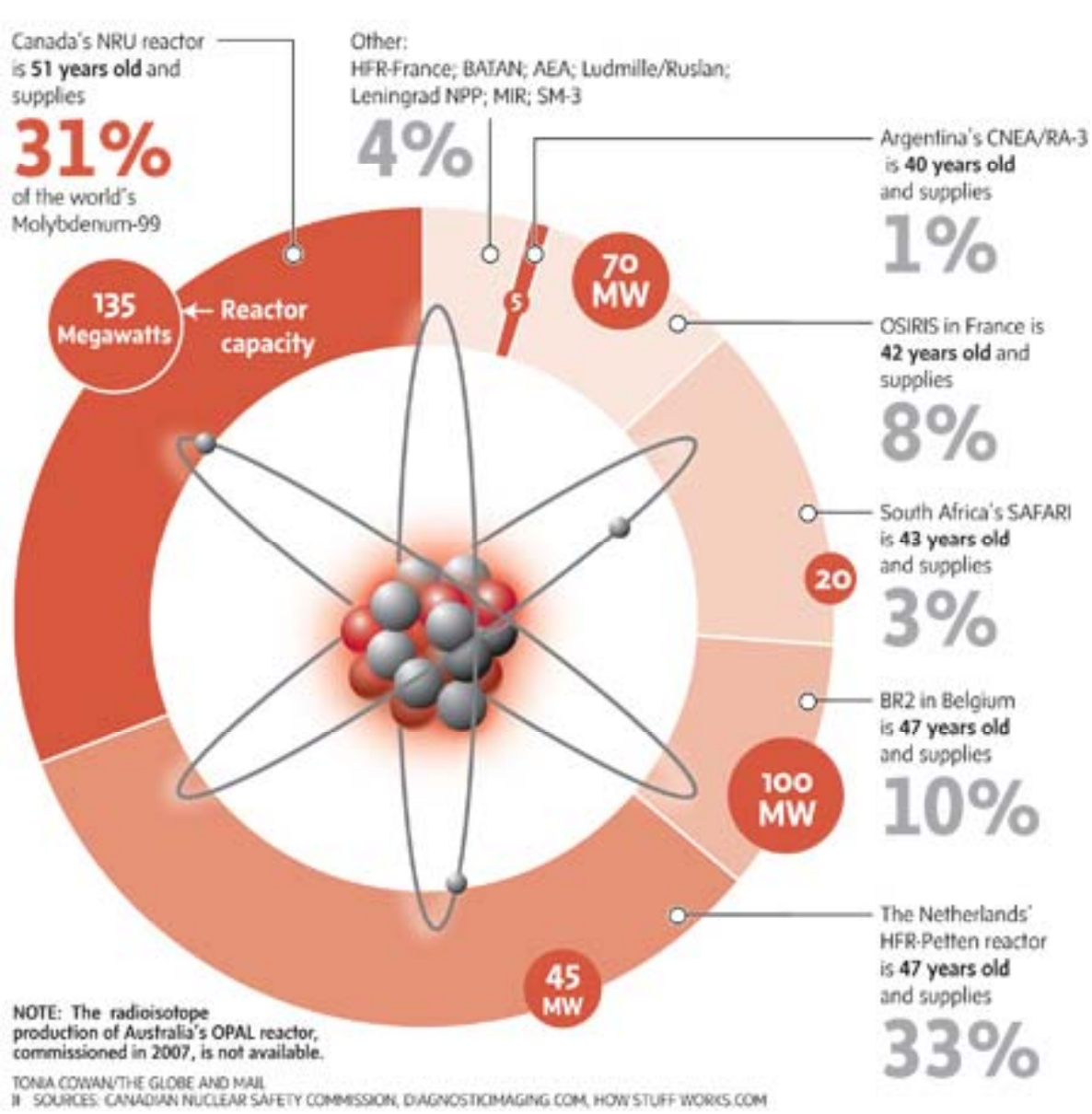
Nuclear reactors

- A nuclear fission reactor uses U-235 (isotope!) which “decays” and creates neutrons which cause other U-235 to decay which...
  - Chain reaction
- And the “decay products” of U-235 are medical isotopes!
  - e.g., Molybdenum-99

