LET THERE BE LIGHT

Een verhandeling over straling

François van Langevelde

The Creation of Light (Genesis 1.3-5)

Gustave Doré – Bible Illustrations

1 In den beginne schiep God den
hemel en de aarde.
2 De aarde nu was woest en
ledig, en duisternis was op den
afgrond; en de Geest Gods
zweefde op de wateren.
3 En God zeide: Daar zij licht! en
daar werd licht.
4 En God zag het licht, dat het
goed was; en God maakte
scheiding tussen het licht en
tussen de duisternis.
5 En God noemde het licht dag,
en de duisternis noemde Hij
nacht. Toen was het avond
geweest, en het was morgen
geweest, de eerste dag.

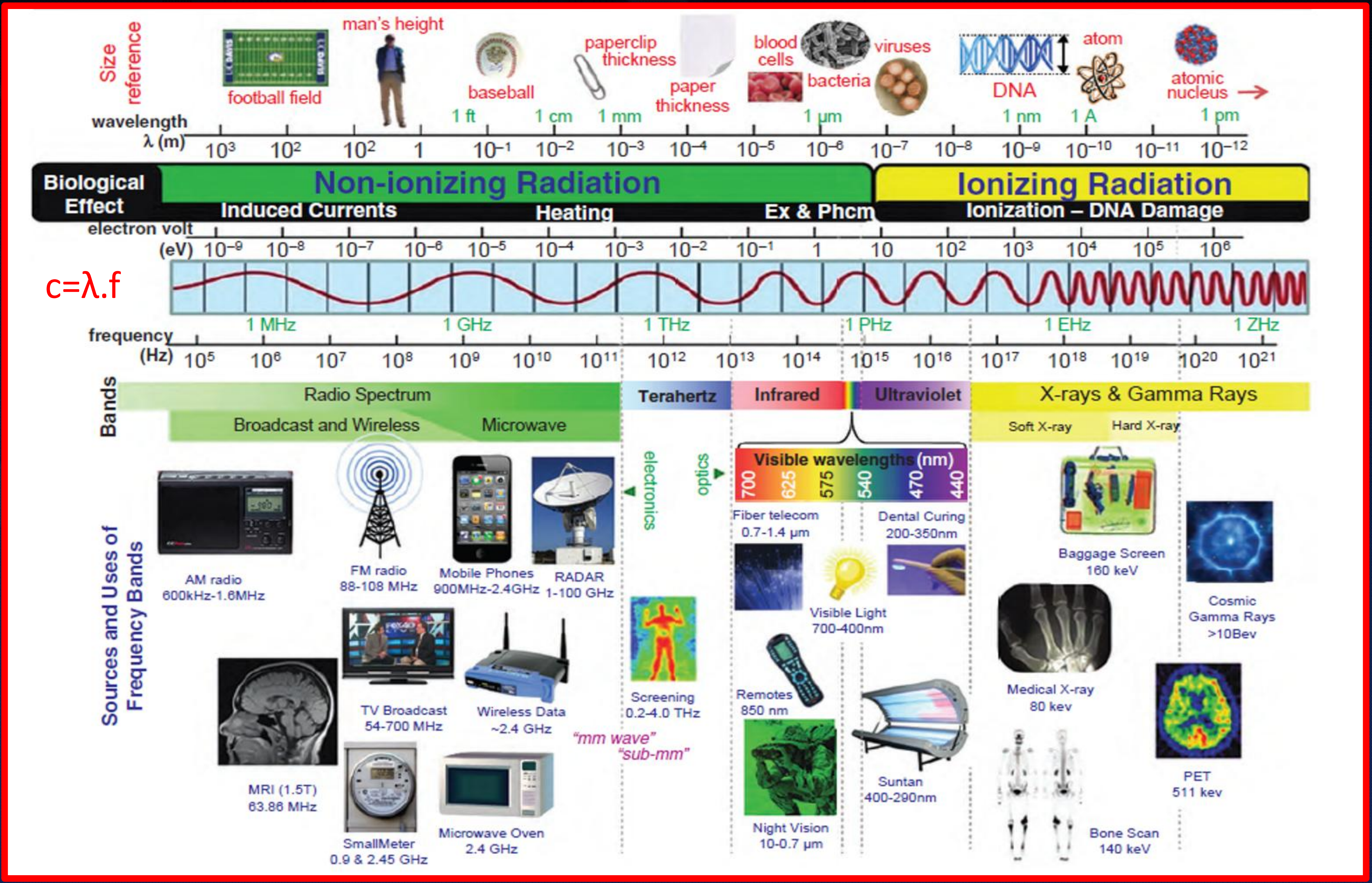
Aldus De Statenvertaling 1637

The Four Fundamental Forces

Gravitonen (?)	Fotonen	W&Z Bosonen	Gluonen
1	10^{38}	10^{15}	10^{40}

The Electromagnetic Spectrum I

$c=\lambda.f$



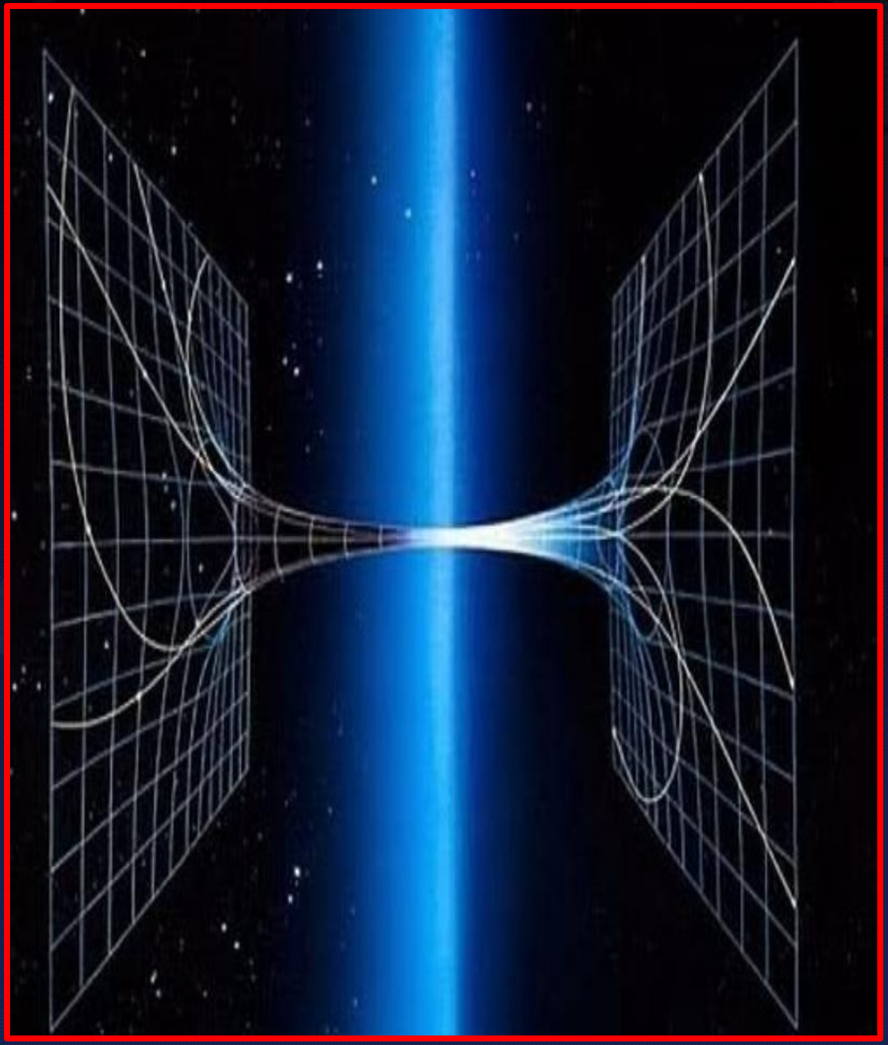
The Electromagnetic Spectrum II

LET THERE BE LIGHT

Een verhaal over straling

François van Langevelde

“Genesis” according to George Gamow



From Big Crunch to Big Bang?

In het begin schiep God Straling en Ylem.
En Ylem was zonder vorm of getal, en de nucleonen raasden als gekken over het oppervlak van het diepe.

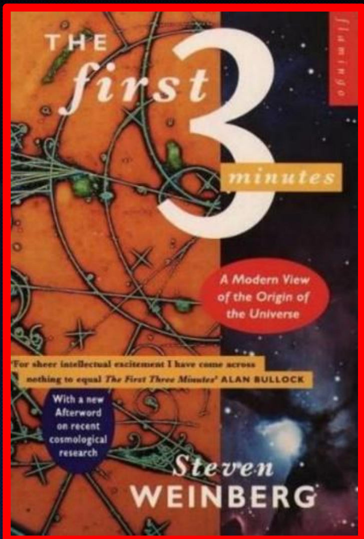
En God zei: "Laat er massa twee zijn."
En er was massa twee.
En God zag Deuterium, en het was goed.

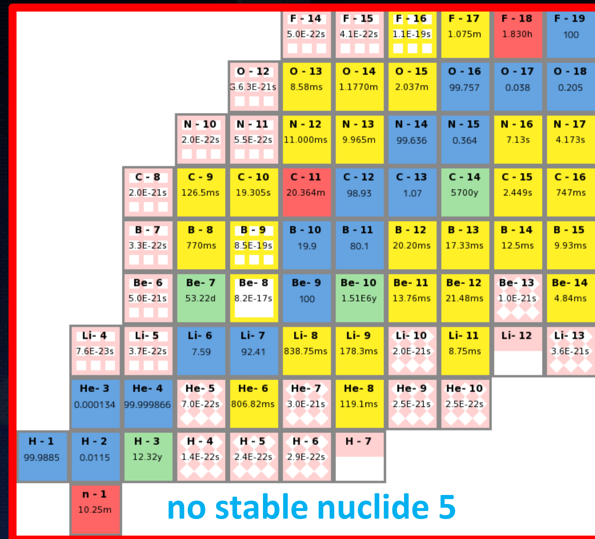
En God zei: "Laat er massa drie zijn."
En er was massa drie.
En God zag Tritium, en het was goed.

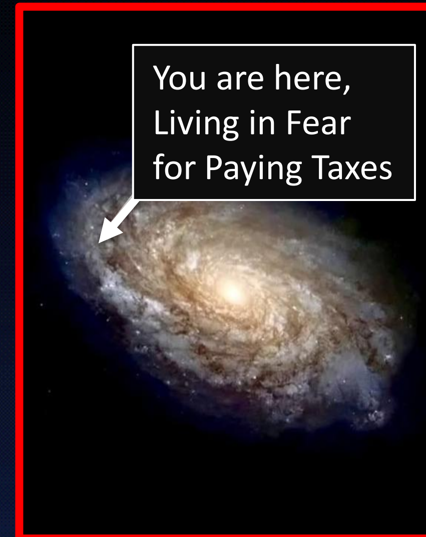
En God bleef getallen noemen totdat Hij bij de Transuranium elementen kwam.
Maar toen Hij terugkeek op zijn werk, zag Hij dat het niet goed was.
In de opwinding van het tellen had Hij gemist om massa vijf te noemen, en dus konden er natuurlijk geen zwaardere elementen gevormd zijn.

