Is nuclear power needed to create medical isotopes?

Number 2 in a series of

Brief Webinars

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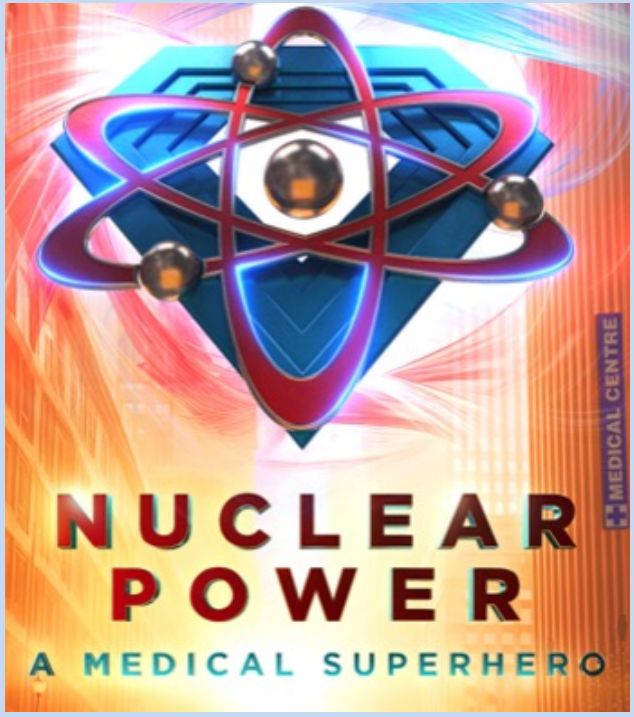
OPG advertising campaign

"For years, popular culture has **distorted perceptions** about nuclear power …

This education campaign aims to recast nuclear power as … **a *medical superhero*.”**

(World Nuclear News, August 24, 2023)



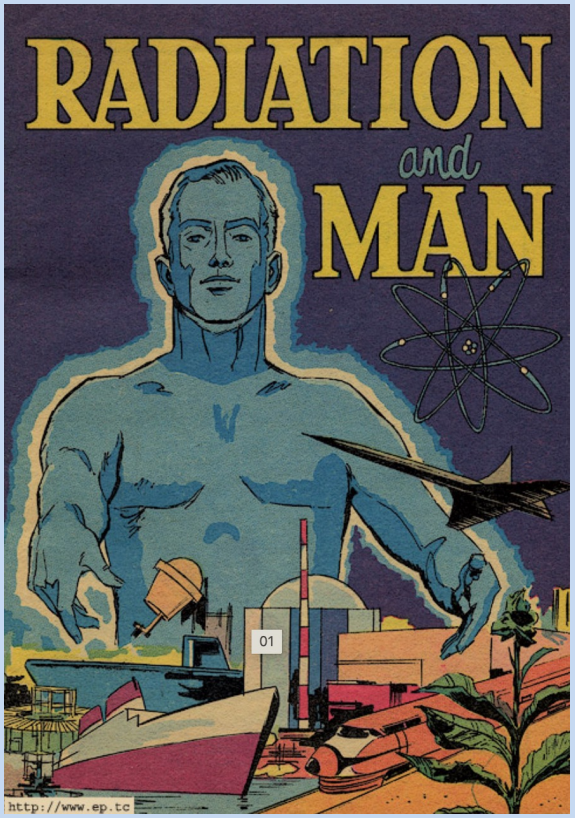
Distorted Perceptions?

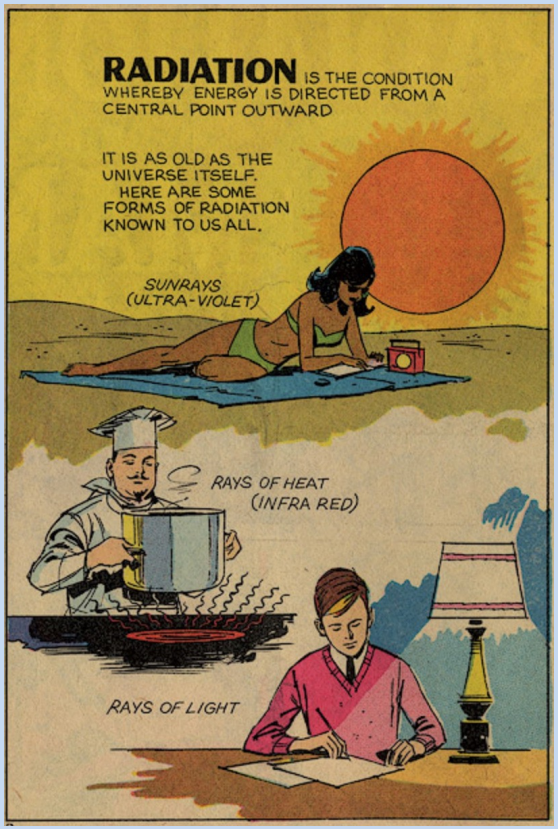
• Medical diagnosis and treatment of patients is not reliant on nuclear power.

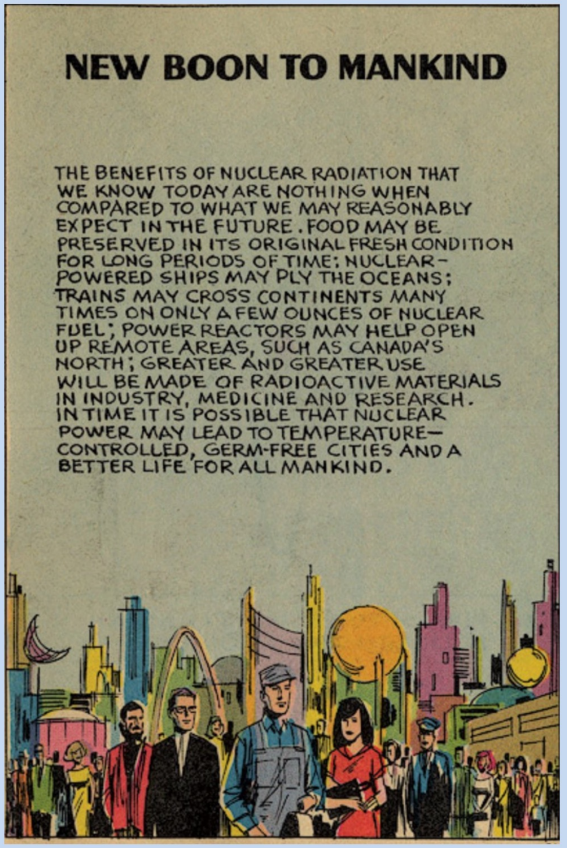
The ATOMIC NUCLEUS is surrounded by orbiting electrons

The force that holds the nucleus together is the strongest force in the universe.