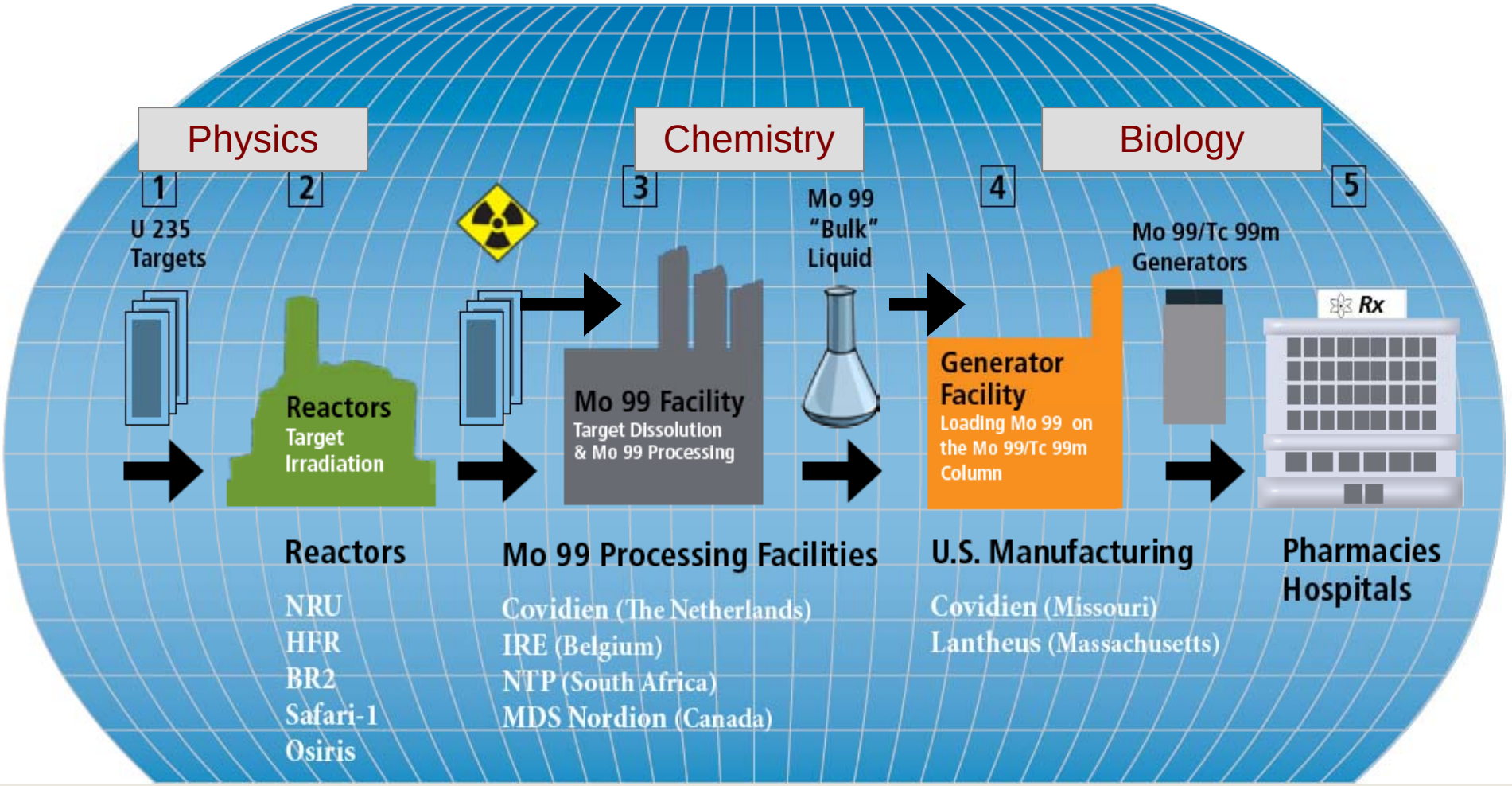


Mo-99 from reactors

- Mo-99 is the most “in-demand” medical isotope
  - Mo-99 is shipped around (66 hrs half life) and at the hospital, its “decay product” Technetium-99m is used in the patient
  - Around the world, 80 million times per year
- Comes “easily” from a handful of existing, publicly funded nuclear research reactors
- Reactors are getting old
  - Canadian one off for repairs since middle of last year
  - Netherlands down for repairs



Mo-99 supply chain



Accelerators (1)

- What really happens in the nuclear reactor is a “beam” of neutrons splits nuclei of uranium
- Do we need a reactor to make the neutron beam?
  - NO
- U.S. just finished a $1,000,000,000 project to make a neutron beam using a particle accelerator (SNS)
  - Europe just approved a similar project (ESS)
- Don’t worry...a nuclear reactor costs up to $10,000,000,000 and takes a decade to build

Questions

- Medical-isotope crisis raises questions
  - How else can we split Uranium?
  - How else can we make Molybdenum?
  - How else can we make Technetium?
  - How much longer will Molybdenum be in such huge demand?

NUCLEAR MEDICINE
Isotope shortage

Medical isotopes: What are the alternatives?

Last Updated: Wednesday, June 10, 2009 | 5:15 PM ET Comments13Recommend20
CBC News

Think the medical isotope shortage of 2007 was bad? Just wait until the middle of July, 2009.

For the first time, the world's two main isotope-producing nuclear reactors will be out of service at the same time. The 52-year-old Chalk River reactor, down since the middle of May, will be joined by the slightly younger reactor in Petten, the Netherlands. The 48-year-old reactor is scheduled for four weeks of maintenance starting in mid-July.

The shutdowns are expected to exacerbate an already critical shortage of nuclear isotopes.

Changes needed to medical isotope production, scientist says

Last Updated: Thursday, January 29, 2009 | 9:15 AM ET Comments9Recommend16
CBC News

A research scientist at Canada's national particle and nuclear physics lab is calling on the federal government to look into ways of delivering radioactive medical isotopes without the need for nuclear reactors.

THE GLOBE AND MAIL NATIONAL

Canada getting out of isotope game, Harper says

PM says he plans to keep Chalk River running as often as possible, while working with other countries and provinces to develop alternative sources of treatment

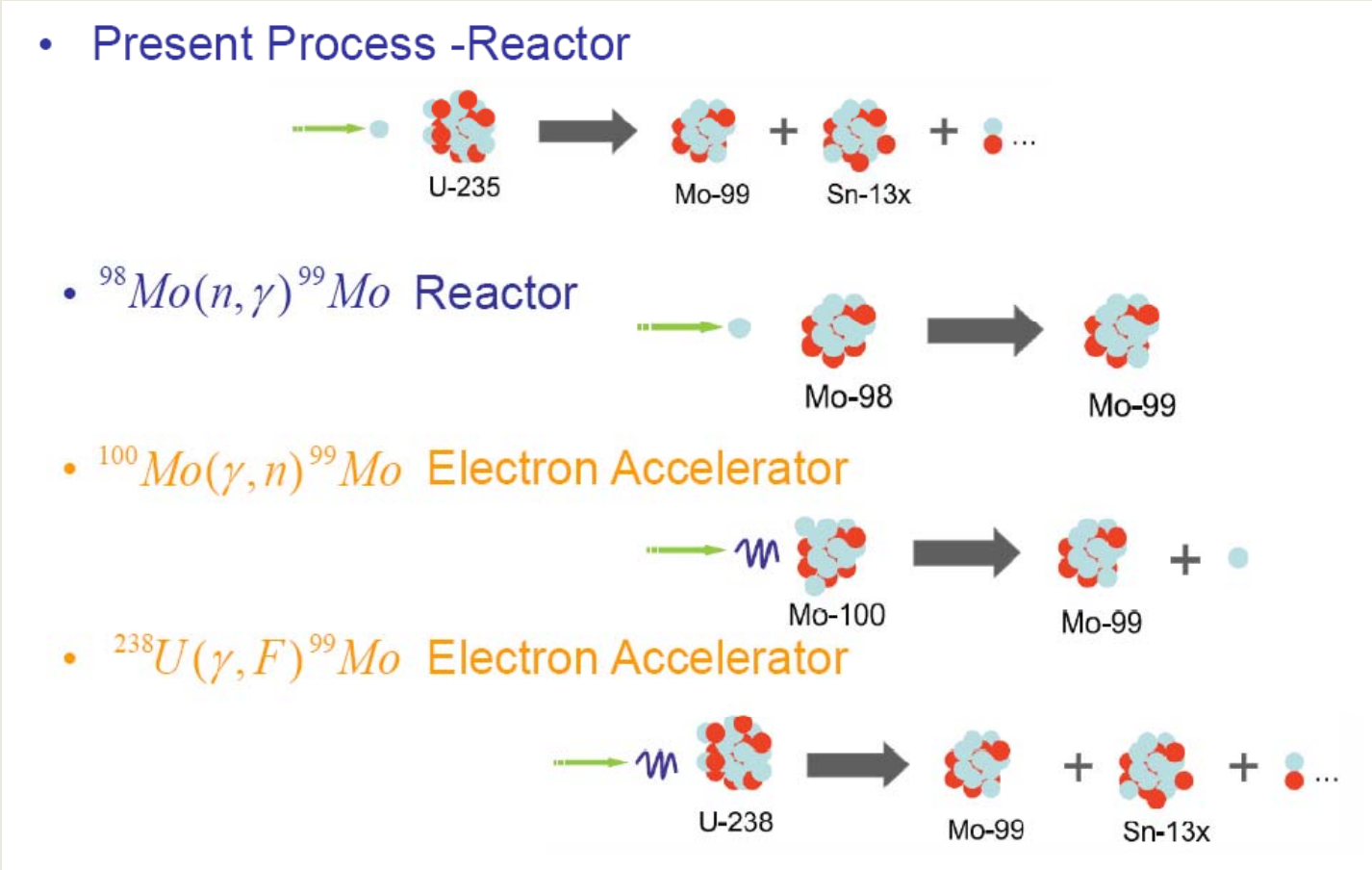
Ottawa — The Canadian Press, Wednesday, Jun. 10, 2009 07:27PM EDT