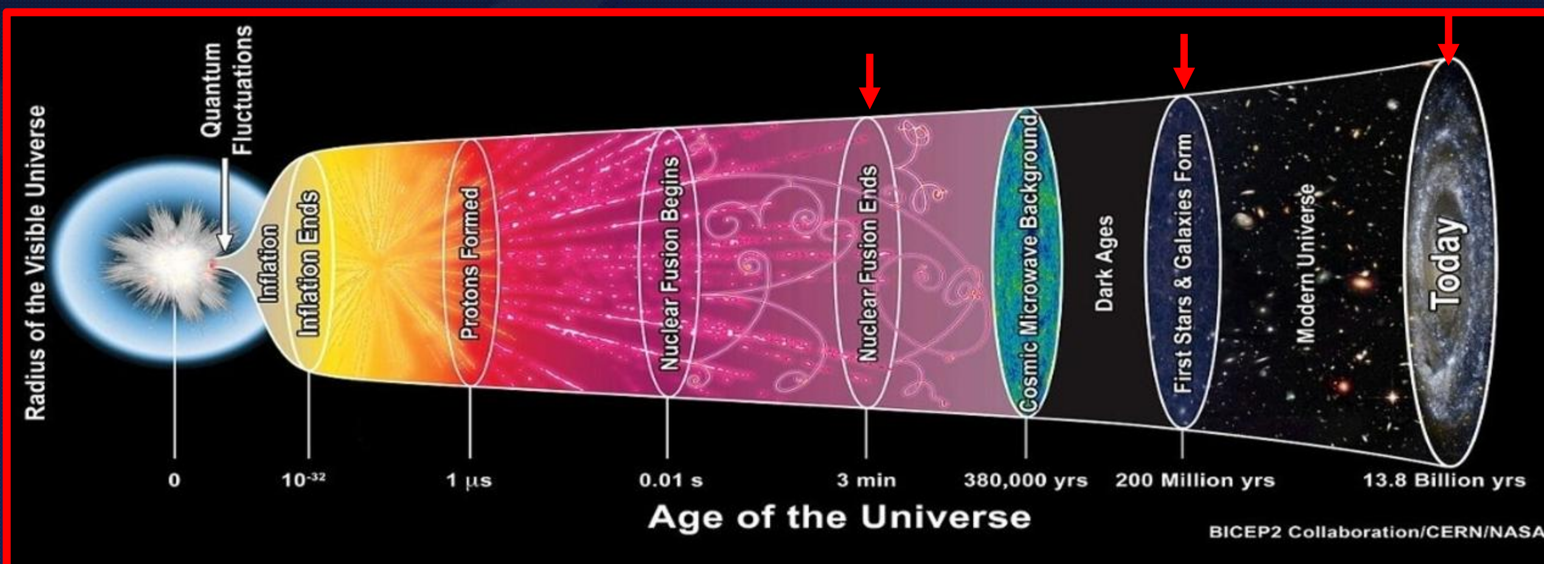
. . . .

First Three Minutes and beyond . . .

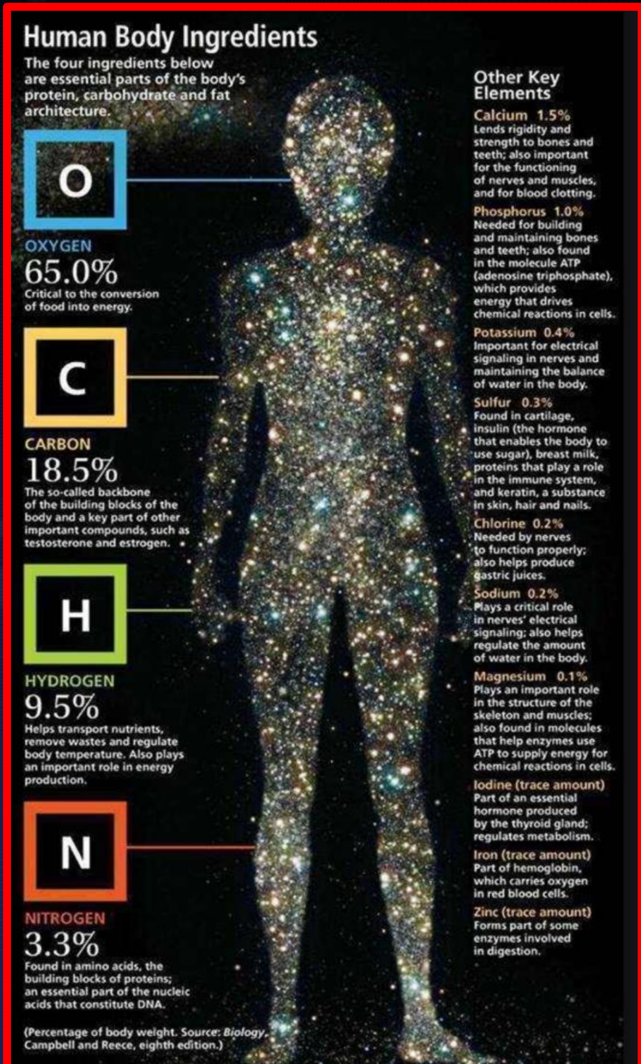


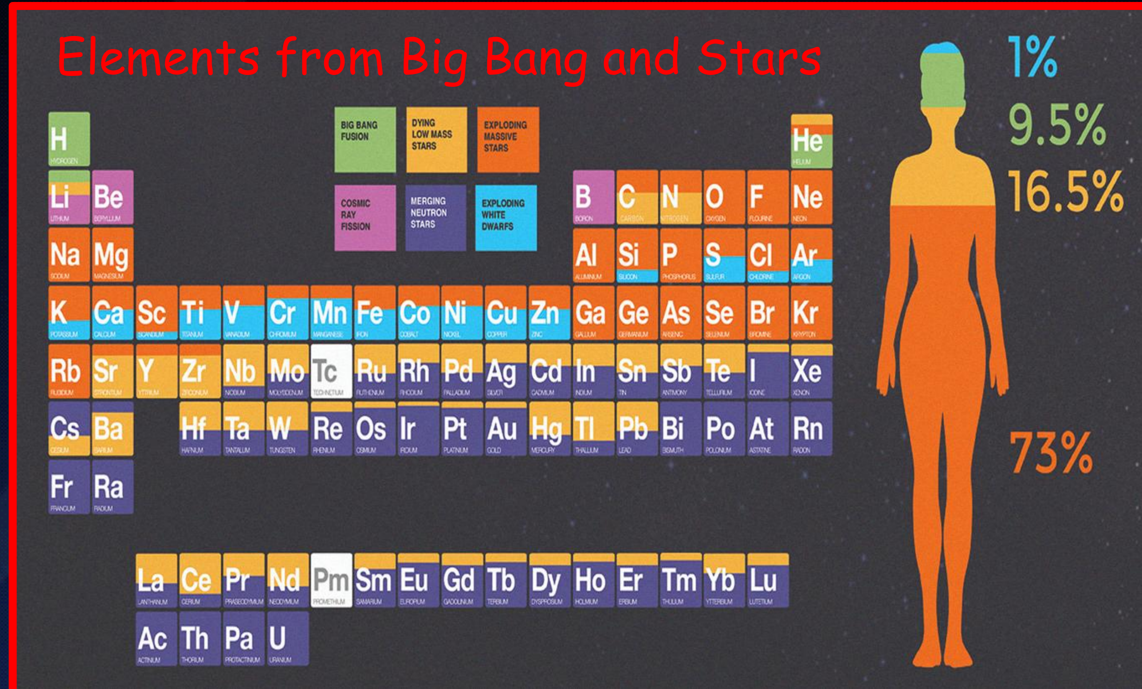






Human Elemental Composition





Radionuclides in the body:

^{40}K isotope of Potassium

^{14}C isotope of Carbon

^{226}Ra isotope of Radium

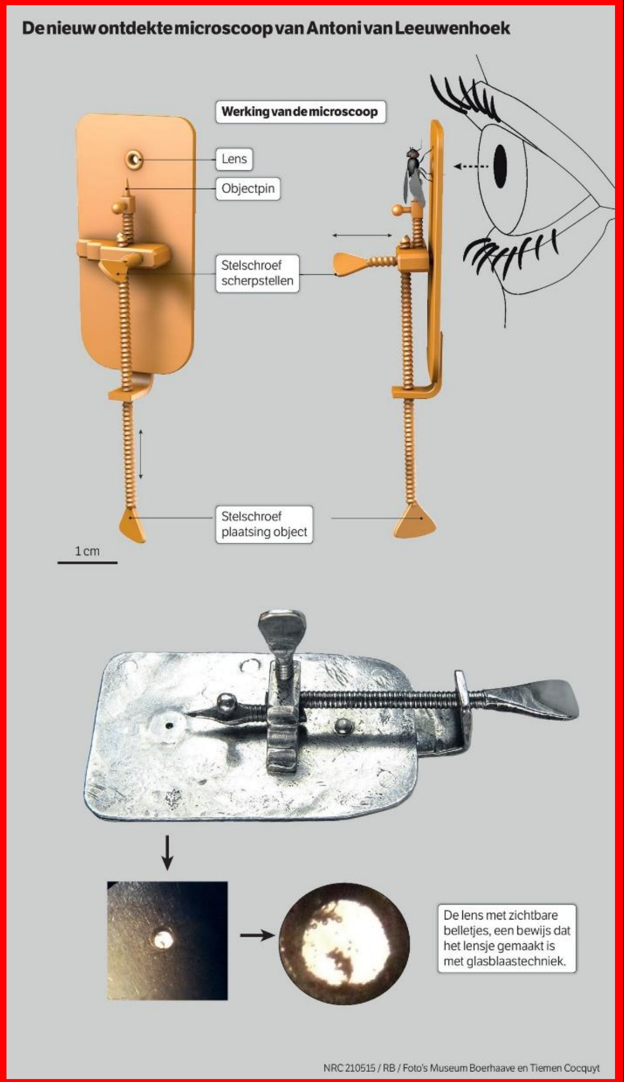
Earliest Human Experience with Light

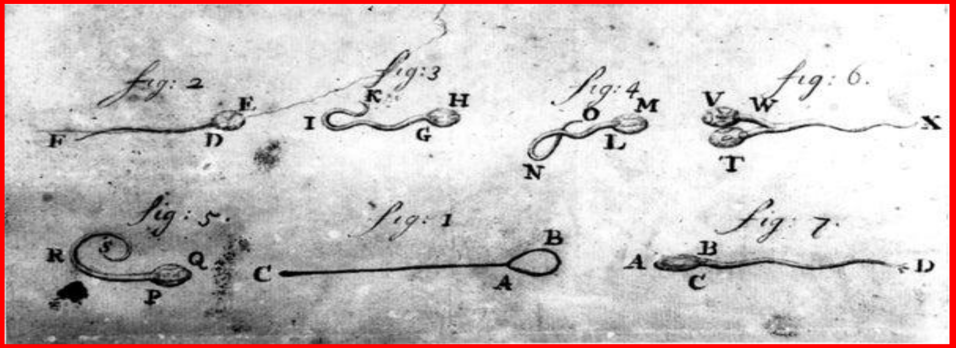
17th Century Age of Light (Telescope)

Johannes Lipperhey

1608

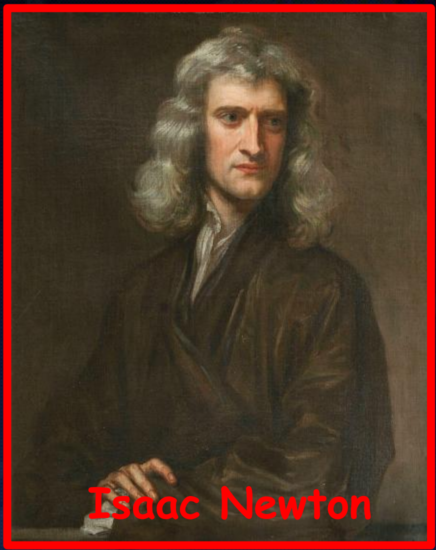
17th Century Age of Light (Microscope)



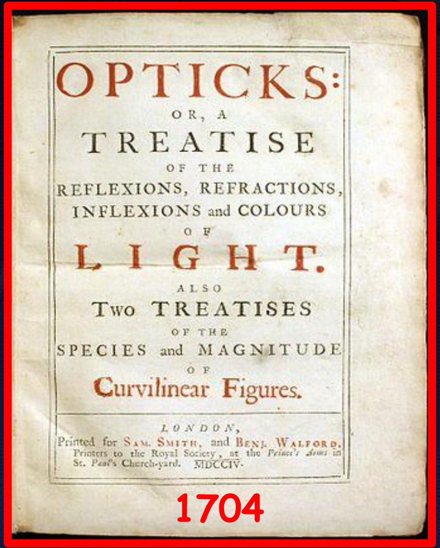


Antoni van Leeuwenhoek 1632-1723

17th Century Age of Light (particles or waves?)

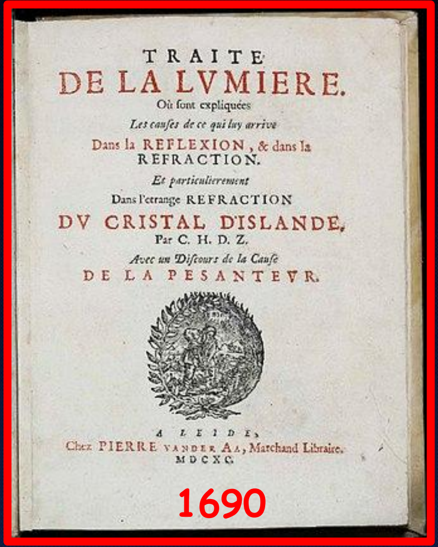


Isaac Newton


OPTICKS:
OR, A
TREATISE
OF THE
REFLEXIONS, REFRACTIONS, INFLEXIONS and COLOURS
OF
LIGHT.
ALSO
Two TREATISES
OF THE
SPECIES and MAGNITUDE
OF
Curvilinear Figures.