WHAT IS “NUCLEAR RADIATION”?







1972 comic book promoting nuclear power and “nuclear radiation” (Canadian Nuclear Society)

Part 1:
Medical Practice and Non-Nuclear Radiation

Willhelm Roentgen1895

discovered x-rays from cathode ray tubes
~ invisible energy given off temporarily ~

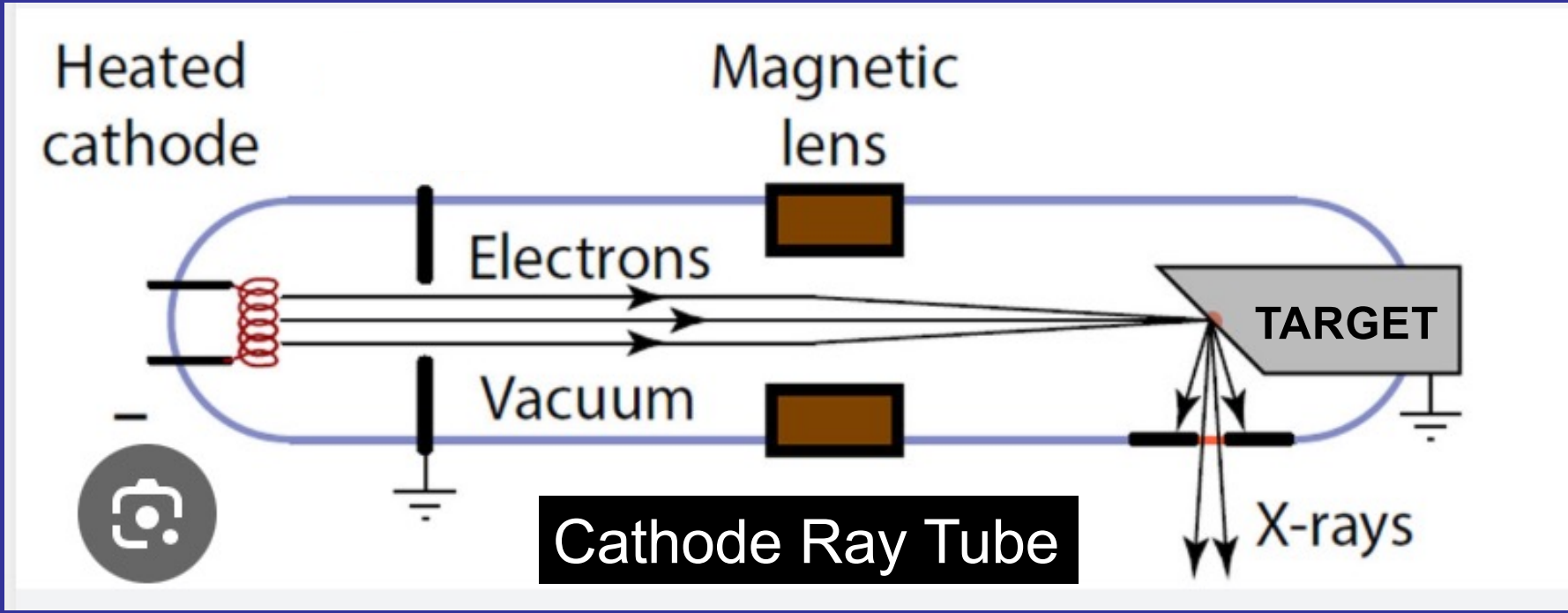
1895

X-Rays

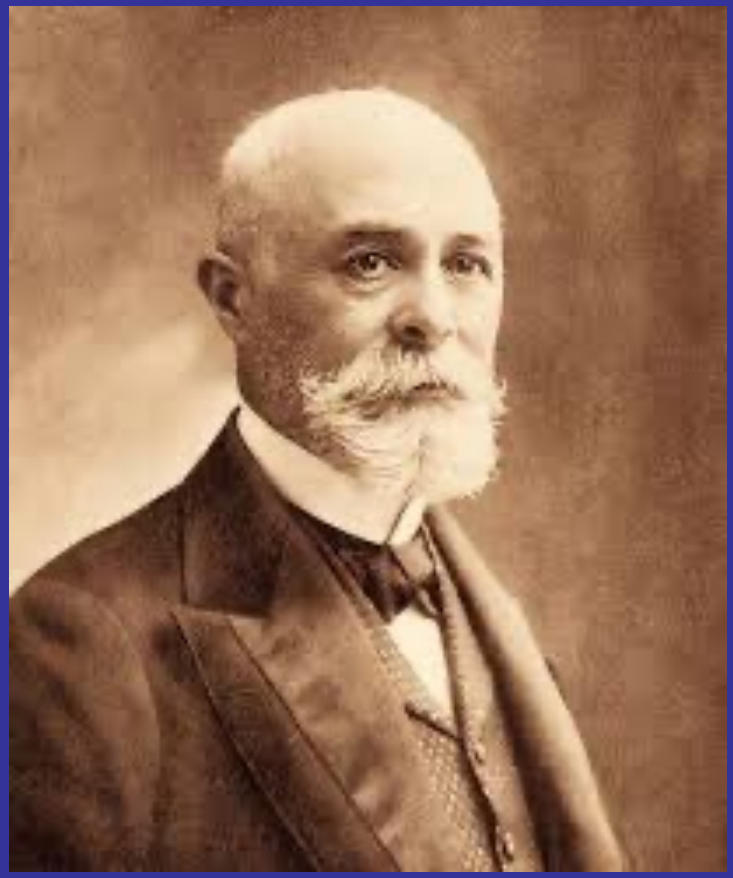
- penetrating E-M energy
- exposes photographic plates
- high dose - radiation burns
- lower doses - cancers and mutations
- women and children at greater risk

X-rays have nothing to do with the nucleus, just the electrons.

Electrons are “accelerated” by electrical attraction towards the positively charged target.