MDS Nordion Not Giving Up On Isotope Business If Canada Does

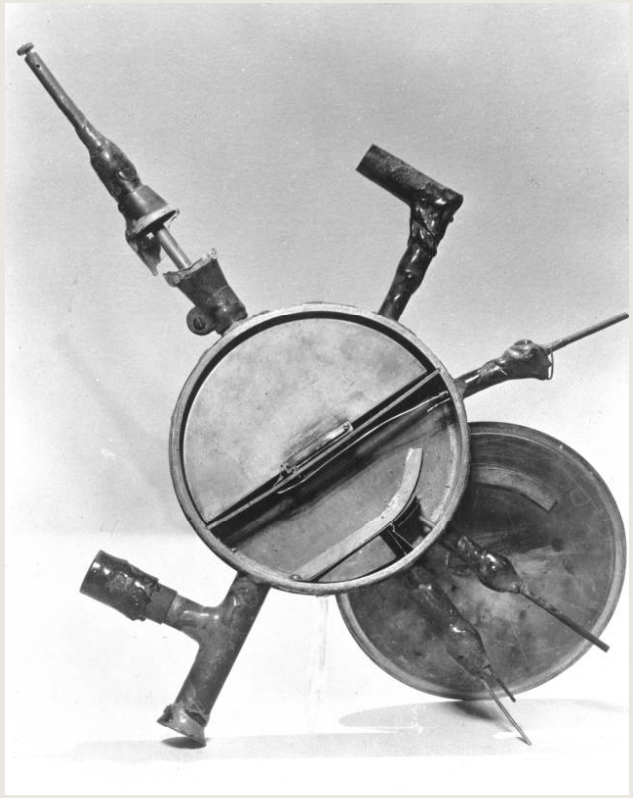
By Andy Georgiades
Of DOW JONES NEWSWIRES

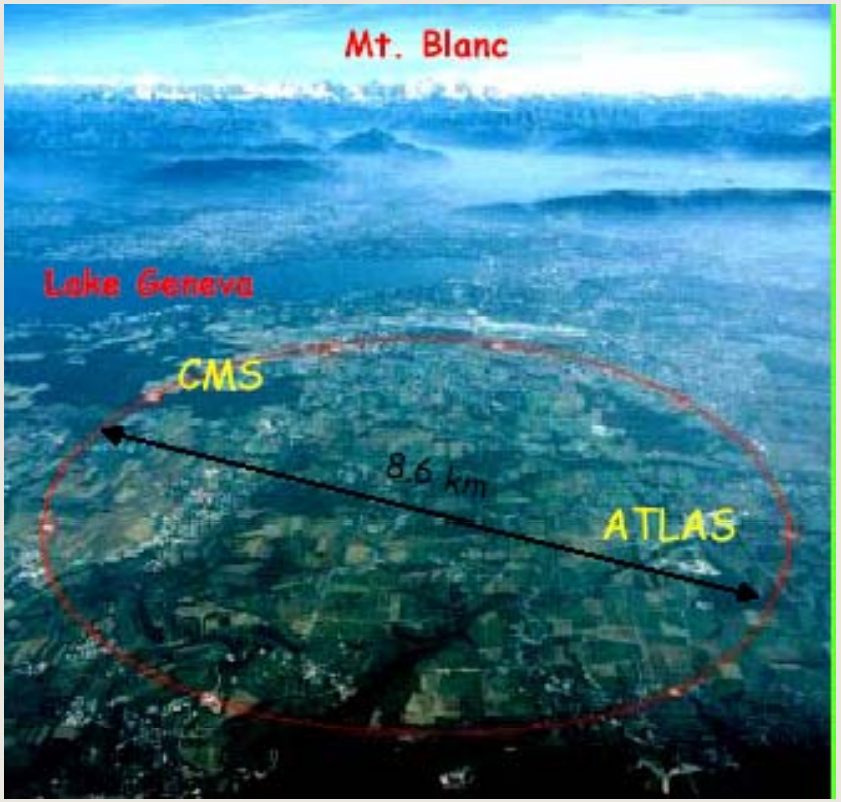
Accelerators (2)

- At the physics level, there are a number of different ways to make Mo-99 for instance