LONDON,
Printed for SAM. SMITH, and BENJ. WALFORD, Printers to the Royal Society, at the Prince's Arms in St. Paul's Church-yard. MDCCIV.

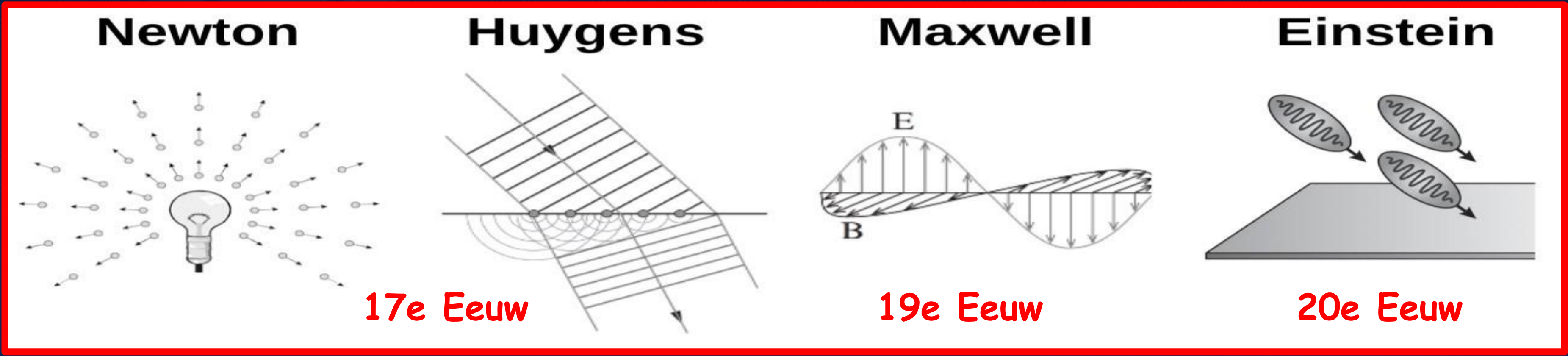
1704


TRAITE
DE LA LVMIERE.
Où sont expliquées
Les causes de ce qui luy arrive
Dans la REFLEXION, & dans la REFRACTION.
Et particulierement
Dans l'etrange REFRACTION
DV CRISTAL DISLANDE,
Par C. H. D. Z.
Avec un Discours de la Cause
DE LA PESANTEVR.

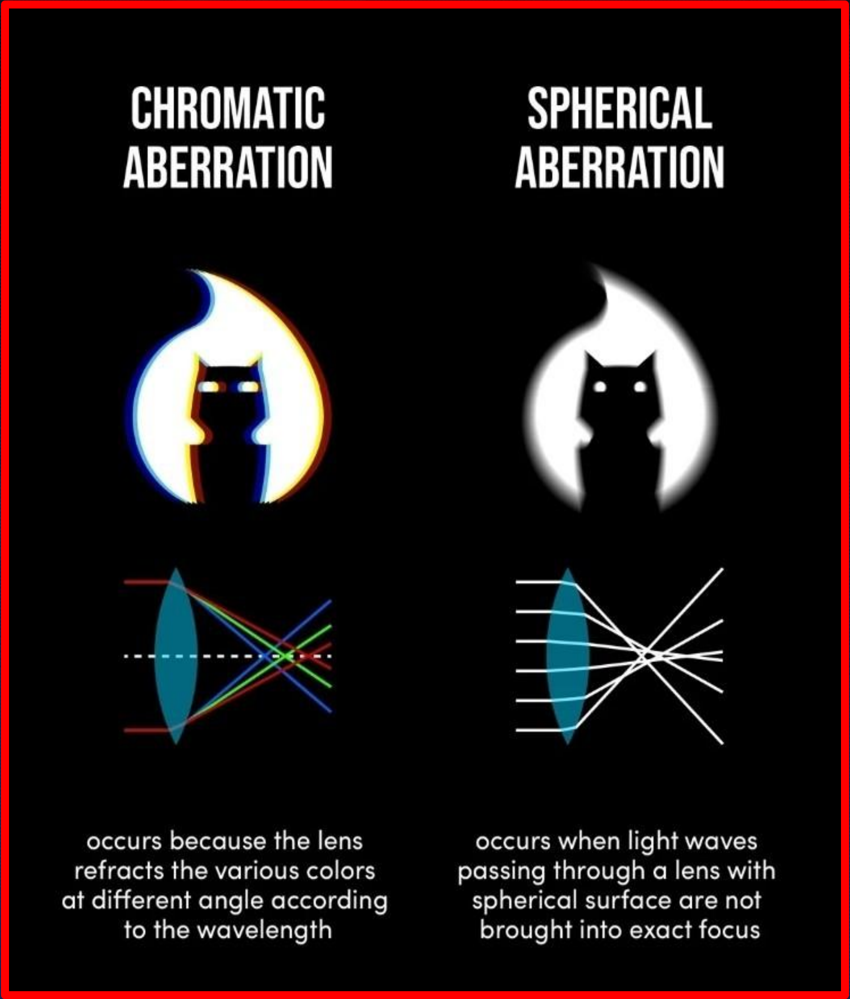
A LEIDE,
Chez PIERRE VANDER AA, Marchand Libraire.
MDCXC.

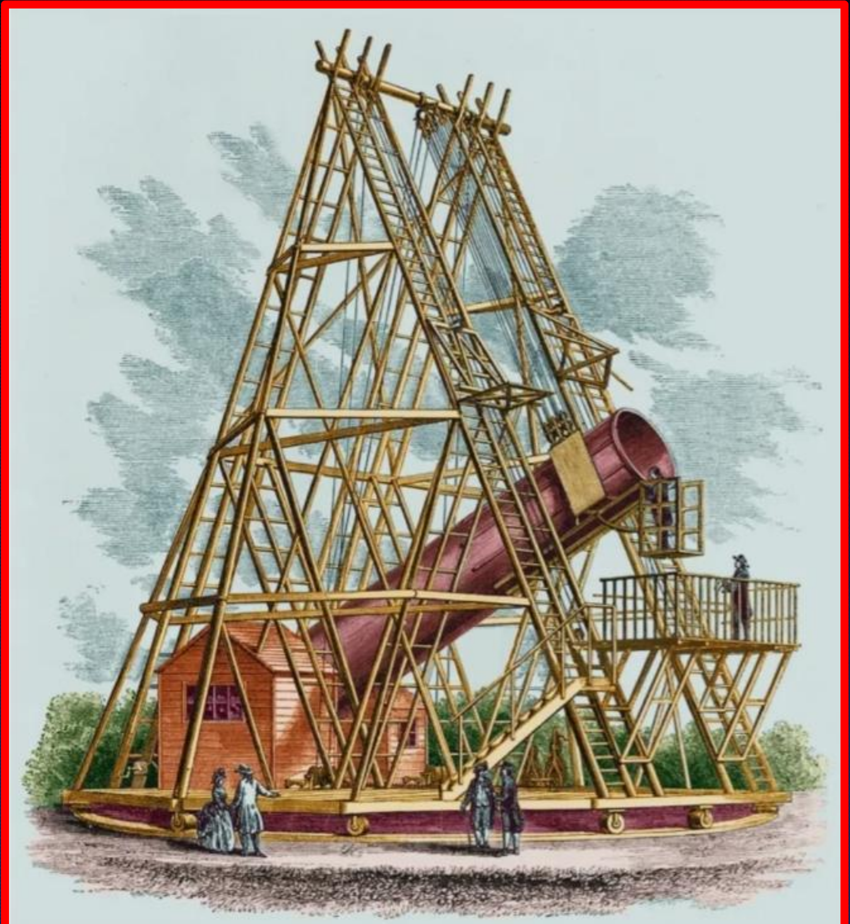
1690

Christiaan Huygens



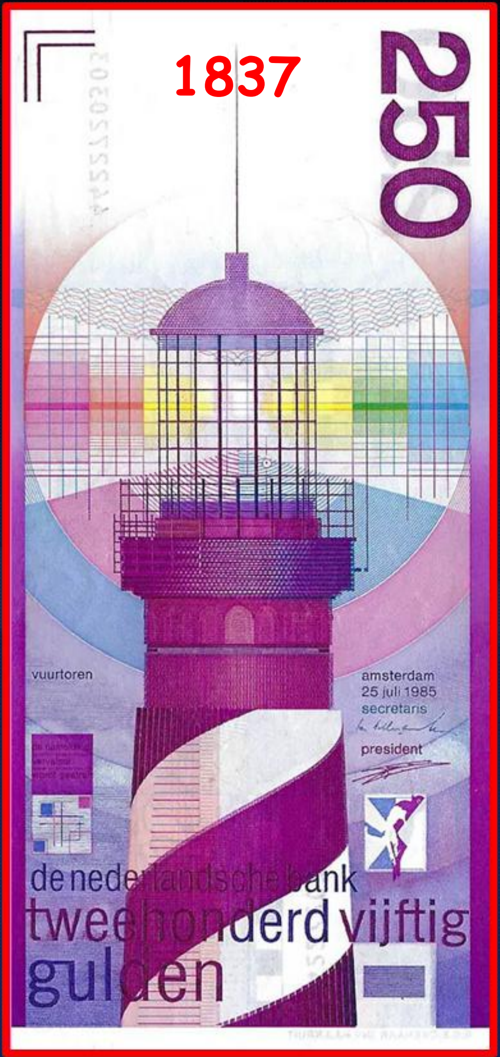
18th Century Age of Light Optics





Herschel Telescope 1787

19th Century Age of Light/Electricity



Davy
Ørsted
Volta
Ampere
Faraday
Ohm
Henry
Morse
Maxwell
Bell
Edison
Thompson

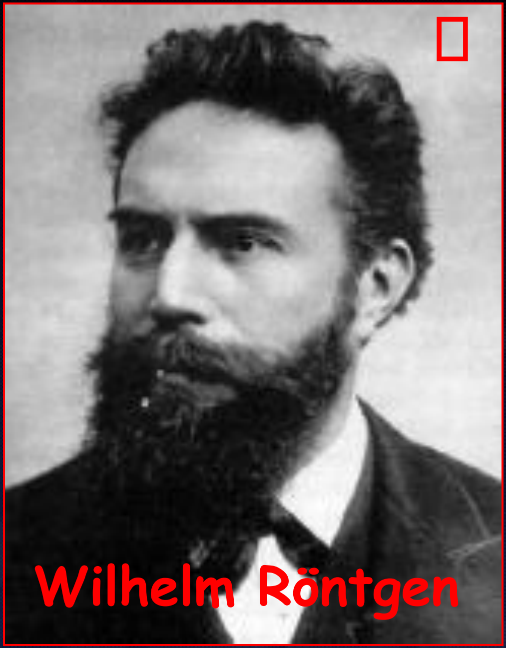
Booglamp
Electromotor
Electromagneet
Dynamo
Telegraafkabel
Brandstofcel
Oplaadbare batterij
EM theorie
Gloeilamp
Transformator
Radiogolven
Draadloze telegrafie
Kathodestraalbuis
Ontdekking electron

New York City 1880 vs Bangkok 2025

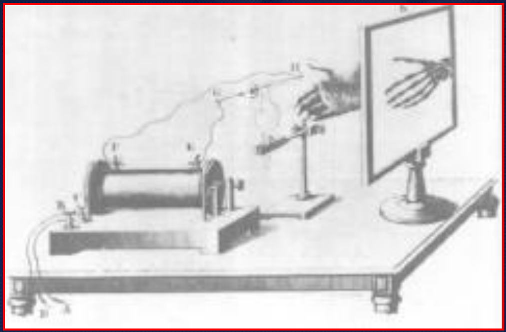
Dit is New York City in de jaren 1880.