When the electrons “collide” with the hard metal target, orbital electrons are “excited” and give off x-rays



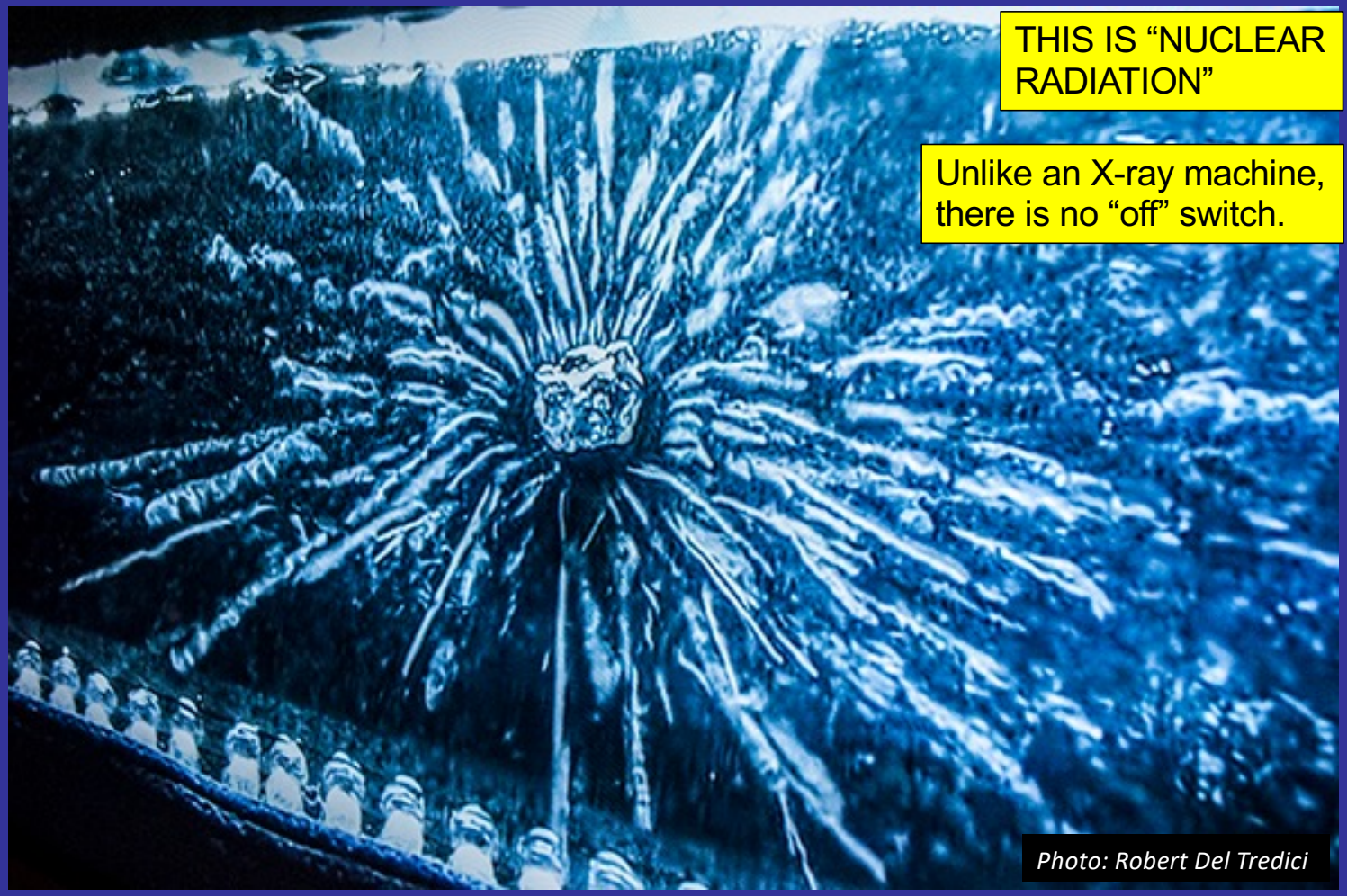
Henri Becquerel 1896

discovered radioactivity of uranium & thorium
~ invisible energy given off ceaselessly ~

1896

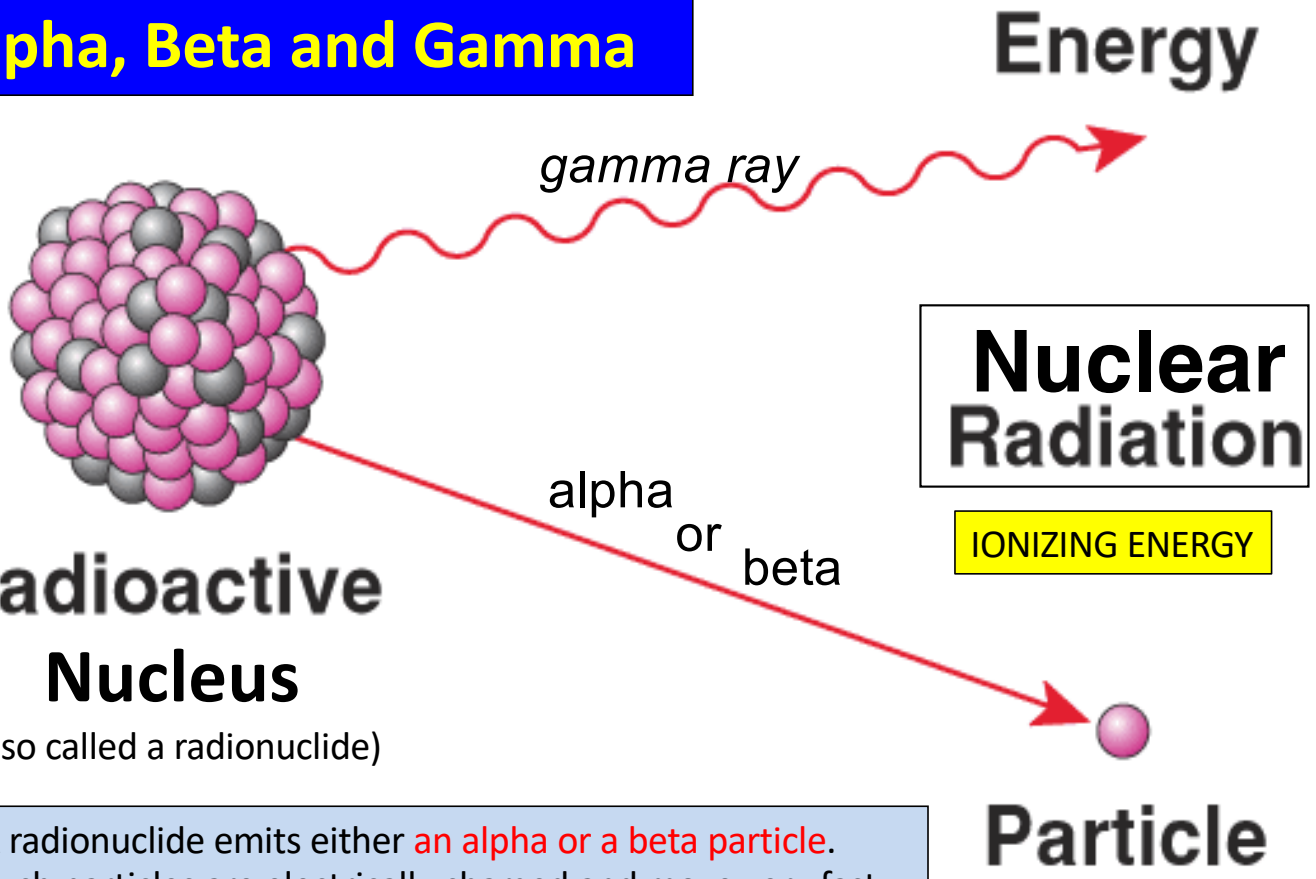
Radioactivity

- invisible energy from ores
- exposes photographic plates
- causes “ionization”
- causes radiation burns
- **cannot be shut off**