Evolution of Accelerators





9 km / 13 cm = 69,231

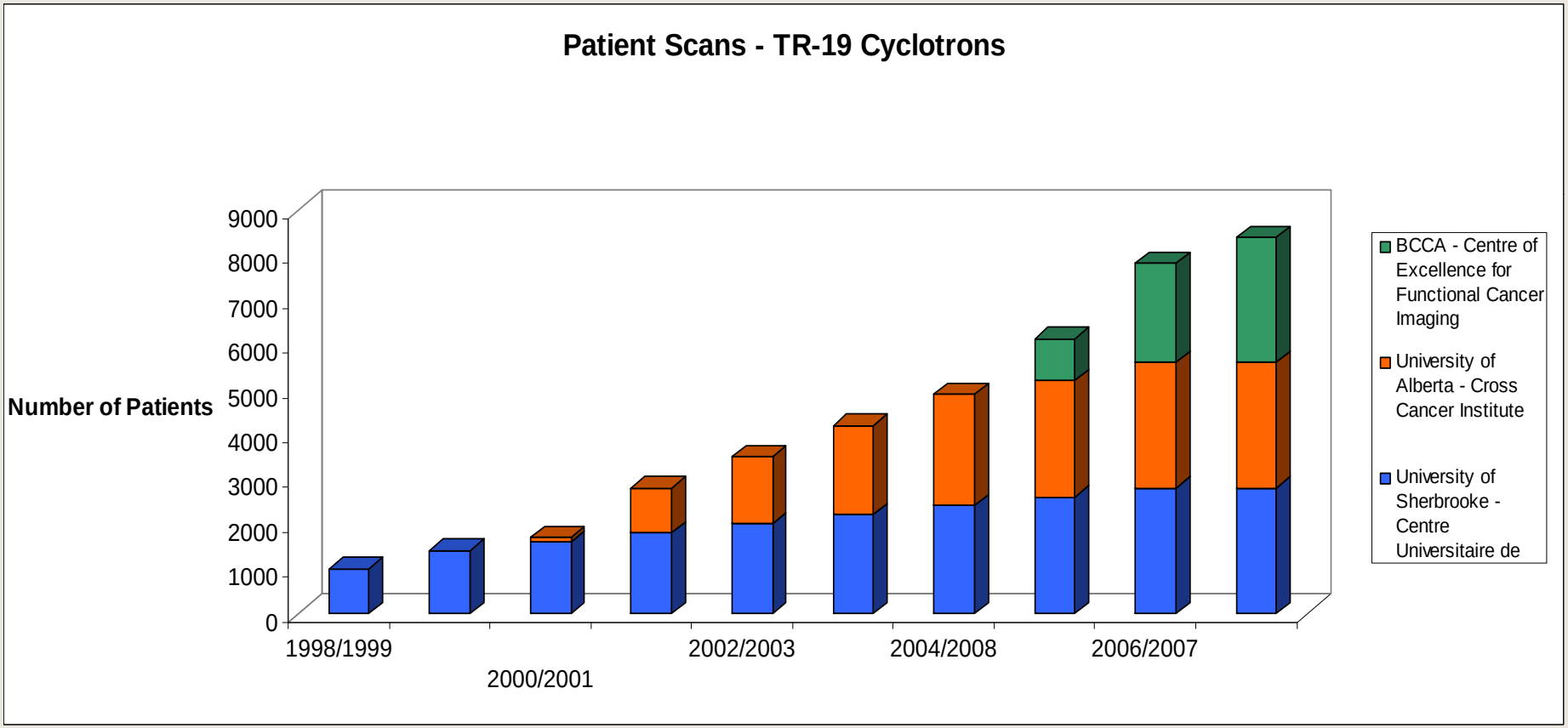
14 TeV / 80 keV = 175,000,000

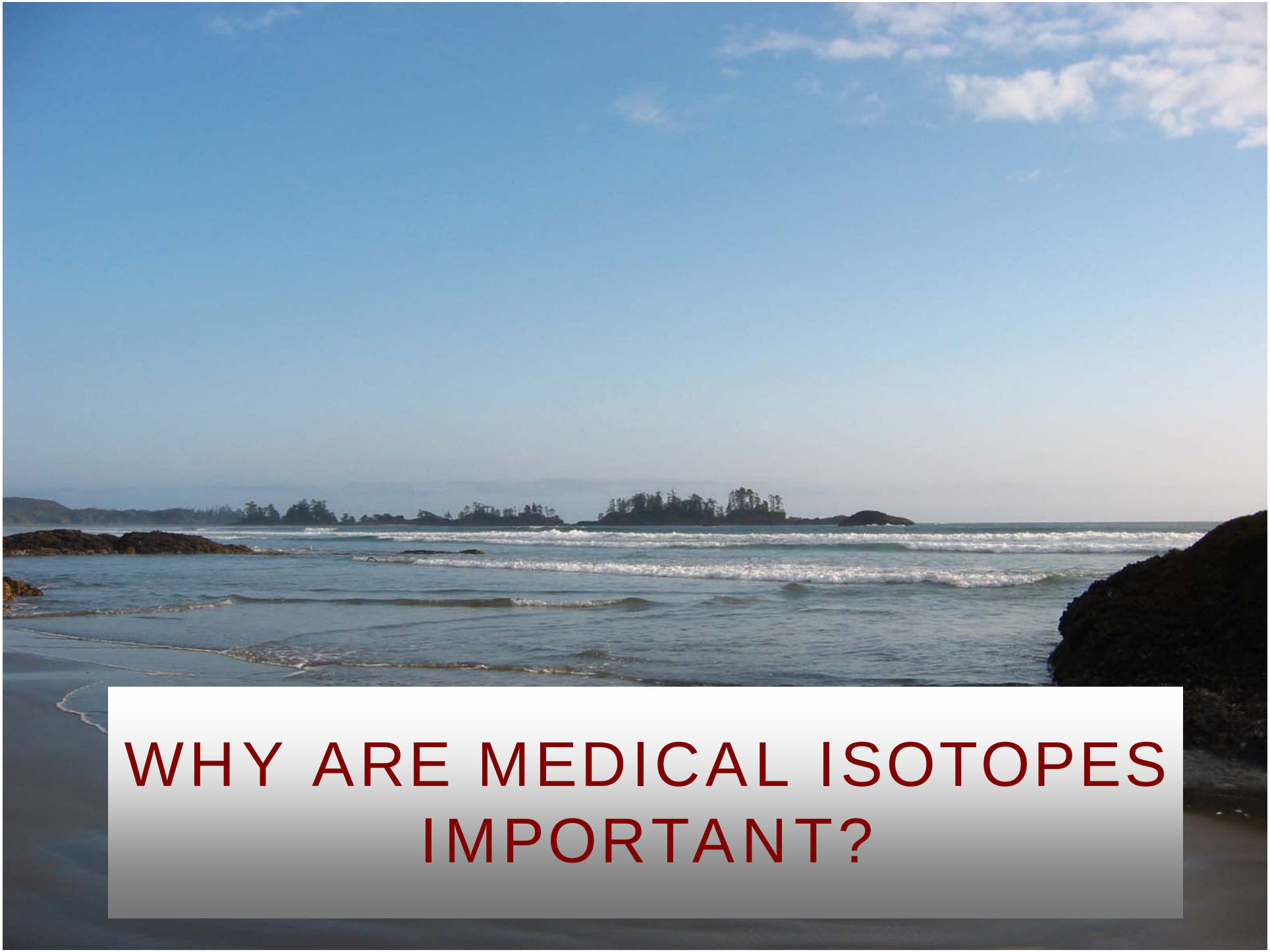
Technology of accelerators has made huge gains

Also...cyclotrons!

- OTHER isotopes can be made with cyclotron particle accelerators (5 of these at TRIUMF) by directing beams of protons on small targets
  - Most popular technique in Canada uses Fluorine-18 and a sugar for cancer screening
- A new team is looking at making Technetium directly using cyclotrons

Cyclotron usage for Medical Isotopes in Canada is growing

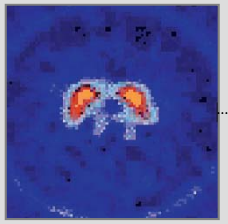




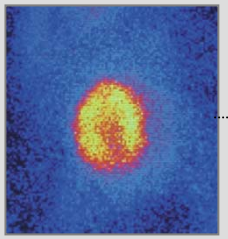
WHY ARE MEDICAL ISOTOPES IMPORTANT?

Medical Isotopes

- A medical isotope is a short-lived radioactive ingredient used in radiopharmaceuticals which are administered to patients
- Through radioactive decay, energy is emitted and captured with a special camera to reveal images of metabolic function in the body
- Also used to deliver targeted radiation therapy to tumours

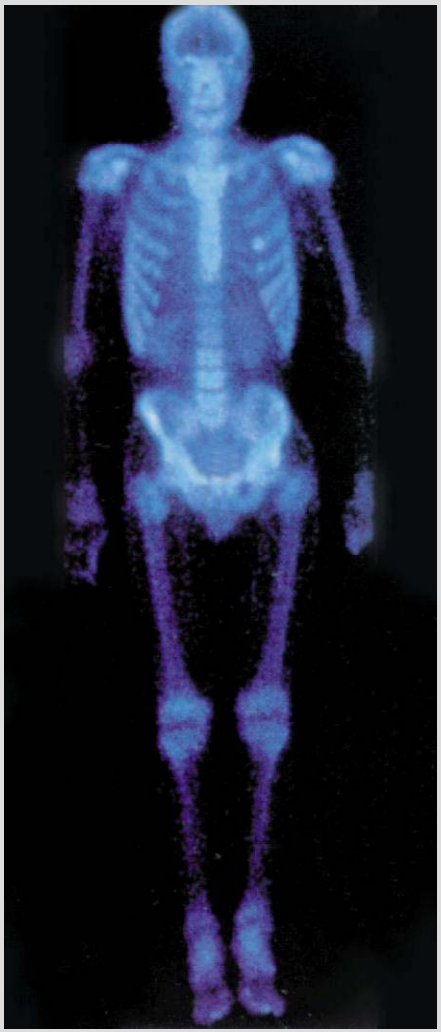


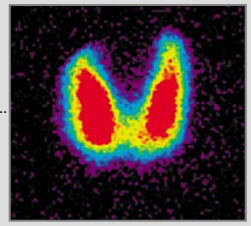
Diagnosing brain disorders
Molybdenum-99**