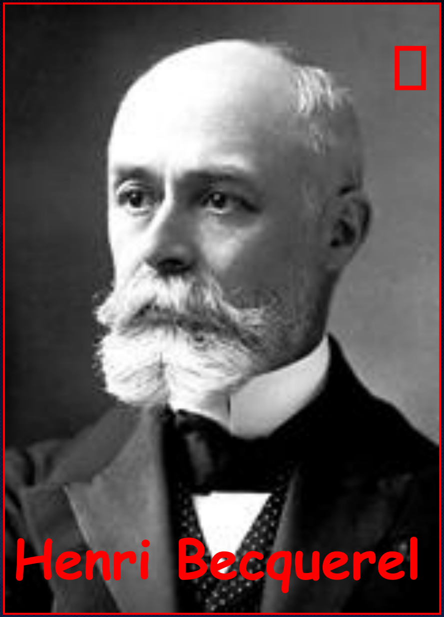
Dit is Bangkok anno 2025.

Discoveries of X-rays & Radioactivity

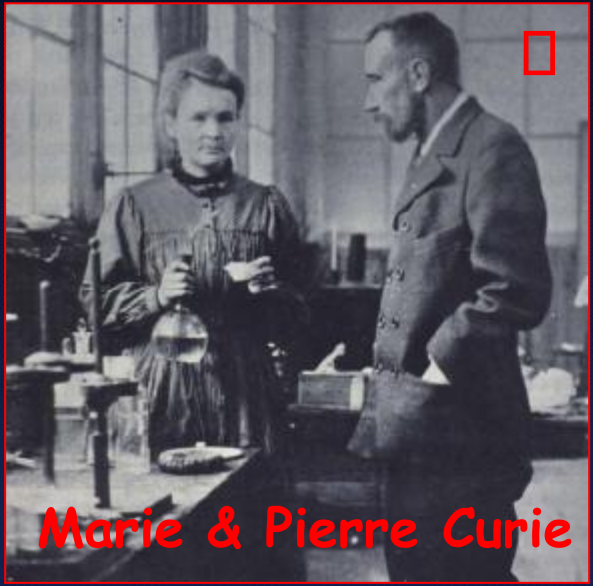

Wilhelm Röntgen

- 1895 X-rays



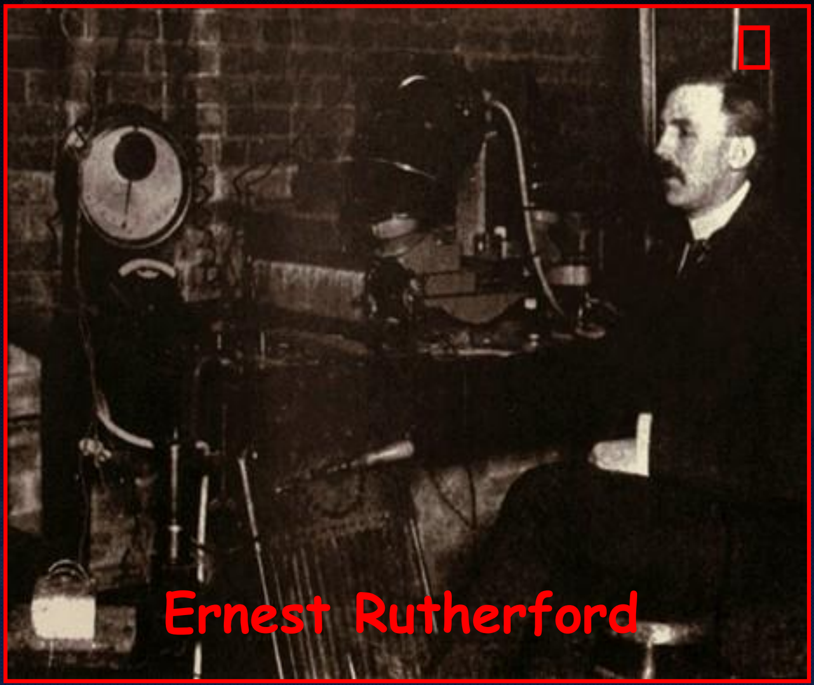

Henri Becquerel

- 1896 Radioactivity

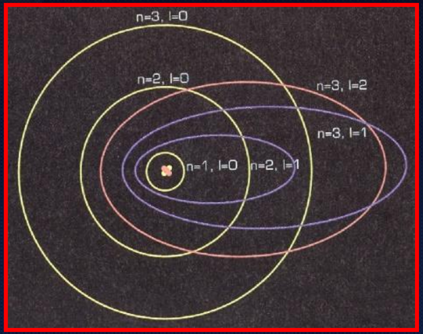

Marie & Pierre Curie

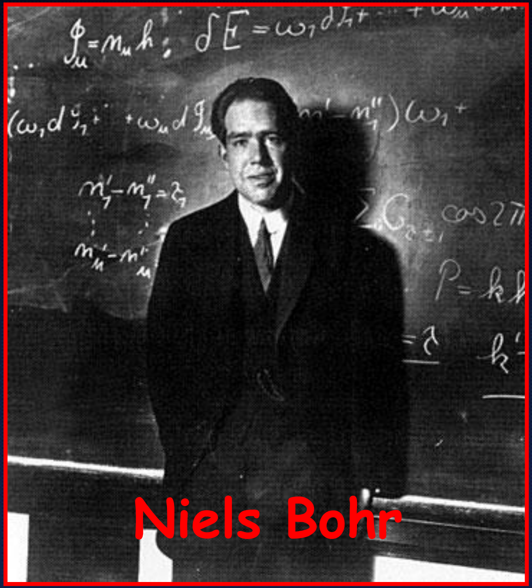
- 1898 Radio-active Elements (Po & Ra)

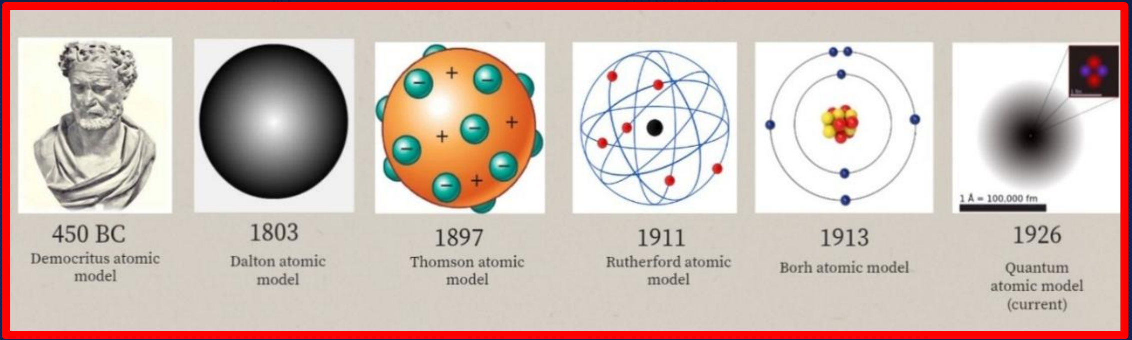
Birth of Atom Physics



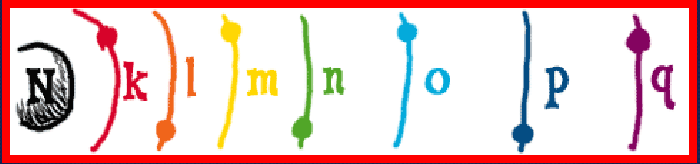
- 1919 nuclear reaction by using radio-active elements



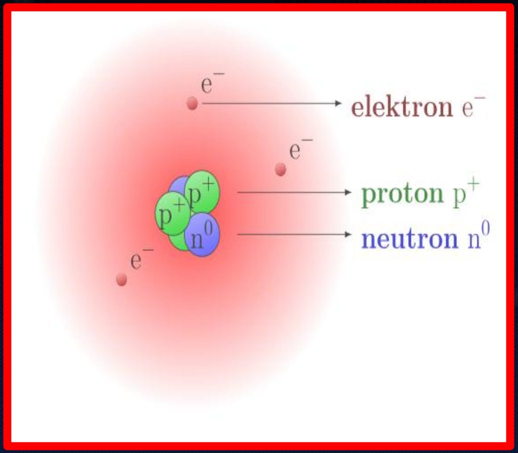


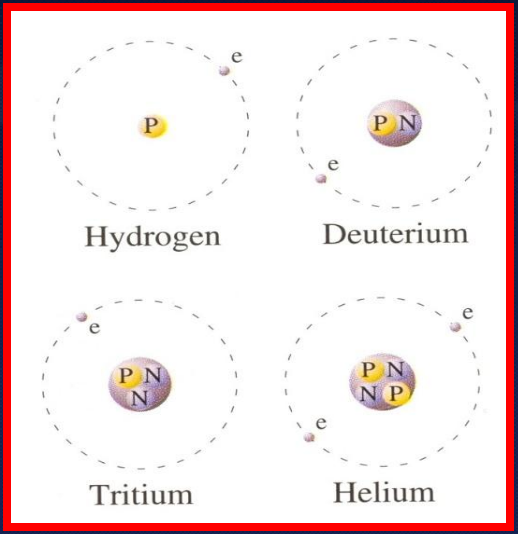


- 1913 Atom Models



The Composition of Matter





- the Elements
  118 elements
  atoms and nuclei
  periodical system
  (Mendeleev)
- the Nuclides
  280 stable
  >2300 instable
  nuclide chart
  (Segrè)

Periodic table of the elements

- Alkali metals
- Alkaline-earth metals
- Transition metals
- Other metals
- Other nonmetals
- Halogens
- Noble gases
- Rare-earth elements (21, 39, 57–71) and lanthanoid elements (57–71 only)
- Actinoid elements

period \ group	1*	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og

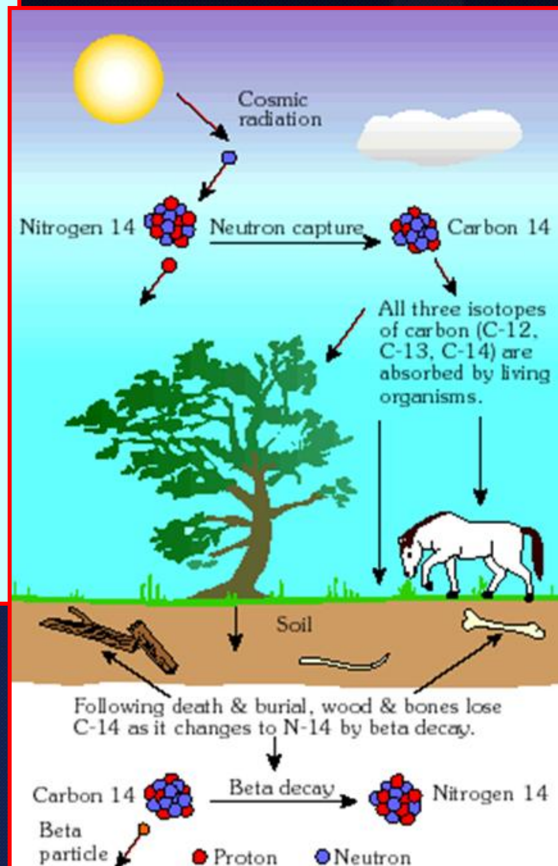
lanthanoid series 6	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
actinoid series 7	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

*Numbering system adopted by the International Union of Pure and Applied Chemistry (IUPAC).