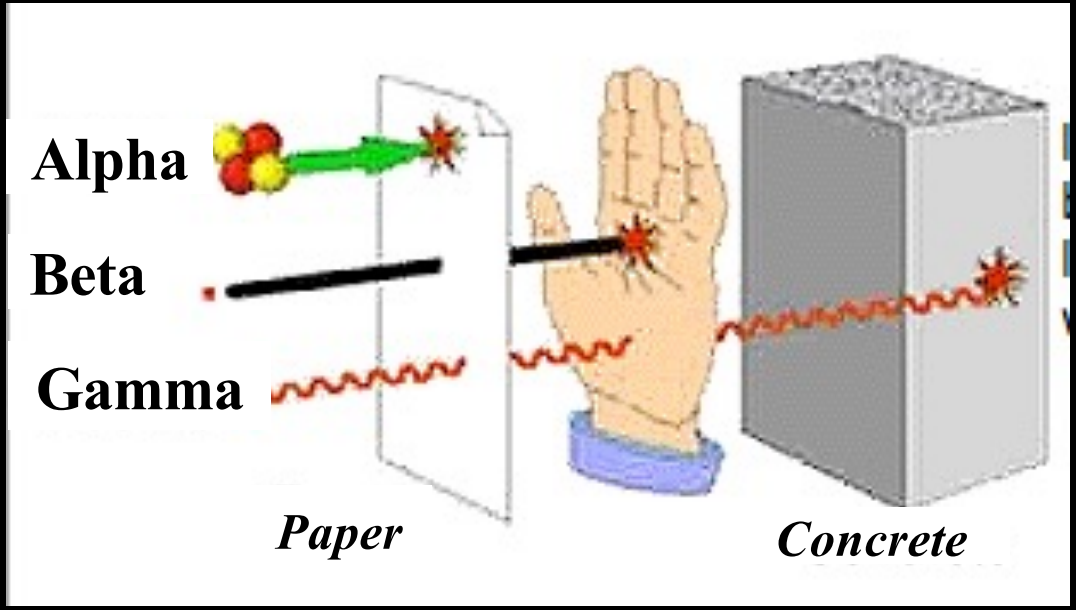
In a “cloud chamber” you can see the tracks of radioactive emissions from uranium ore.
Enough energy given off in a few 1000 years to destroy the Earth ~ but no trigger at hand…

Three types of emissions: Alpha, Beta and Gamma



A radionuclide emits either an alpha or a beta particle.
Such particles are electrically charged and move very fast.
In some cases a powerful gamma ray is also given off.
All three forms of atomic radiation damage living cells.

Alpha particles can be stopped by a sheet of paper.
Alpha emitters are harmless outside the body, but exceedingly dangerous when ingested or inhaled.



Beta particles penetrate only part-way.
They can damage eyes or skin externally but the main danger is internal exposure.

Gamma rays are highly penetrating.
They give "whole body" radiation.
Heavy shielding is often needed.

Lesson

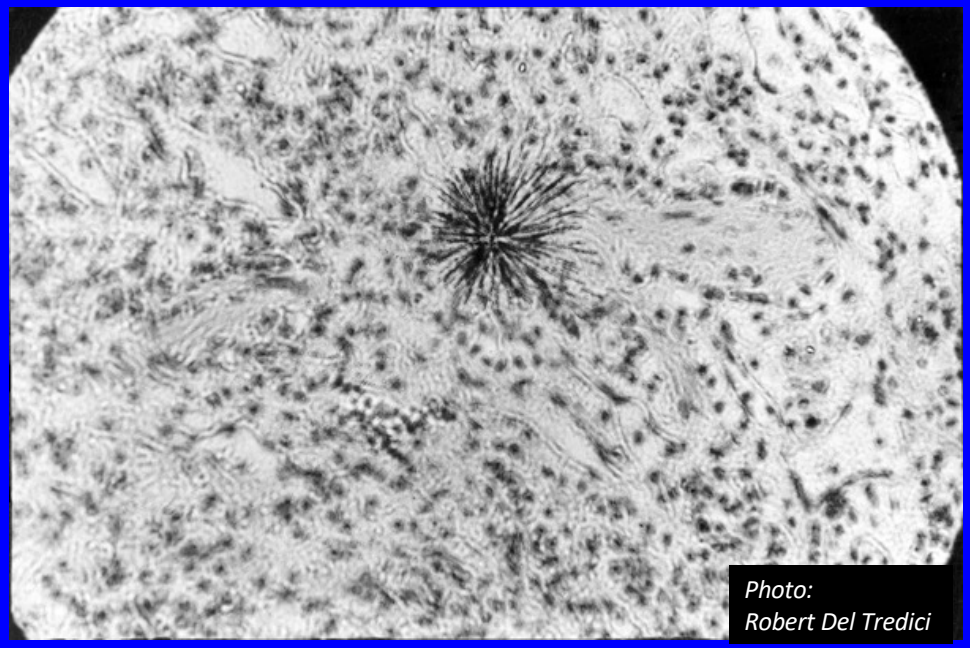
- a radioactive atom is unstable

- it will disintegrate suddenly and violently giving off "atomic radiation"