Accurately diagnosing heart attacks and disease
Molybdenum-99

Scanning bones for infection
Molybdenum-99



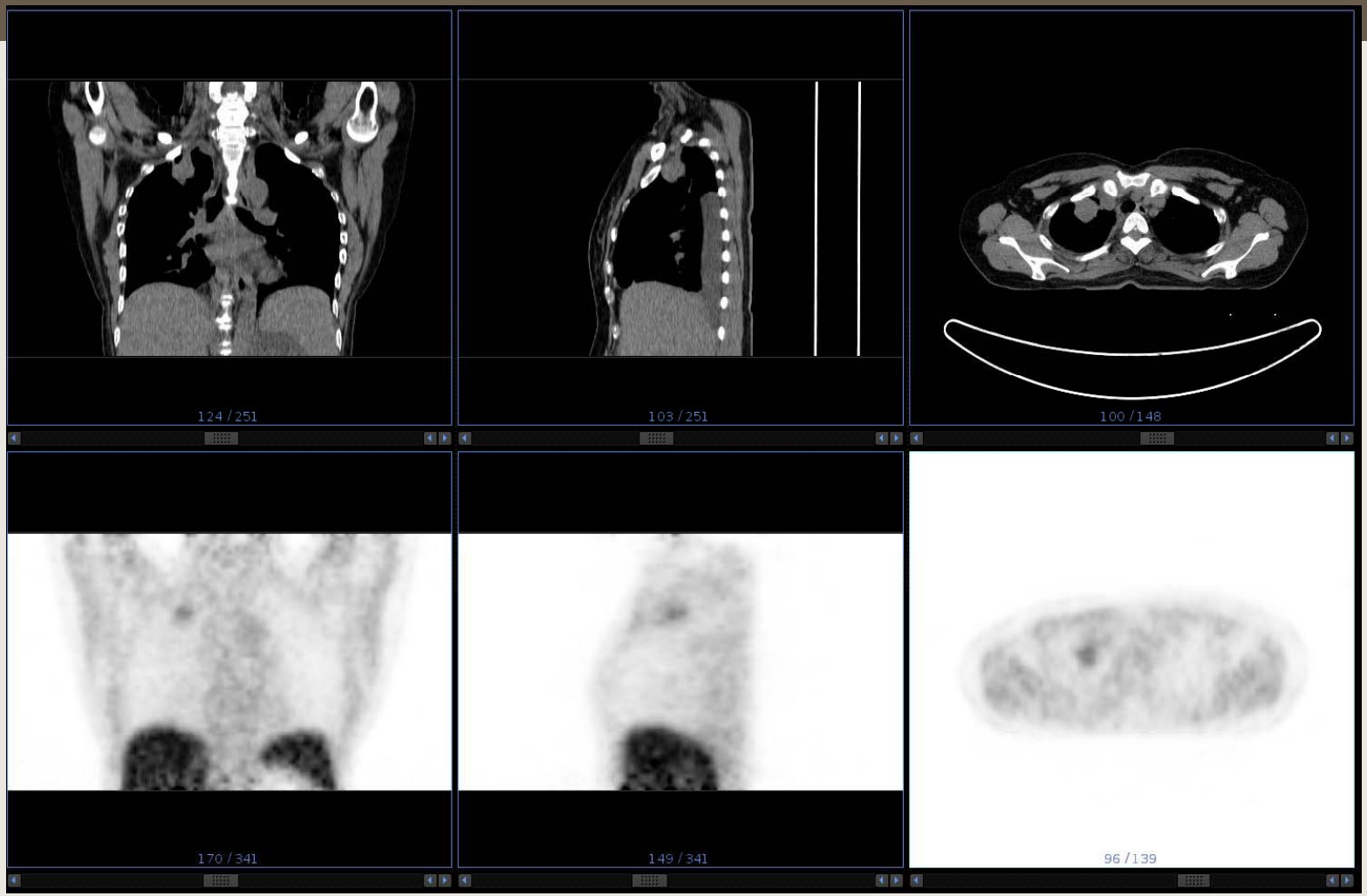


Treating thyroid cancer
Iodine-131

Exposing the spread of cancer
Molybdenum-99

Imaging the lungs for blood clots
Xenon-133

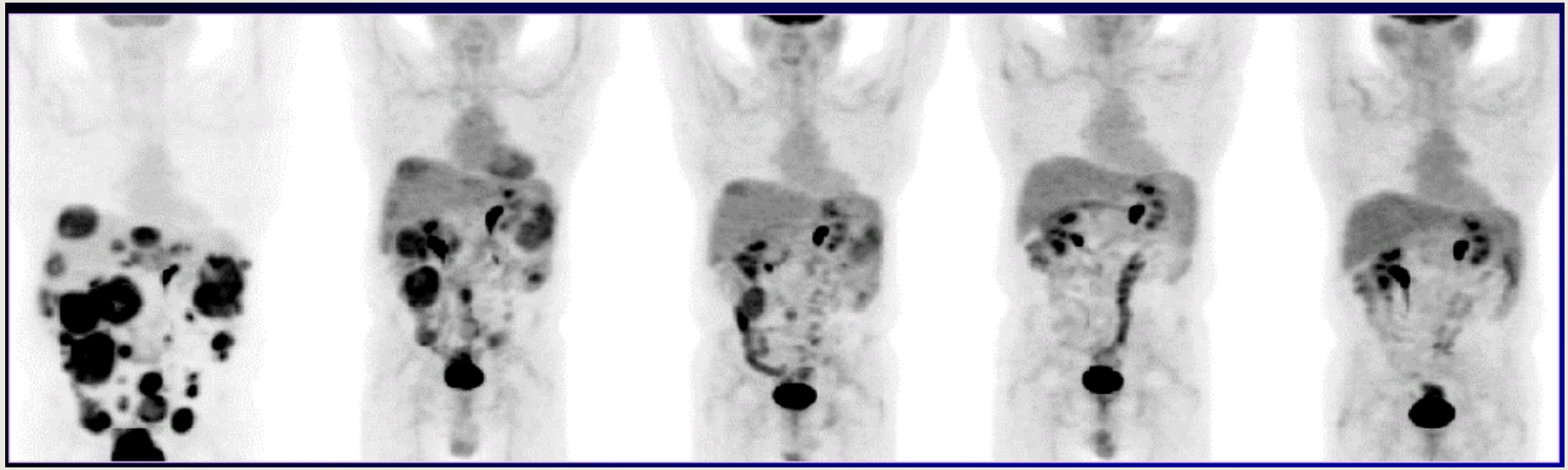
Success: EF5-^{18}F (a 1st in Canada)



Tests for Hypoxia – radiation-resistant tumours

PET Measures Metabolic Response

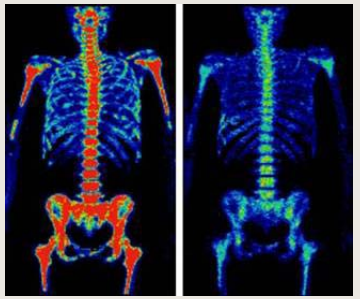
PET image is very powerful indicator of cancer metabolism
Response can be seen within 24 hours



Baseline 24 hours 1 week 2 months 5.5 months

Dana Farber Cancer Institute

MSNBC/Health: March 4, 2009



"Doctors typically must wait weeks or months to see if a treatment is shrinking tumors or at least halting their growth. But researchers are exploring a new use for medical imaging that could shorten the stay in purgatory, possibly revealing within a few days whether chemo is working"

This scan is called FLT-PET, after radioactive fluorothymidine. These scans show whether cancer cells are dividing.