Natural and Other Radionuclides

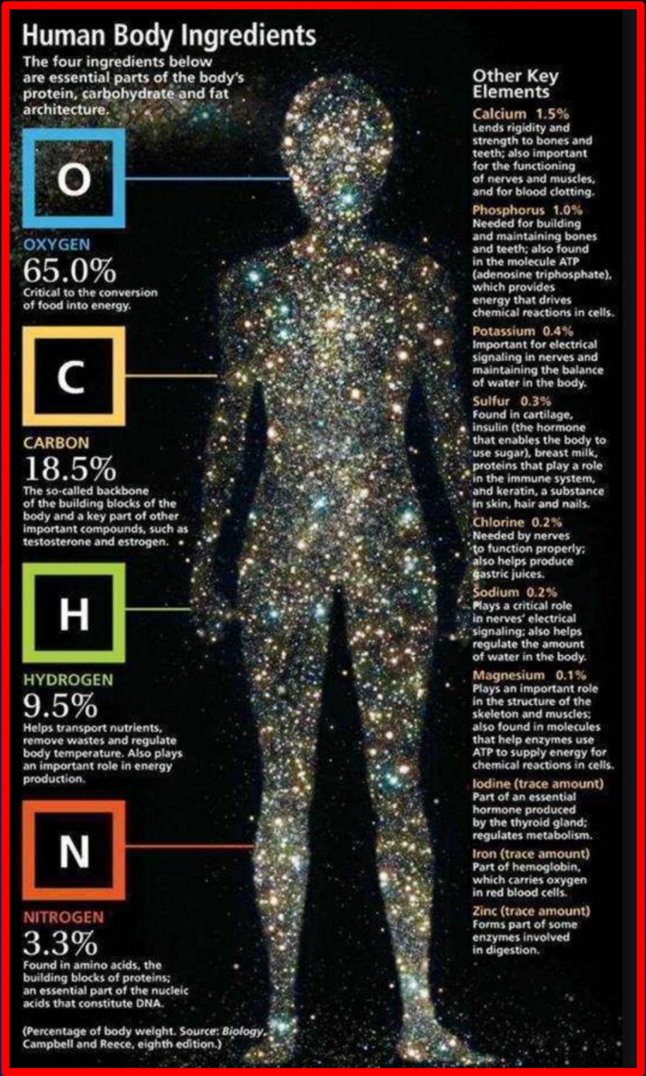
URANIUM 238 (U238) RADIOACTIVE DECAY

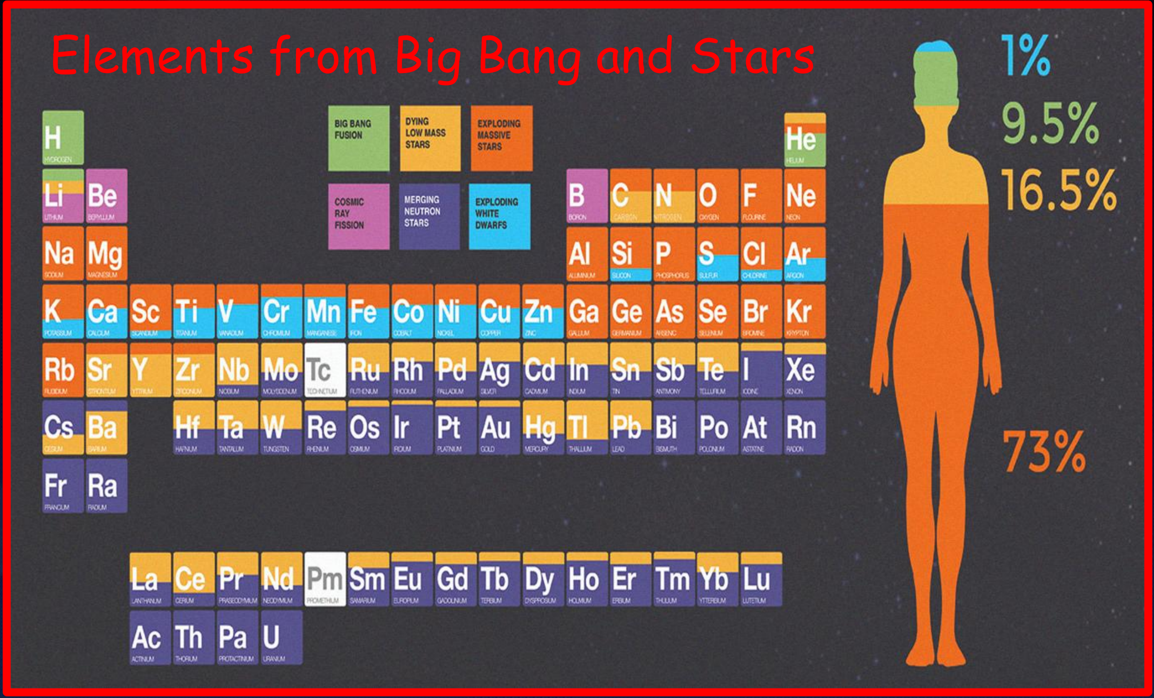
type of radiation	nuclide	half-life
	uranium—238	4.5 x10^{9} years
α	thorium—234	24.5 days
β	protactinium—234	1.14 minutes
β	uranium—234	2.33 x10^{5} years
α	thorium—230	8.3 x10^{4} years
α	radium—226	1590 years
α	radon—222	3.825 days
α	polonium—218	3.05 minutes
α	lead—214	26.8 minutes
β	bismuth—214	19.7 minutes
β	polonium—214	1.5 x10^{-4} seconds
α	lead—210	22 years
β	bismuth—210	5 days
β	polonium—210	140 days
α	lead—206	stable



- Terrestrial radionuclides:
  ^{238}U(4.5*10^{9}y), ^{232}Th(1.4*10^{10}y), ^{40}K(1.3*10^{9}y), ^{235}U(7*10^{8}y), . . .
- Cosmogene radionuclides:
  ^{3}H(12,4y), ^{7}Be(53d), ^{14}C(5730y), ^{22}Na(2,6y), . . .
- Artificial Produced Radionuclides
  medical:
  ^{18}F(2h), ^{99m}Tc(6h), ^{131}I(8d), . . .
  industrial:
  ^{60}Co(5,7y),^{241}Am(432y), . . .

Human Elemental Composition



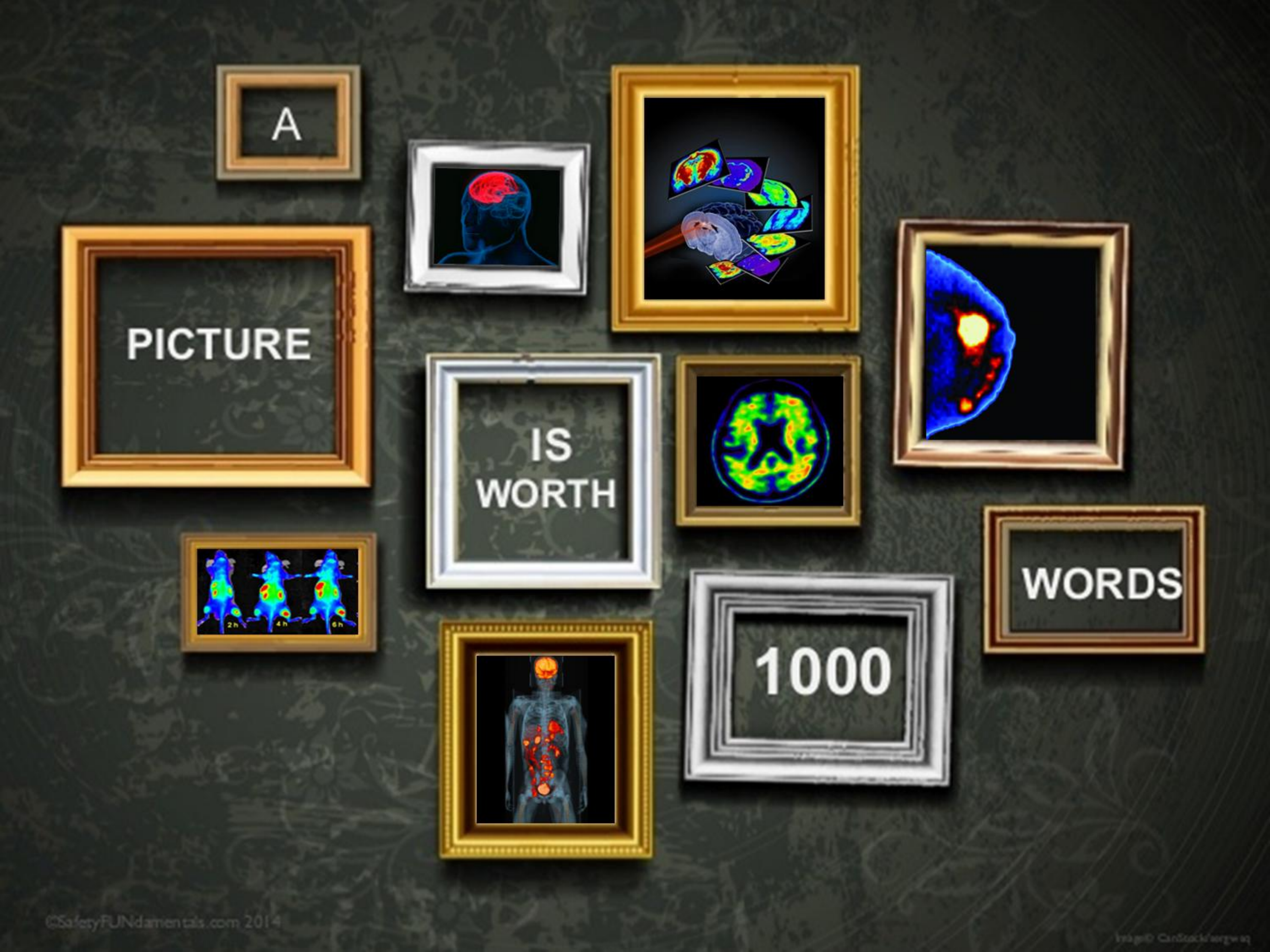


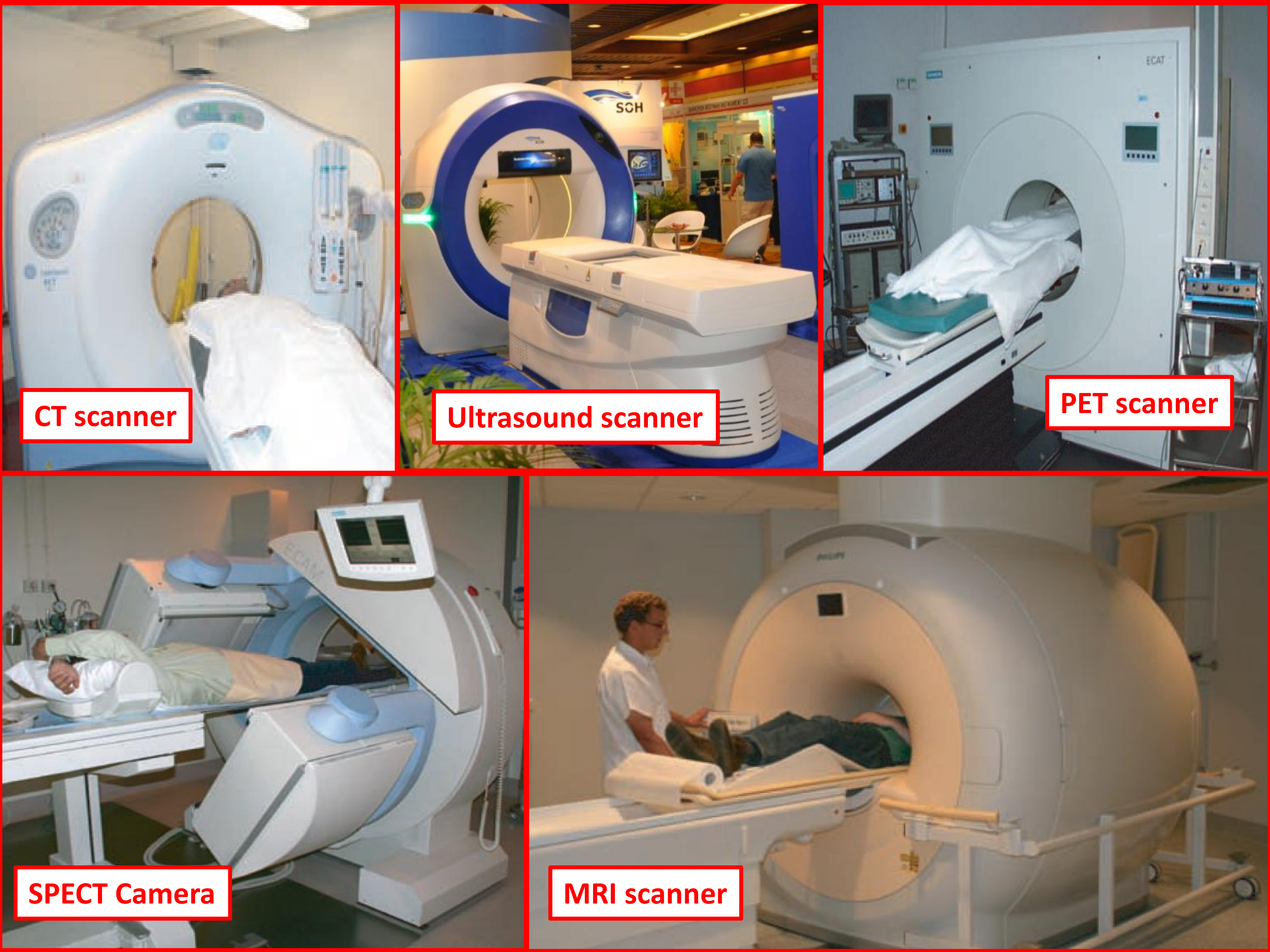
Radionuclides in the body:

^{40}K isotope of Potassium

^{14}C isotope of Carbon

^{226}Ra isotope of Radium


A
PICTURE
IS
WORTH
1000
WORDS
2h
4h
6h
©SafetyFUNdamentals.com 2014


CT scanner
SOH
Ultrasound scanner
ECAT
PET scanner
SPECT Camera
MRI scanner

Medical Imaging Modalities

- Non-ionizing Radiation Techniques

  MR Techniques (MRI)

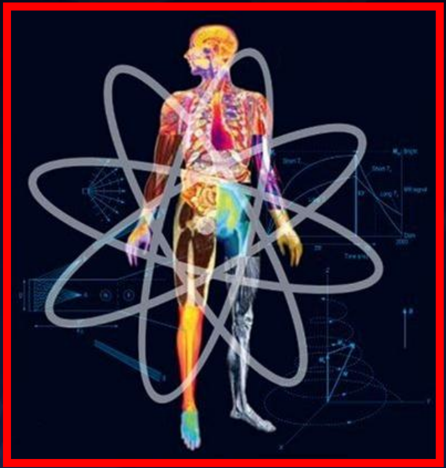
  Ultrasound

- Ionizing Radiation Techniques

  X-ray Techniques (CT)

  Nuclear Imaging (PET)

Why are there so many modalities?



structure or function?