- the half-life is how long it takes for half the atoms to disintegrate

- radioactivity cannot be shut off

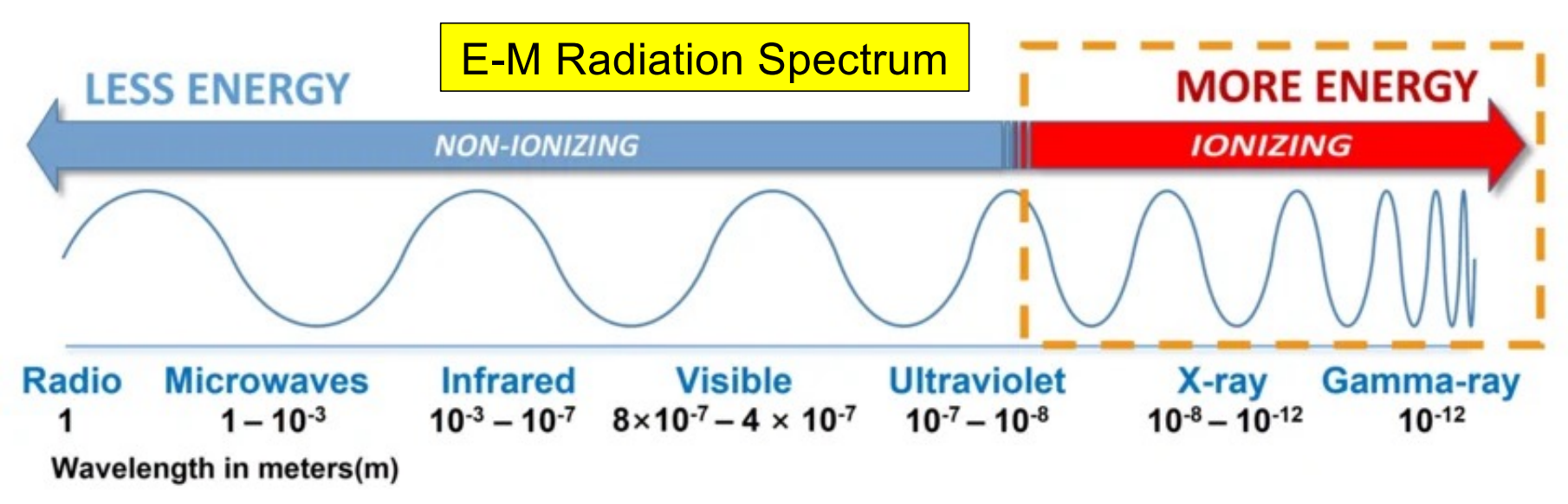
Through the microscope – an alpha-emitting speck of material in the lung tissue of an ape



Tracks of alpha particles emitted during a 48-hour period

BOTH X-RAYS AND GAMMA RAYS ARE “IONIZING”

Ionizing radiation (highest energy) penetrates tissues,
rips electrons loose, creates ions, breaks molecular bonds.



MOST “NUCLEAR RADIATION” IS NOWHERE TO BE FOUND ON THIS “SPECTRUM”
Alpha “rays”, Beta “rays”, Neutrons, are missing – only Gamma radiation appears here.

Harmful Effects of Ionizing "Radiation"

- Acute exposure causes radiation burns and can even be deadly
- Chronic exposure increases the incidence of cancer, leukemia, genetic damage, strokes, heart attacks, & lowered intelligence
- For cancer, there is a "latency period" – the onset of disease occurs years or even decades after exposure.

X-rays are NOT “nuclear radiation”

Greatest medical use of ionizing radiation (by far!) are:

* Dental x-rays
* Chest x-rays
* Mammograms
* CT scans
• cancer therapy using X-rays or particle beams

These have nothing to do with nuclear power
or with nuclear reactors of any kind.

THERE IS NO RADIOACTIVITY INVOLVED.

NOTE: MRI’s and ultrasounds do not involve the use of ionizing radiation at all.

DANGEROUS USES OF X-RAYS
(ALL OF THEM DISCONTINUED)

- Shoe stores
- Routine chest x-rays for school children
- Abdominal x-rays of pregnant women

Dr. Alice Stewart –x-rays & childhood leukemia

Karl Morgan Ph.D. – no safe dose of radiation

Data from the Canadian Nuclear Safety Commission

Typical organ doses from various radiological examinations		
Study Type	**Relevant Organ**	**Dose (mSv)**
Dental x-ray	Brain	0.01 [1]
Chest x-ray	Lung	0.1 [1]
Screening mammography	Breast	3 [2]
Adult abdominal CT	Stomach	10 [2]
Neonatal abdominal CT	Stomach	20 [2]

https://www.cnsc-ccsn.gc.ca/eng/resources/radiation/radiation-doses/

Notice that the dose from a CT scan to the abdomen of an adult is 1000 times greater than the dose from a dental x-ray, for an adult.

For a neonatal CT scan to the abdomen, the dose is 2000 times greater than the dose from a dental x-ray.

DIFFERENCES BETWEEN X-RAYS AND “NUCLEAR RADIATION”

- X-rays can be shut off. Nuclear radiation cannot be shut off.
- X-rays produce no long-term wastes. Nuclear power leaves a multimillion year toxic legacy.
- X-rays cannot contaminate the environment. Radioactive materials mix with food, air, water, soil.
- X-rays cannot be internalized. Radioactive materials can be inhaled, ingested, absorbed, and stored.
- X-rays of pregnant women can be avoided. Radioactive exposures in a contaminated world cannot.

Part 2:
Medicine and Nuclear Radiation (natural radioactivity)

Marie Curie 1898

1898

Marie Curie discovered other radioactive materials – radium and polonium – byproducts of uranium – as well as radon gas

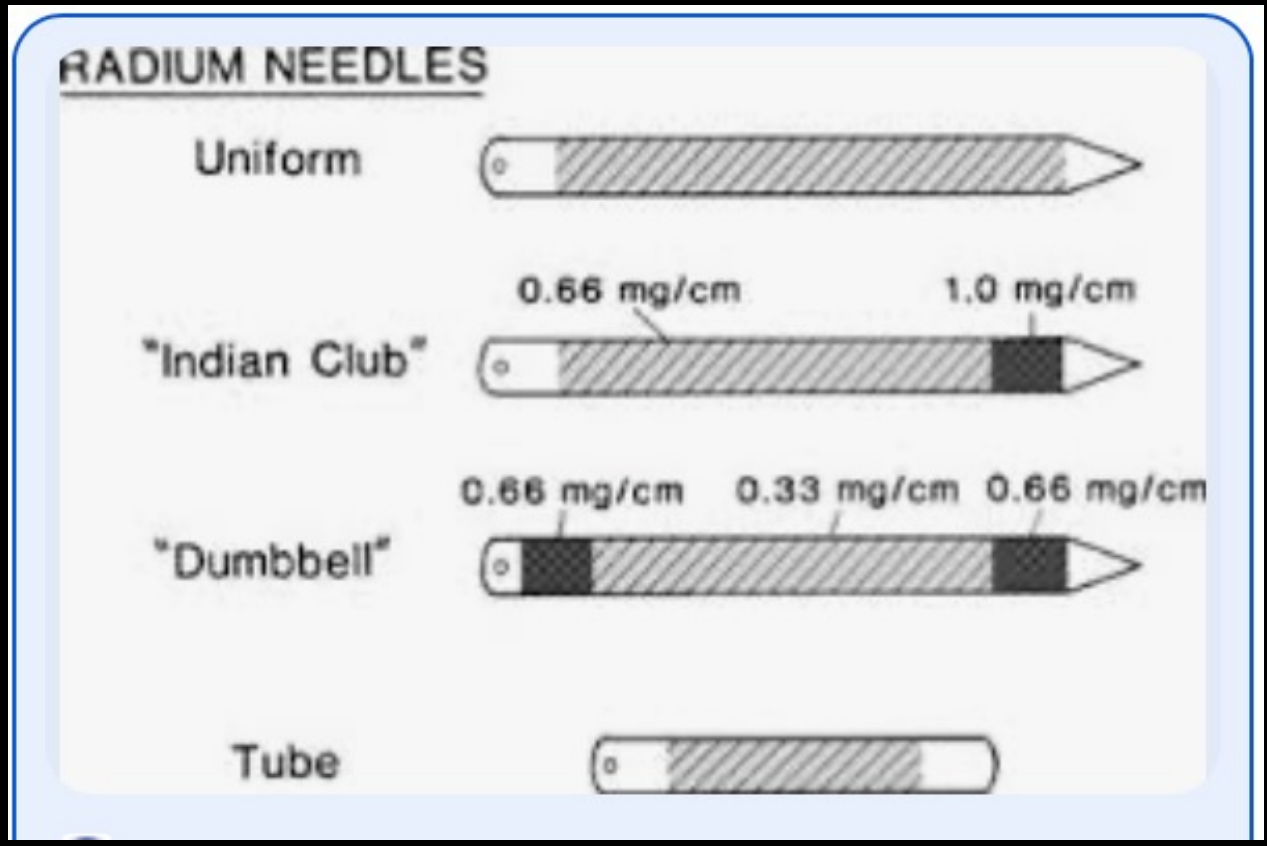
We now know that uranium atoms disintegrate, giving off ionizing radiation, and changing into a series of other unstable elements.