"'Our hope ... is you might be able to give a single dose of a chemotherapy agent and within a day or two figure out whether the tumor is going to respond,' says Dr. Michael Graham of the University of Iowa. If the tumor doesn't respond, doctors would 'go on to Plan B,' he said. 'This is really ... giving us the ability to tailor the therapy to the disease.' The researchers reported that just one week after treatment began, they could tell with 93 percent certainty which patients would eventually respond to the drug and which would not."

TRIUMF chemists have made FLT, FES, FDG, and working on more….

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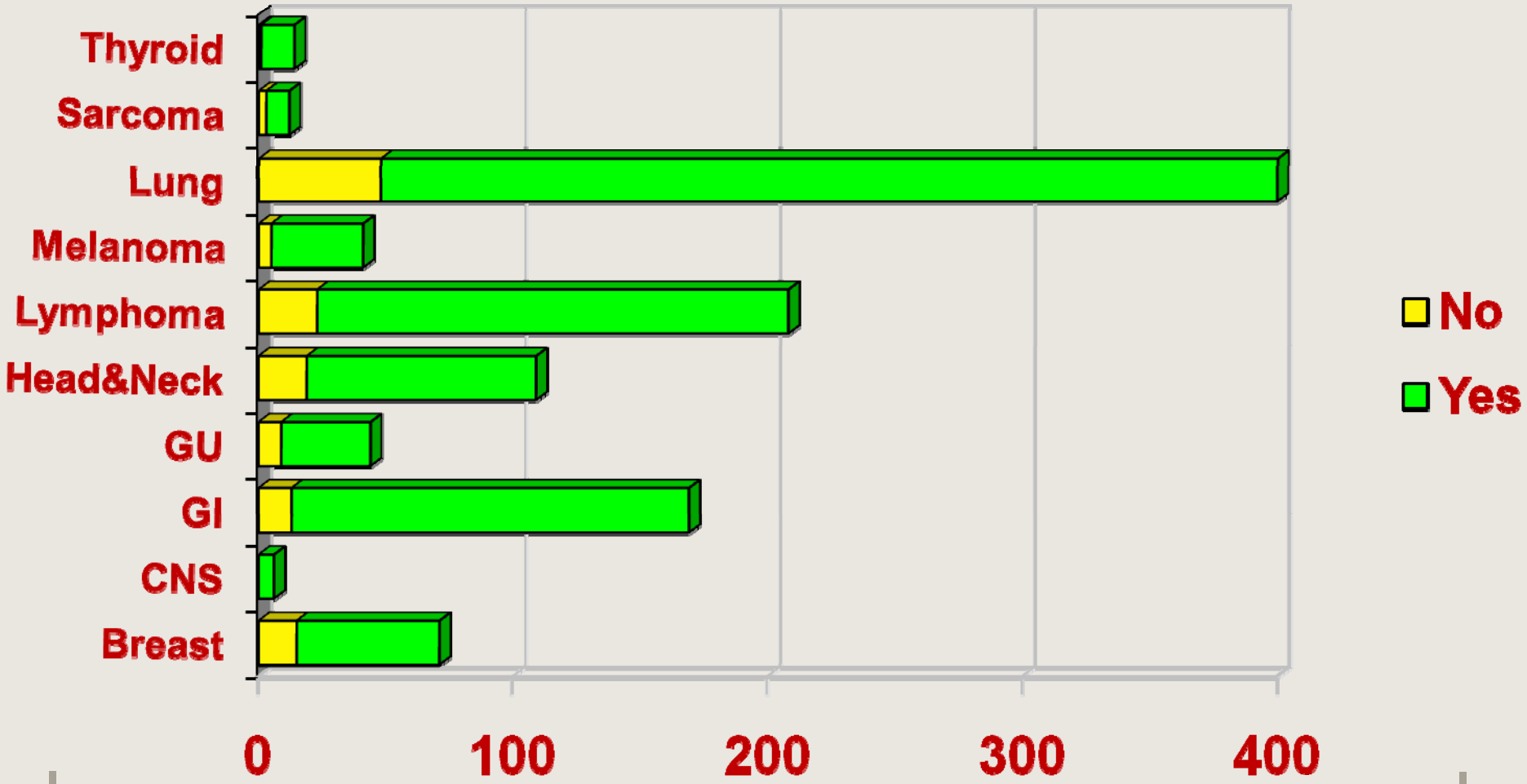
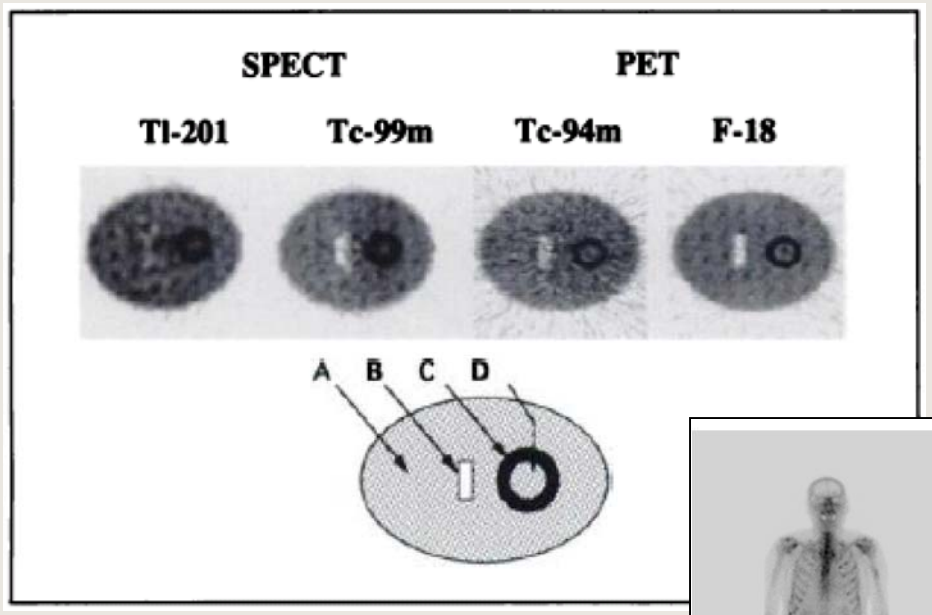
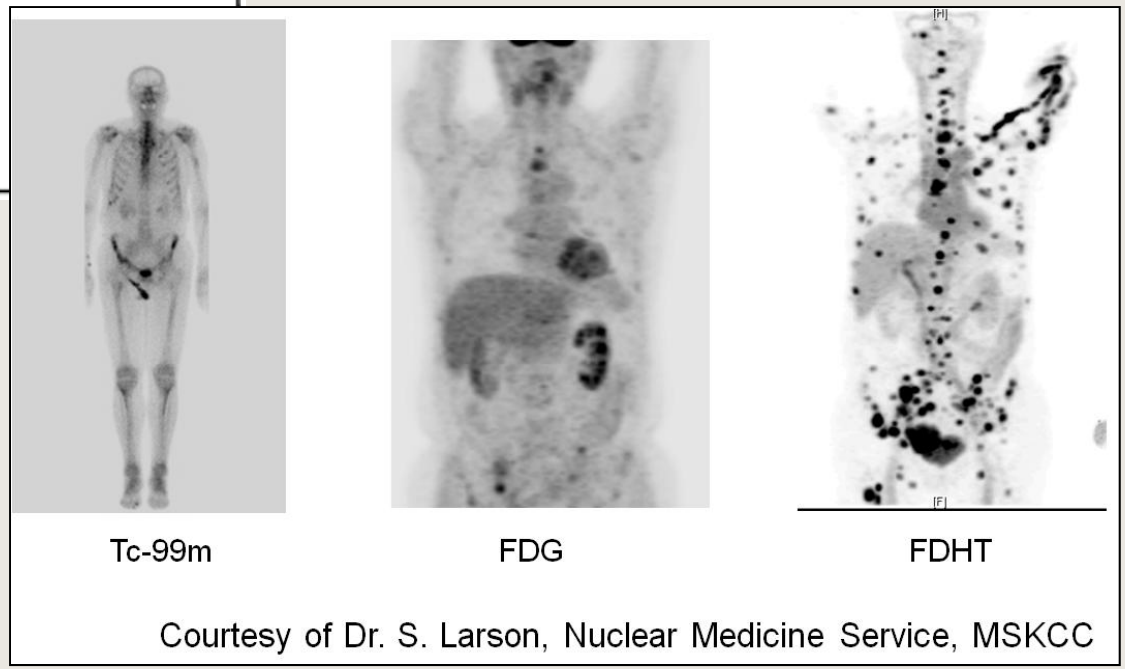
Did PET scan make a difference?