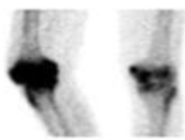
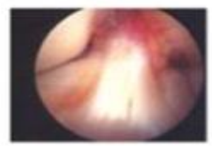
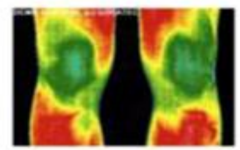
desired temporal resolution

desired spatial resolution

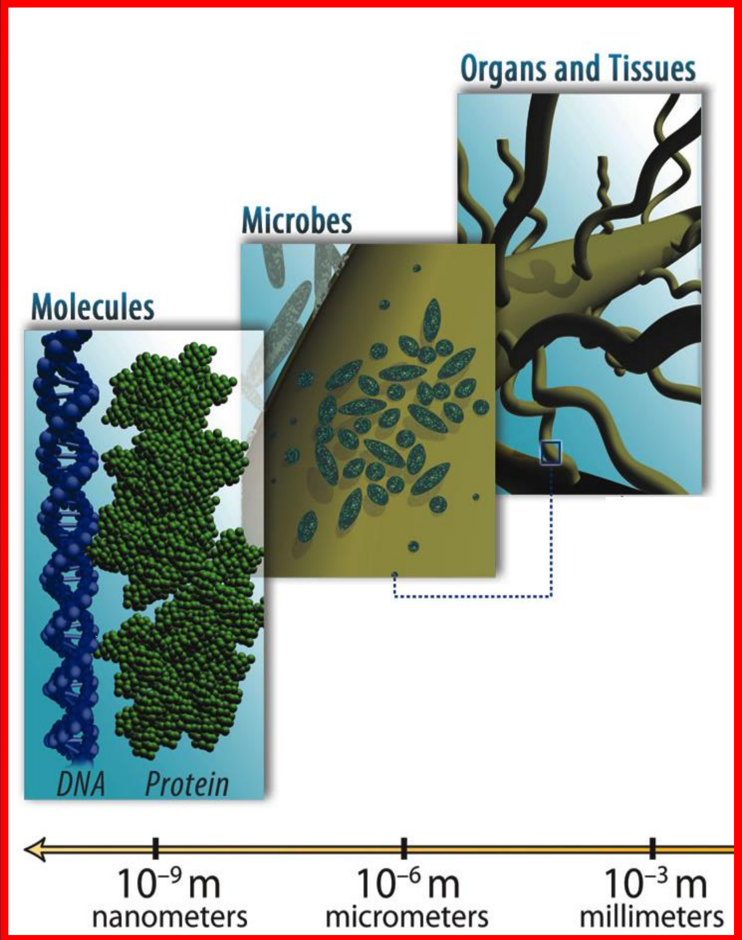
desired field of view

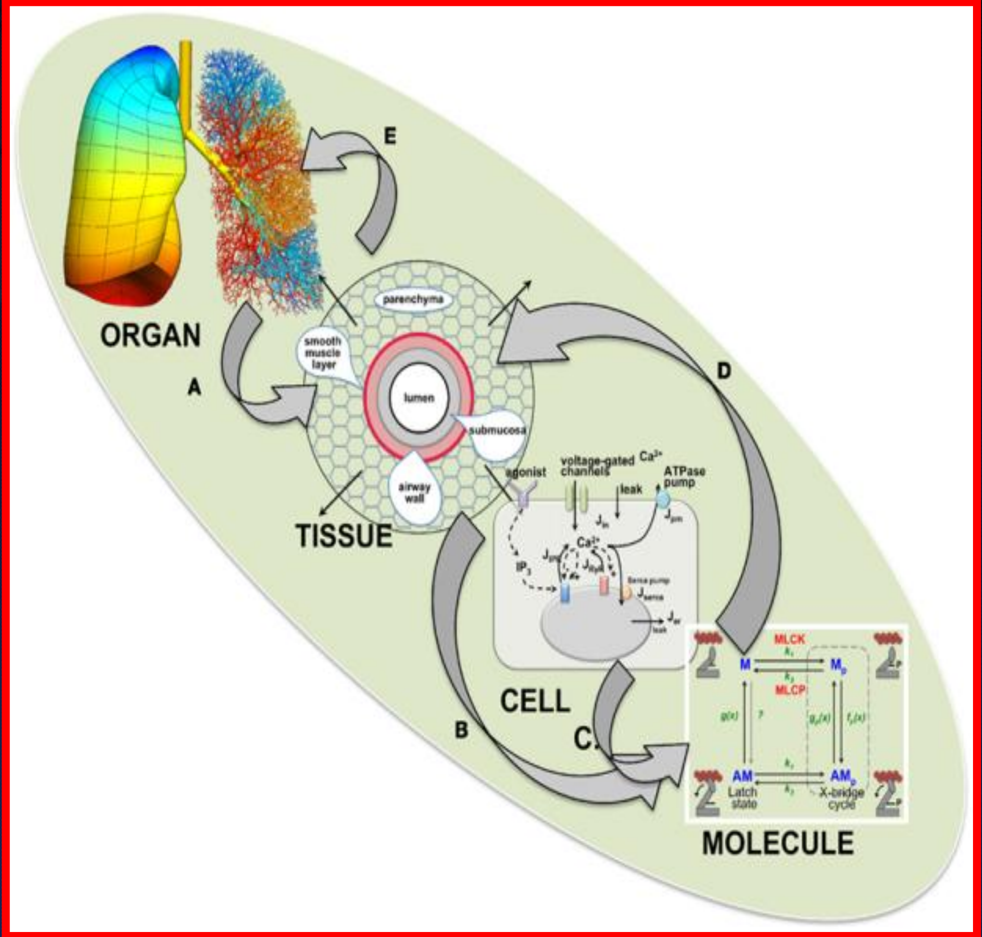
tissue culture, tissue slice, or in vivo ?

The Electromagnetic Spectrum

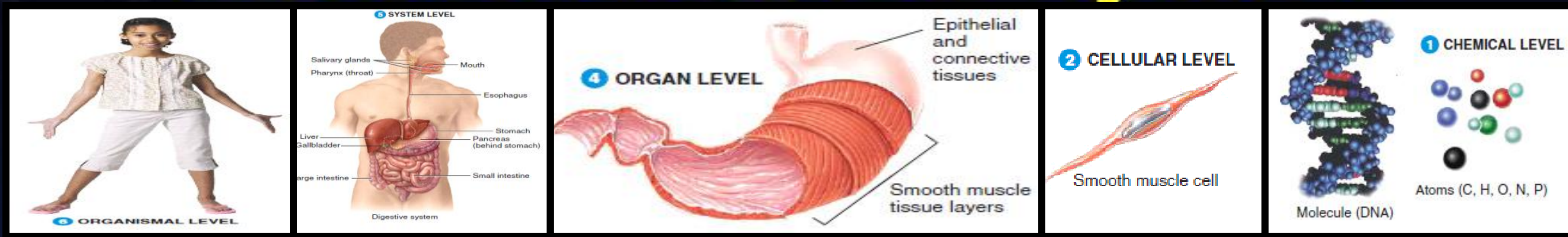
Radiation / Wavelength	Gamma ray 10^{-12}	X-Ray 10^{-10}	Ultraviolet 10^{-8}	Visible Light 10^{-6}	Infrared 10^{-5}	Microwave 10^{-2}	Radio Wave 10^{-3}
Modality	 Scintigraphy	 X-Ray	 UV-radiation	 Arthroscopy	 Infrared Imaging	 MRI image	 Ultrasound
Medical information	*Physiology*	*Anatomy*	*Healing/Therapy*	*Anatomy*	*Anatomy and Physiology*	*Anatomy*	*Anatomy*
	Inflammation, metabolism of the bone	Bone injuries	Skin, chronic Inflammation	Intraarticular structure, inflammation	Surface temperature	Tissue structure characteristics, flow	Edema, flow Chemical composition

Spatial Scales





Spatial Scales in the Central Nervous System



CNS	Systems	Maps	Networks	Neurons	Synapses	Molecules
1 m	10 cm	1 cm	1 mm	100 μm	1 μm	0.1 nm