Marie Curie realized that the harmful effects of nuclear radiation can be used to destroy tumours.

From 1910 radium needles became a preferred treatment for shrinking solid tumours.

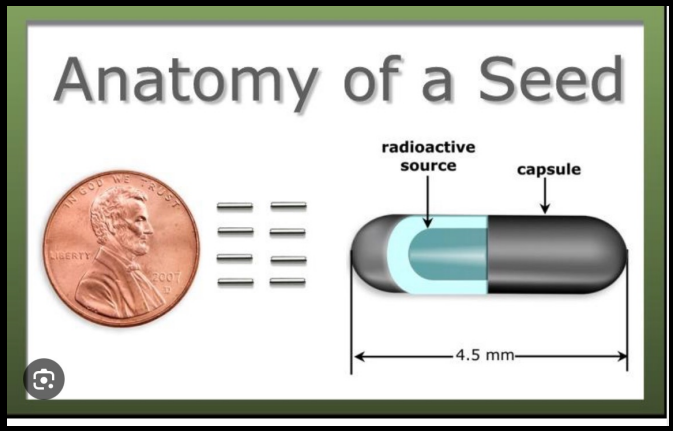
Radium disintegrates and produces gamma-emitting “decay products”.

PROBLEM: Radium has a half-life of 1600 years!!



Since 1925, “radon gas” (a decay product of radium) was used instead – it has a half-life of 3.8 days, and it produces the same gamma-emitting decay products.

The radon gas is sealed inside a “seed” that can then be injected into the solid tumour.



These are examples of radon seed injectors that were used at that time.

Part 3: accelerators and artificial radioisotopes (before nuclear power)

NEW POSSIBILITIES: cyclotrons and neutrons

1930: Inventon of the **cyclotron** (a compact particle acceleraror)

This device enables one to accelerate charged particles (electrons, protons, deuterons) using repeated electro-magnetic impulses to go faster and faster in a spiral pattern.

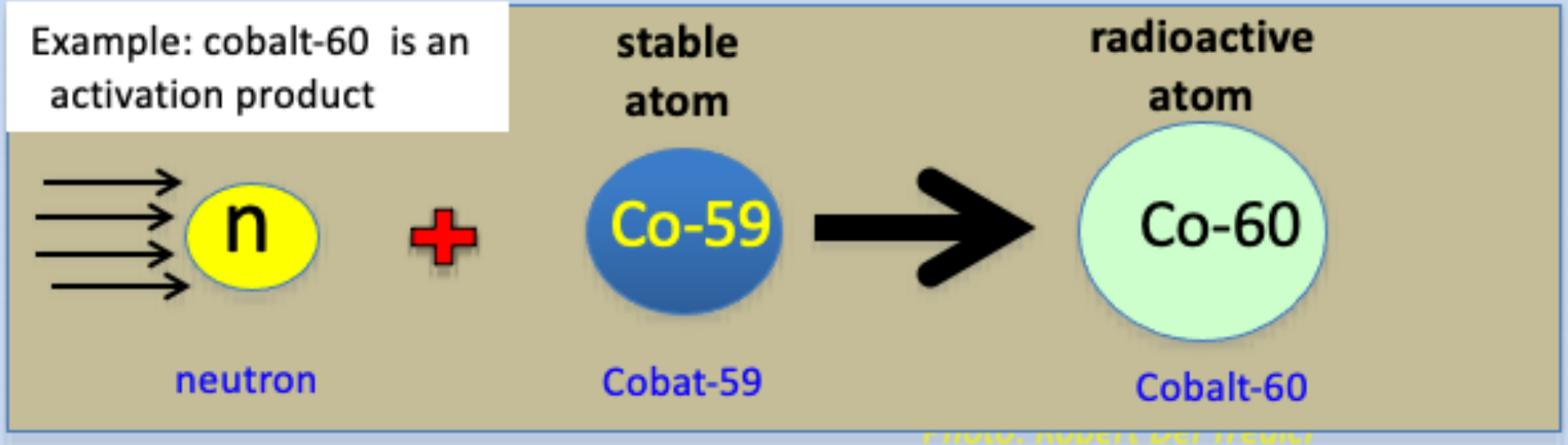
When the accelerated particle collides with a target atom it can change its nucleus

1932: Discovery of the **neutron**, an uncharged particle with the same mass as a proton.

Neutrons are easily absorbed by other atoms, changing the nucleus of those atoms. The new, altered nucleus, is called an “activation product”. One example is cobalt-60.

THE NEUTRON CANNOT BE ACCELERATED because it is not charged.
It can be slowed down however, and slower neutrons are more easily absorbed.

Both neutrons and cyclotrons can be used to create artificial radioactive elements (radioisotopes).



The diagram shows how a non-radioactive atom of cobalt-59 becomes a radioactive atom of cobalt-60 when it absorbs a neutron.

1934: Phosphorus-34 was the first artificial radioactive element created using alpha particles. It was subsequently used to treat leukemia.

1934: Neutrons were first used by Enrico Fermi to produce an artificial radioactive isotope of aluminum.

1934: First radioactive isotope made in a cyclotren : technetium – filling a gap in the periodic table.