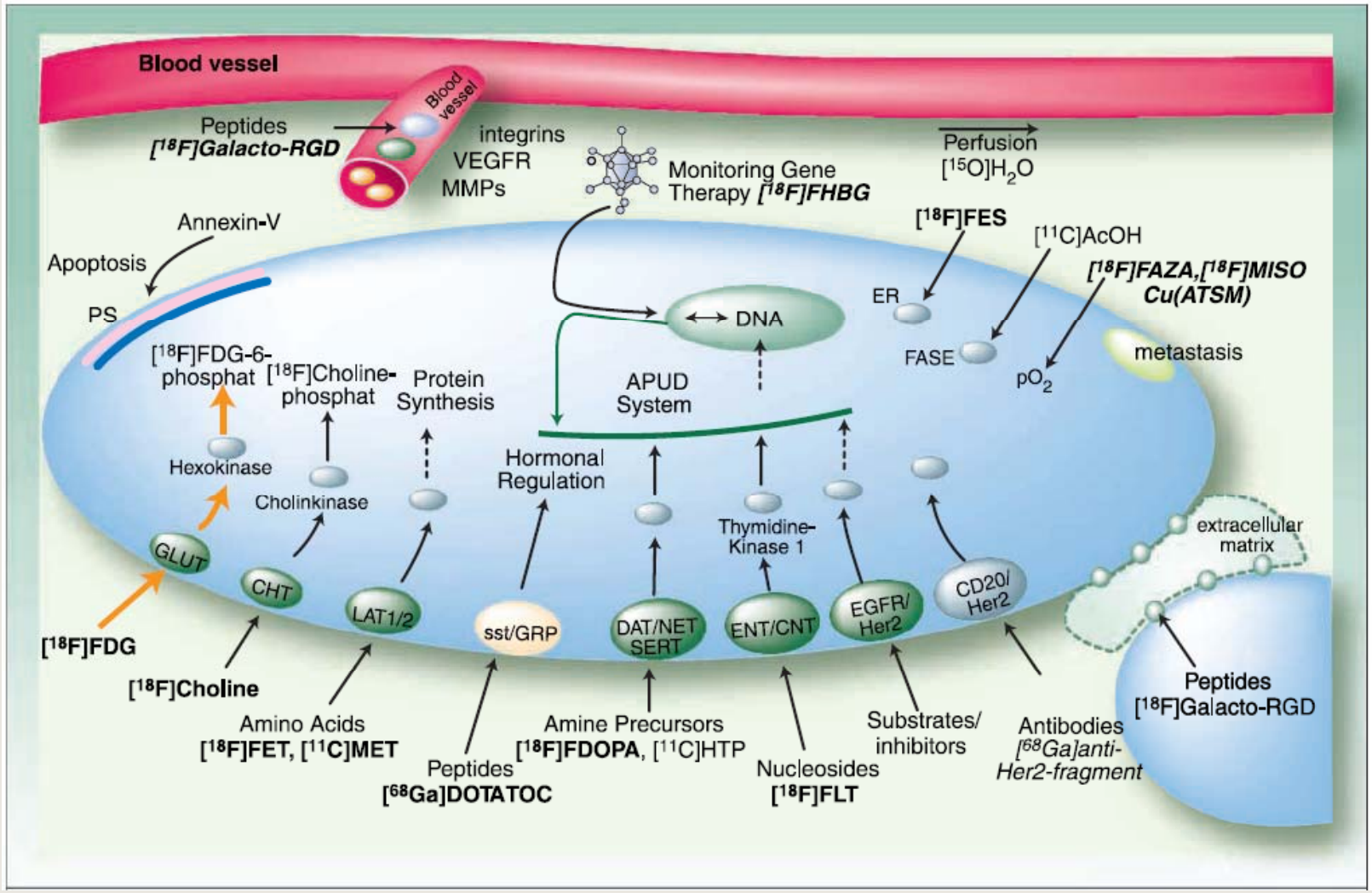


Not all isotopes created equal





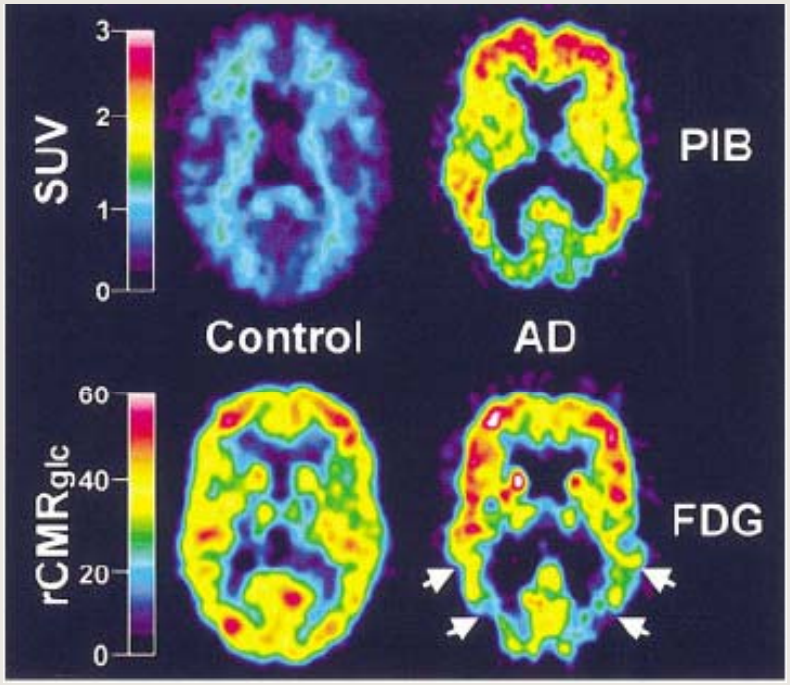
Radiotracers for Oncology



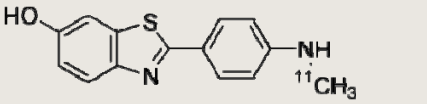
From: Wester, HJ. Nuclear Imaging Probes: from Bench to Bedside. Clin Cancer Res 2007;13(12): 3470-3481