Positron Emission Tomography

Electron Microscopy

Ultrasound Imaging

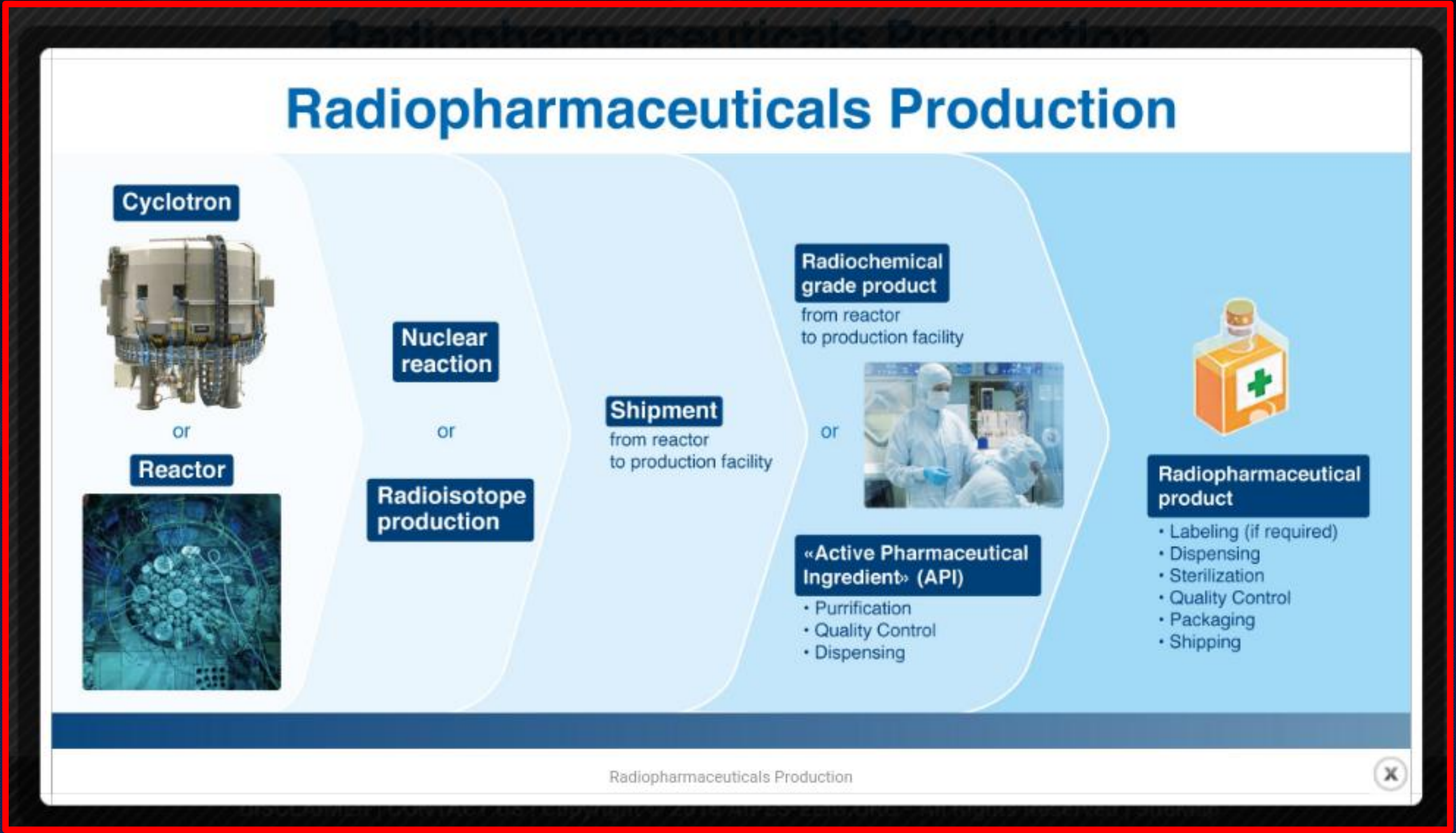
Light Microscopy

Autoradiography

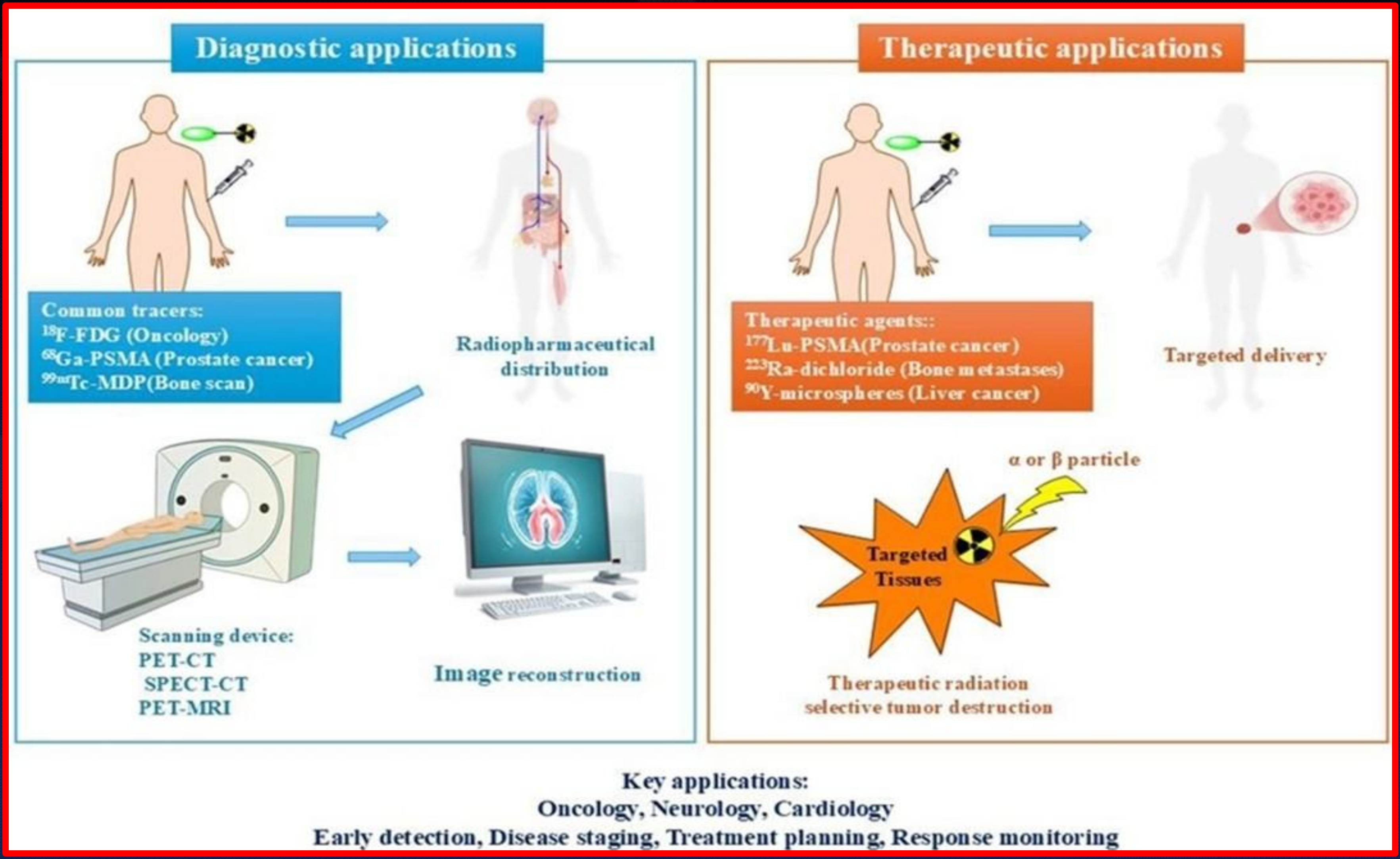
Computed Tomography

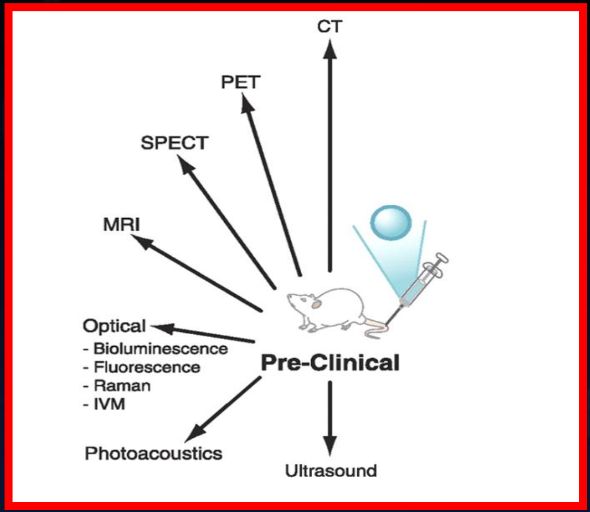
Magnetic Resonance Imaging

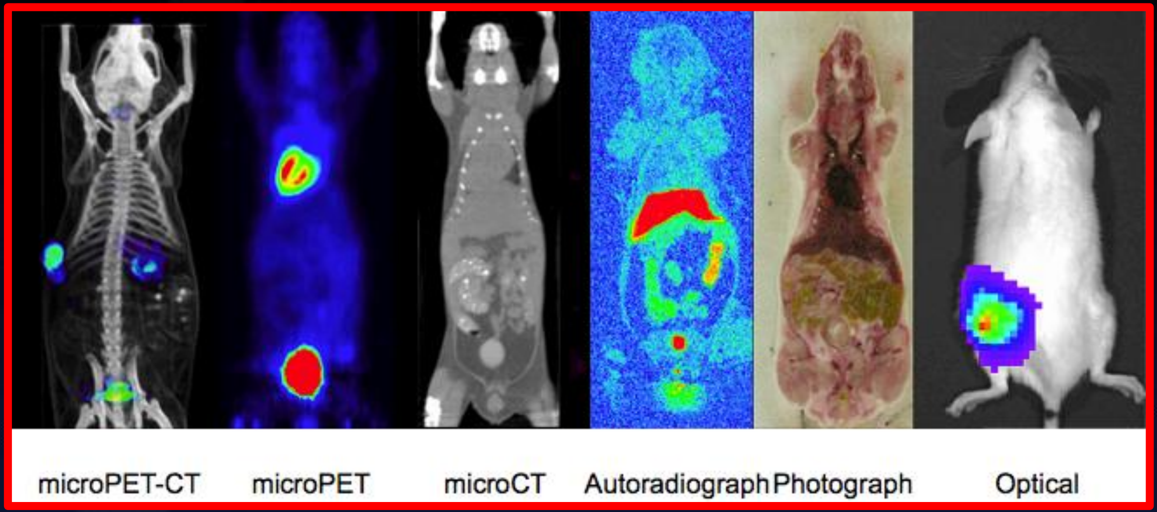
Artificial Produced Radionuclides & Radiopharmaceuticals