Radioisotopes are useful for **tracing** how bodily fluids move in the body or how nutrients are utilized by the organism The first use of radioactive tracers was as early as 1925, using naturally-occurring bismuth-214.

1947: The NRX reactor is started up at Chalk River, followed by the NRU reactor in 1957.

1948: Powerful electron accelerator (25 MeV) for cancer treatment, the BETATRON is built at U of Sask.

1951: Using cobalt-60 from the NRX reactor, both Ottawa and Saskatoon started in on “gamma therapy”. THIS IS NUCLEAR RADIATION< BUT IT IS NOT FROM A NUCLEAR POWER PLANT.

1956 (Ottawa) New “cobalt bomb” installed in Ottawa’s Civic hospital
Cobalt-60 therapy has since been phased out in all well-off countries.

External beam radiation therapy (particle accelerator) is preferred.
No radioactive waste to be isolated from the environment

Nationwide Recovery Of Radioactive Devices By Los Alamos National Lab Hits Major Milestone

October 2024: "Off-Site Source Recovery Program" removed a high-activity radioactive device. The truck departed the facility at 1:18 a.m. to minimize impacts to city roadways. Photo: LANL

RADIOACTIVE WASTE – COMMERCIAL GAIN, PUBLIC PAIN

The main use of caesium-137 and cobalt-60 is in large commercial “irradiators” used to sterilize equipment and some kinds of food. Such facilities use thousands of times more of these gamma emitters (cesium-137 and cobalt-60) than are used by medical facilities like hospitals. Quintillions rather than quadrillions of becquerels.

The Los Alamos Labs have removed 7,030 trillion becquerels of cesium-137 in 100 shipments over six years, from 2019 to February 2025. That’s less than 8 percent of the cobalt-60 activity that is planned to be permanently stored in the Chalk River megadump, the NSDF.

The megadump is to be located beside the Ottawa River, on the unceded ancestral lands of the Kebaowek First Nation and other Algonquin tribes of the Ottawa Valley. Despite the UN Declaration on the Rights of Indigenous Peoples, that has been incorporated into Canadian law, the megadump has never received the free prior and informed consent of the Algonquin people.

Social injustice is an unavoidable consequence of abandoning radioactive waste.

The Bottom Line

In 2022, I wrote a “Fact Sheet” about nuclear power and modern medicine.

At that time, I observed that NO medical isotopes used for diagnosis or treatment were being produced in nuclear power reactors. That was a true statement.

All such medical isotopes were produced either by paricle accelerators (i.e. for PET scans – positron emission tomography) or by research reactors (in Canada, primarily the NRU reactor and the McMaster University reactor).

My fact sheet was intended to “debunk” the false message from the nuclear power industry that modern medicine would suffer if we were to phase out nuclear power for whatever reason – economic, environmental, public health, social justice, nuclear weapons proliferation, or caring about future generations.

Lo and behold, in order to prop up the false image that it phas ropogated about its “superhero” role in modern medicine, it started producing medical Isotopes in Ontario’s power reactors for the very first time in history.

MOLYBDENUM-99 from Darlington

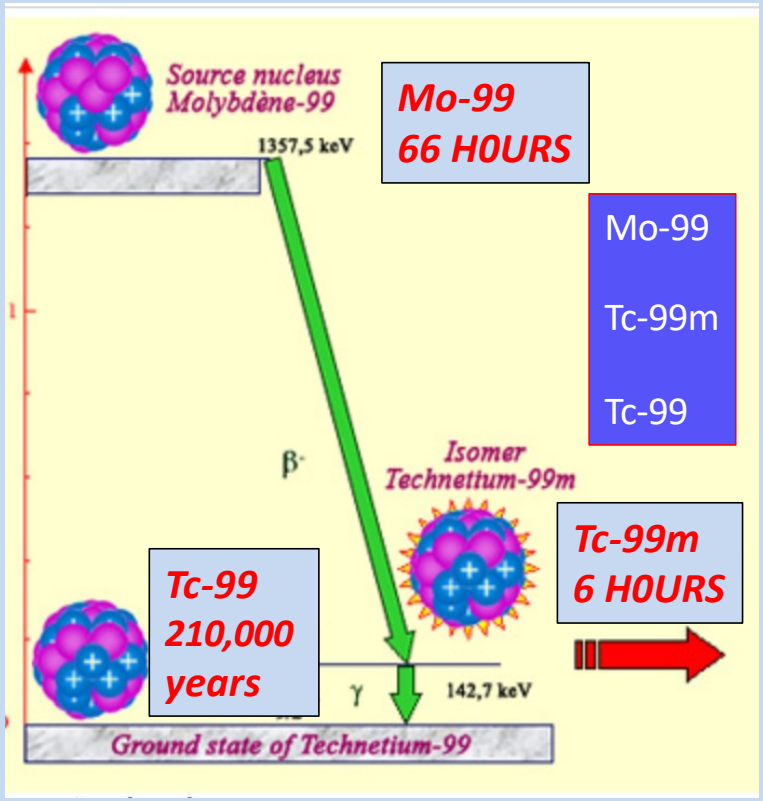
In 2024, the Darlington plant started producing Molybdenum-99 for medical use, noting that this was the first time that any nuclear power reactor had ever done so.

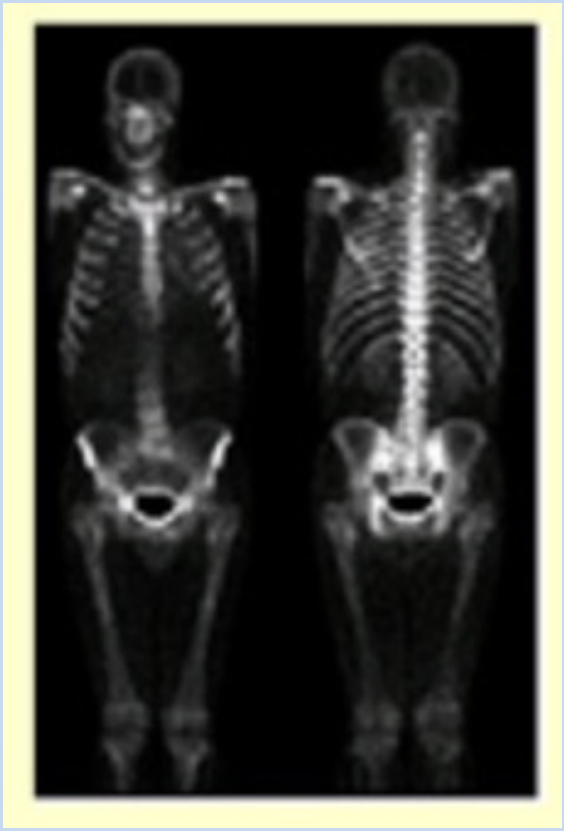
Previously, the entire world supply of molybdenum-99 was produced by five very old research reactors situated on three continents., including the NRU Reactor at Chalk River before it was retired.