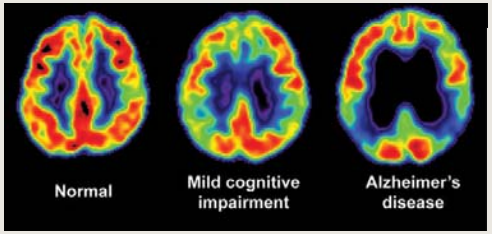
Neurological Applications: Parkinson's, Alzheimer's, Addiction

- World-leading Pacific Parkinson's Research Centre (PPRC) at UBC
  - 1500 patient visits a year
  - Entire program depends on TRIUMF
  - Major discoveries: Placebo effect; Trauma origins



Klunk *et al.*, Ann. Neurol. 2004; 55: 306-19





GOAL: Determine if amyloid imaging with PIB can be a useful biomarker in mild cognitive impairment (MCI) and Alzheimer's Disease (AD).

Biomarker and imaging studies that track the development and progress of AD and reflect the change in people's bodies may lead to a predictive test or effective treatment of AD, which would be beneficial to MCI patients.

Placebo effect

- Recent UBC studies have shown that effectiveness of a placebo pill is influenced by how much the patient believe it will work

WRAP UP

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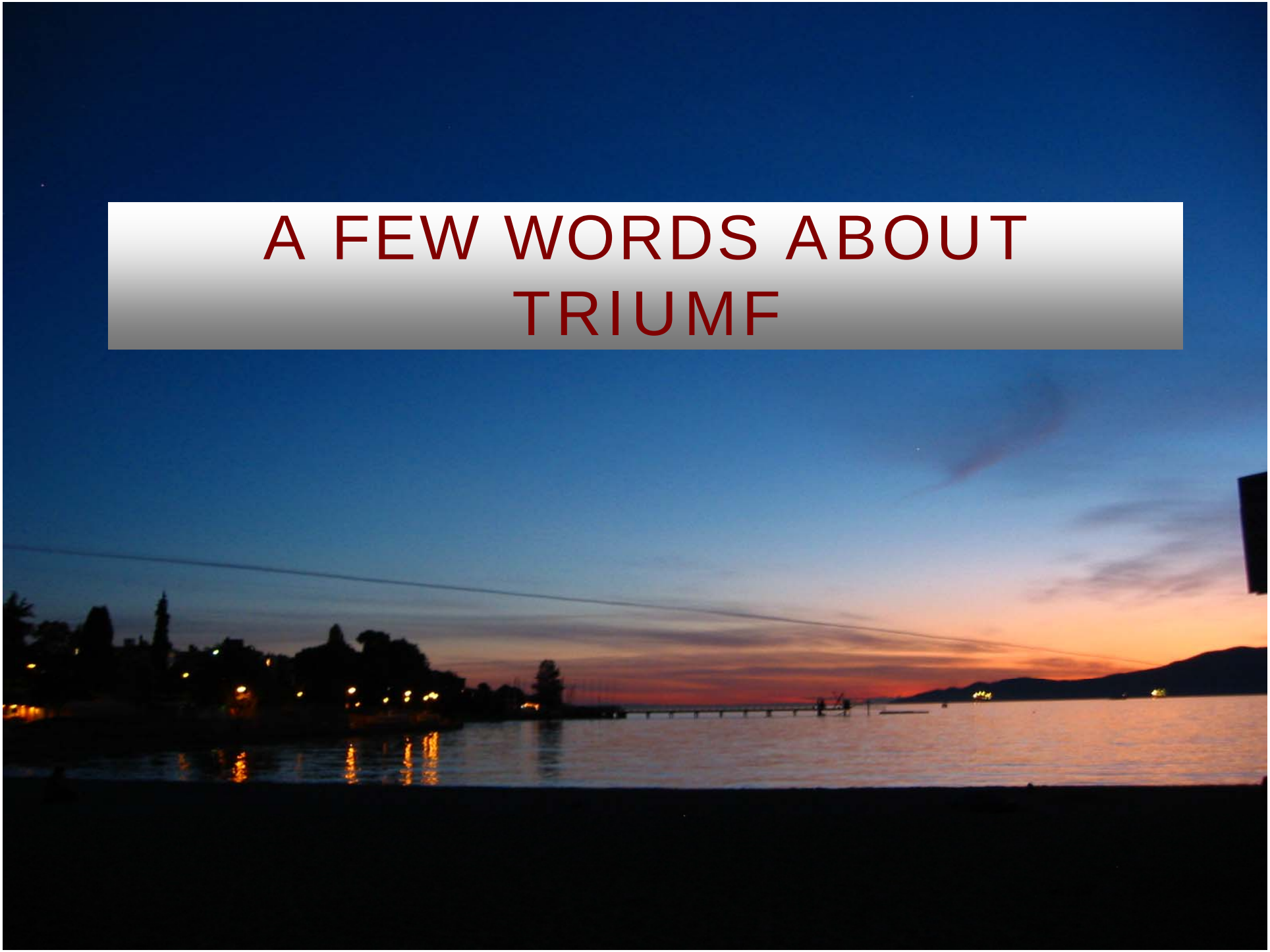
What have we learned?

- Isotopes are cousins of a chemical element all in the same “family” but with different numbers of neutrons
- Medical isotopes are produced by physics, combined with molecules by chemistry, and used in biology for diagnosing/treating disease
- A very exciting future awaits!


A FEW WORDS ABOUT
TRIUMF

Welcome to TRIUMF

Members

Carleton University
University of Guelph
Queen's University
Simon Fraser University
University of Alberta
University of BC
University of Manitoba
Université de Montréal
University of Toronto
University of Victoria
York University

Associate Members

University of Calgary
McMaster University
Saint Mary's University
University of Regina

TRIUMF is Owned and Operated by 15 Canadian Universities

Founded by UBC, SFU, UVic 40 Years Ago

Coming out of the closet

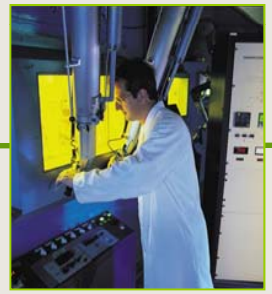
- TRIUMF has played a quiet but critical role in nuclear medicine for decades
  - Radiation beam therapy (now w/protons for eye cancer, used to include pions)
  - Work w/BC Cancer Agency & others in cancer screening, treatment
  - Work w/UBC Parkinson's program to study dopamine system in brain

- Expertise in and contributions to the physics, chemistry, and biology
  - PET Imaging (2nd detector in Canada built at TRIUMF)
  - Radiochemistry and biomarkers (18F, 11C, … nearly 2 dozen)
  - Cyclotrons, target development techniques

Cyclotron Dev. → Target Dev. → Isotope Prod. → Tracer Prod. → (Pre)clinical Studies → Detector Dev.

Commercial Success

MDS Nordion + TRIUMF



- Team produces 15% of Canada's exported isotopes
  - Licensing arrangement for technology
  - 2.5 million patient doses per year
  - Using TRIUMF-designed accelerators
  - 30 year manufacturing partnership

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