Meanwhile, researchers at the Université de Sherbrooke in Quebec had developed a simple system to produce molybdenum-99 using a cyclotron, without the need for any nuclear reactor at all. It is less expensive and easily adaptable to other climes.

Molybdenum-99 has a 66-hour half-life, during which time it produces a steady supply of Techetium-99m, with a 6-day half-life. Technetium-99m is the most used medical isotope In the world. But when it disintegrates it turns into Technetium-99 (without the “m” for “metastable”) and that latter isotope has a 210,000 year half-life!!

AECL designed two very small (10 MWth) MAPLE reactors, each of which could replace The total output of medical isotopes from the much larger (250 MWth) NRU reactor.





Molybdenum-99 has a half-life of 3 days and 9 hours.
It turns into technetium-99m with a half-life of 6 hours.
And that turns into technetium-99 with a half-life of 210,000 years!!

Images of internal organs and their functioning using techentium-99m

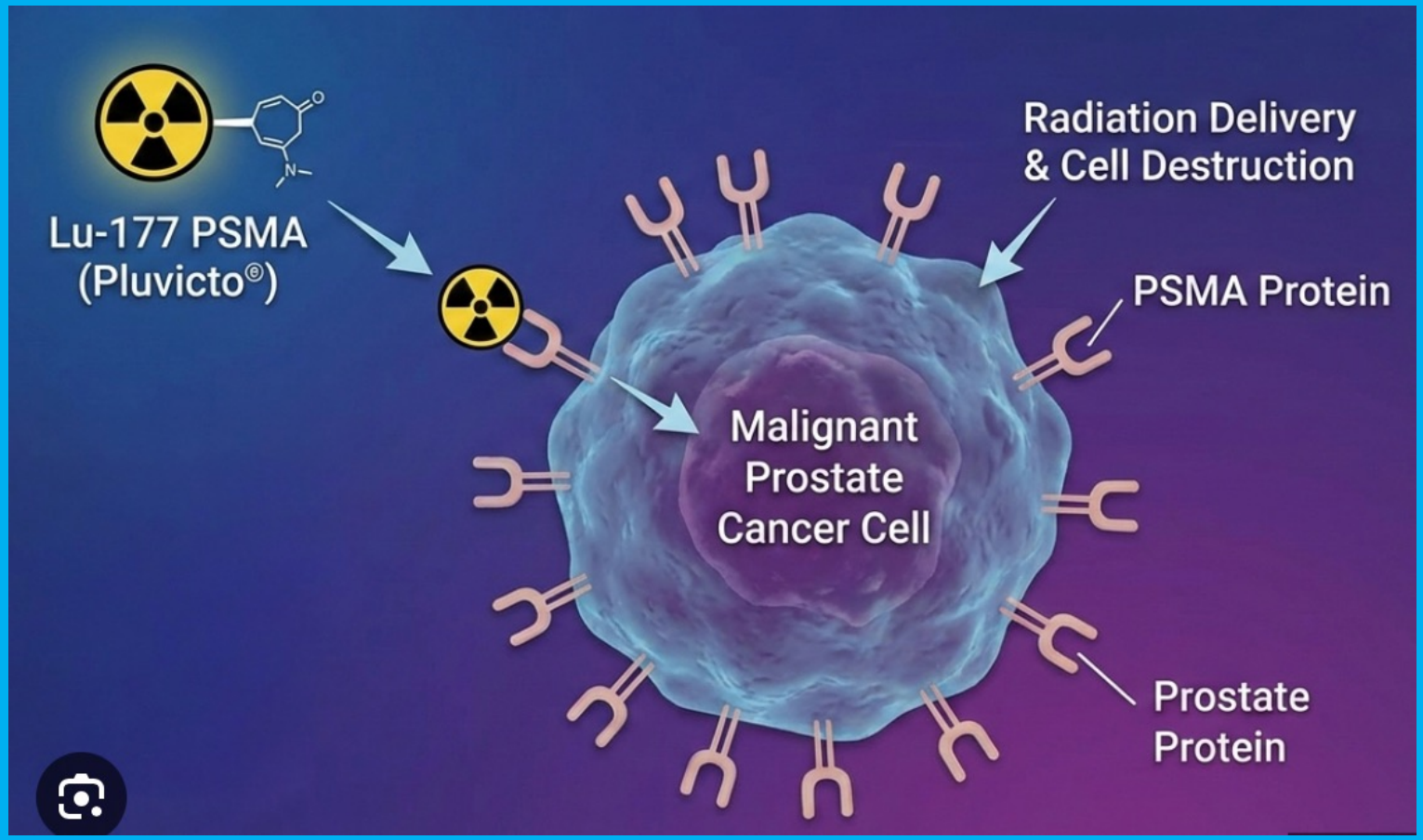
LUTETIUM-177 from BRUCE

In 2022, after my medical Fact Sheet had been distributed, Bruce Power became "the first commercial nuclear power reactor in the world to produce lutetium-177, a short-lived medical isotope, using a first-of-a-kind Isotope Production System (IPS)."

This isotope is intended to provide targeted radiotherapy to treat Metastatic (Stage IV) prostate cancer, which occurs when cancer cells spread from the prostate to other parts of the body, most commonly the bones, lymph nodes, lungs, or liver. While typically considered incurable, it is treatable with therapies aimed at extending life and reducing symptoms,

When this "targeted" isotope was discussed in the medical literature several years ago, there was no mention whatsoever of using power reactors to produce the product. Instead, it was seen as an opportunity for reseaerch reactors around the world to join the effort to produce this isotope.

Yes, the isotope can be produced in a power reactor, but there is no necessity for that.



Leutetium-177 attacks a malignant prostate cancer cell and destroys it.

ACTINIUM-225 from Chalk River

There is no power reactor located at Chalk River, and no operating research reactor either, since the NRU reactor was permanently shut down. Nevertheless, Chalk River has been producing a relatively new medical isotope – Actinium-225 – since 2017.

Indeed, the production of Actinium-225 uses naturally-occurring radium-226 as a target in a cyclotron. Positively-charged protons are accelerated and collided with radium-226 atoms to produce the desired actinium-225 atoms.

So there you have it. Naturally-occurring radioactive materials and particle accelerators are ruling the day. There is still room for isotopes created in nuclear reactors, using the abundant neutrons that are flying around in the core area from nuclear fission, but those reactors do not have to be large power reactors. Much smaller research reactors are fully able to meed the global demand for these radioactive materials.

The End

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