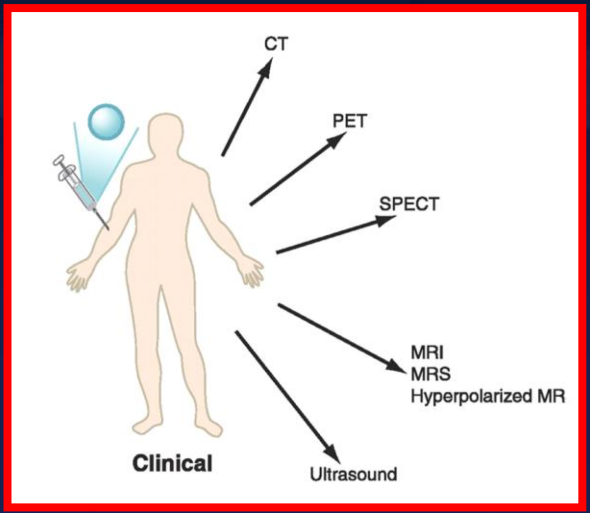


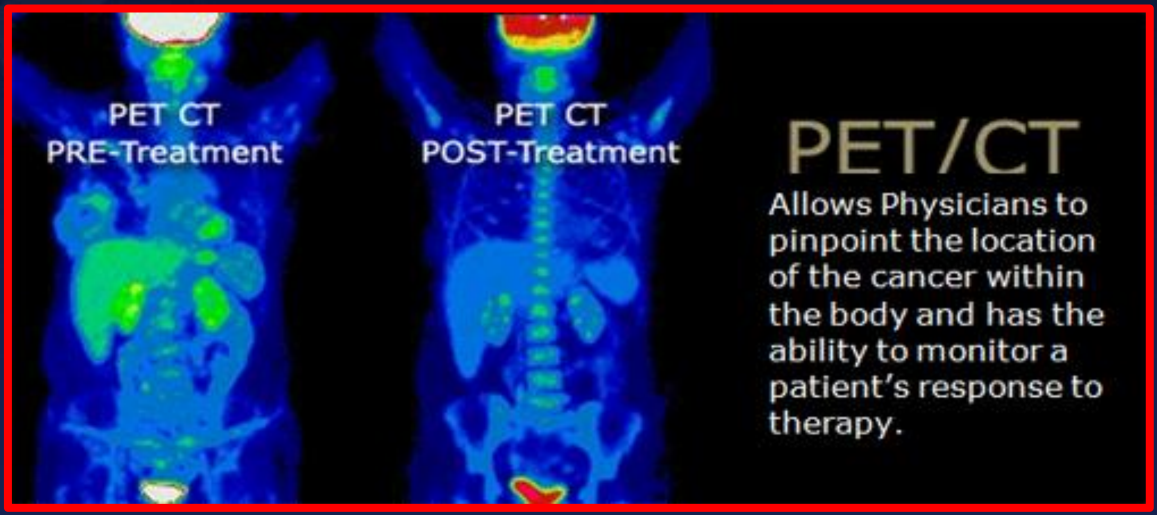
Radionuclides for Diagnosis and Therapy

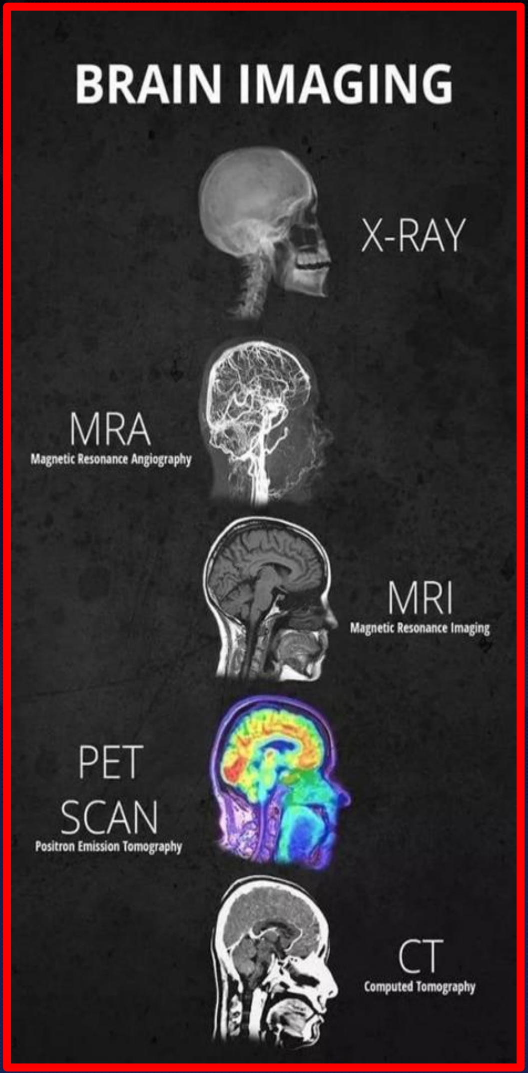


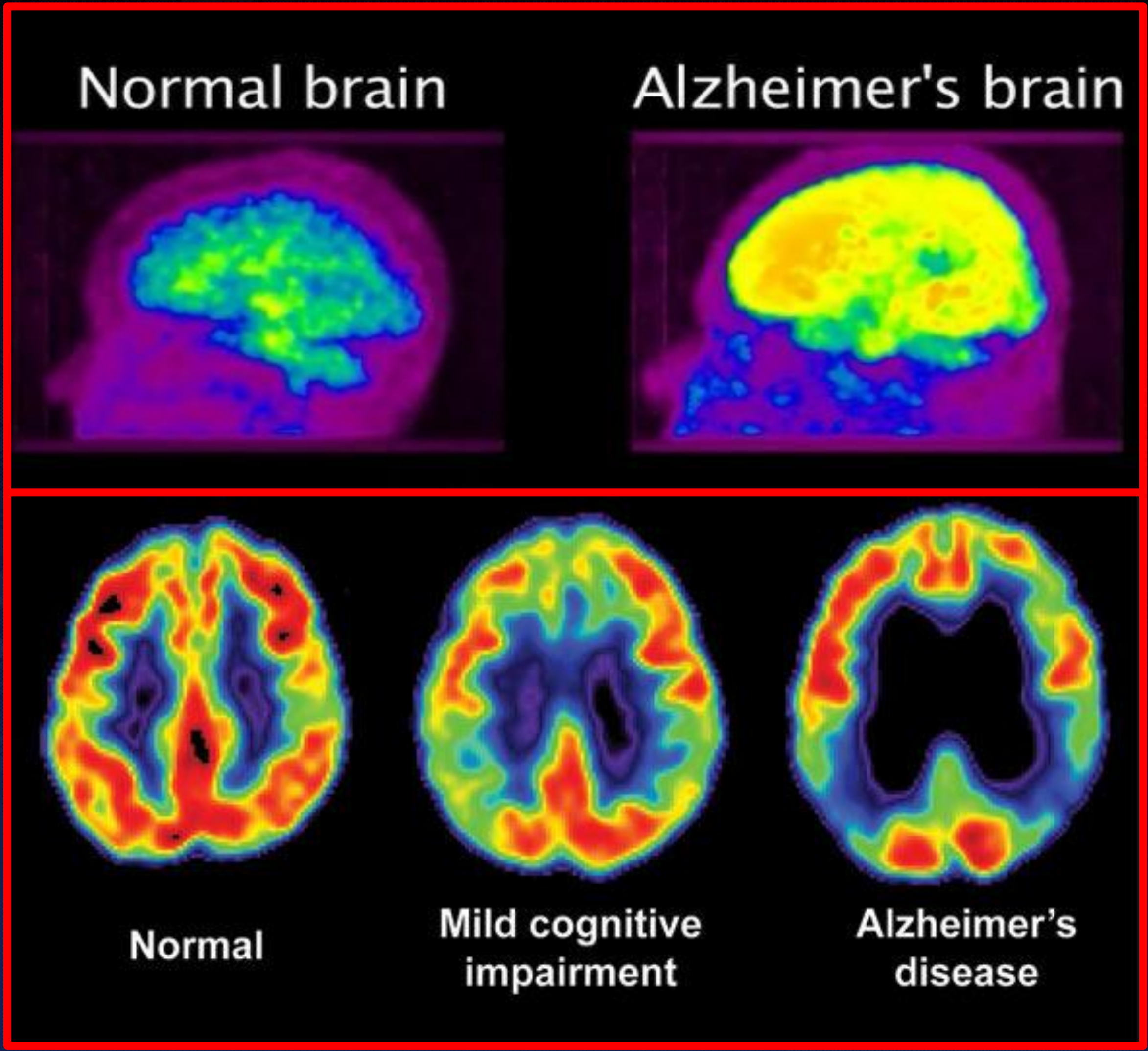

CT
PET
SPECT
MRI
Optical
- Bioluminescence
- Fluorescence
- Raman
- IVM
Pre-Clinical
Photoacoustics
Ultrasound


microPET-CT
microPET
microCT
Autoradiograph
Photograph
Optical

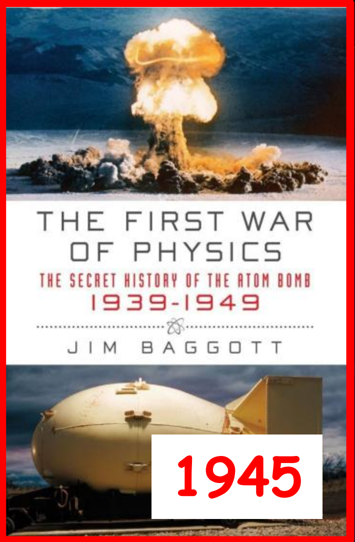

CT
PET
SPECT
MRI
MRS
Hyperpolarized MR
Clinical
Ultrasound

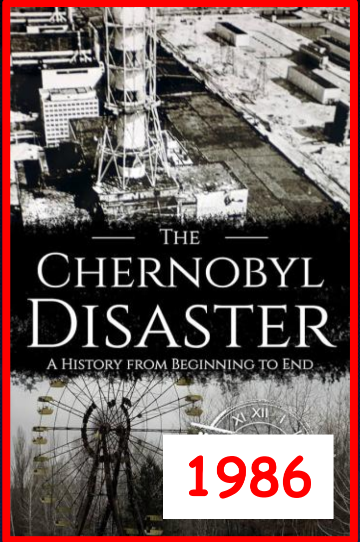

PET CT
PRE-Treatment
PET CT
POST-Treatment
PET/CT
Allows Physicians to pinpoint the location of the cancer within the body and has the ability to monitor a patient's response to therapy.

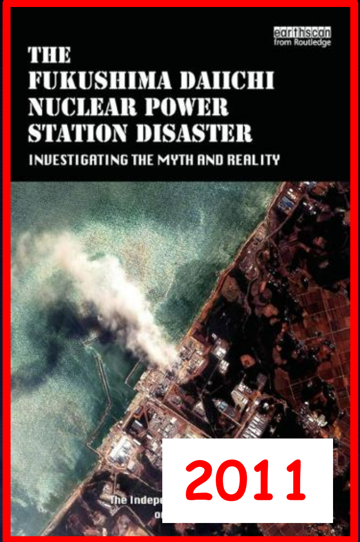

BRAIN IMAGING
X-RAY
MRA
Magnetic Resonance Angiography
MRI
Magnetic Resonance Imaging
PET
SCAN
Positron Emission Tomography
CT
Computed Tomography


Normal brain
Alzheimer's brain
Normal
Mild cognitive impairment
Alzheimer's disease

20th Century Age of (Ionising) Radiation

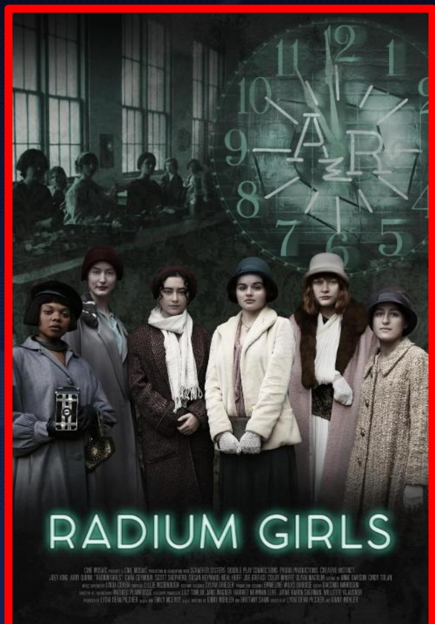


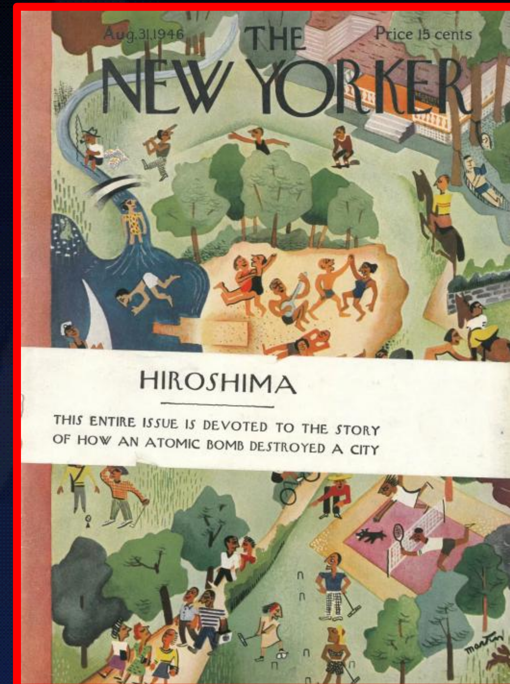




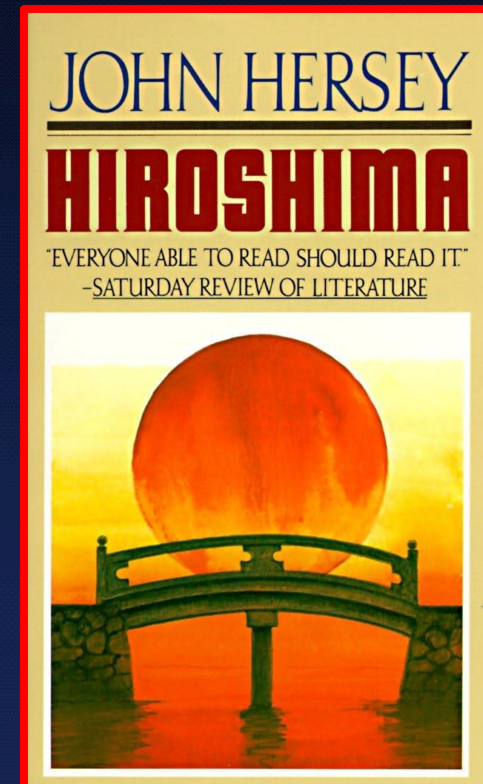
Examples of Collective Exposure

- 1879
  Uranium mijnwerkers
  Erzgebergte (CZ/DE)

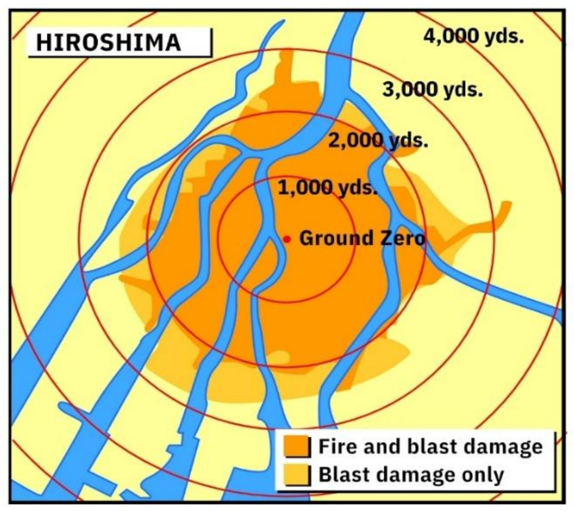




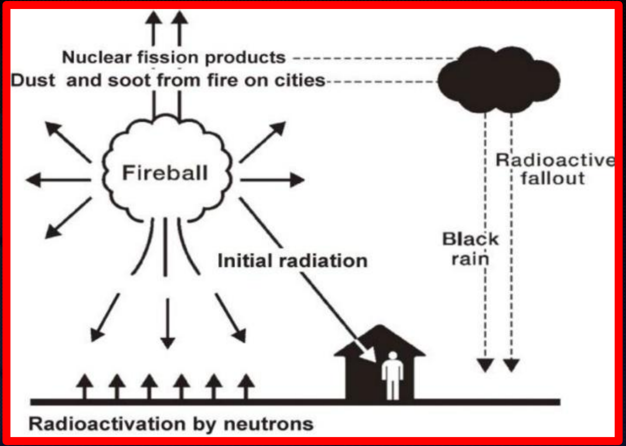
- 1945
  Hiroshima

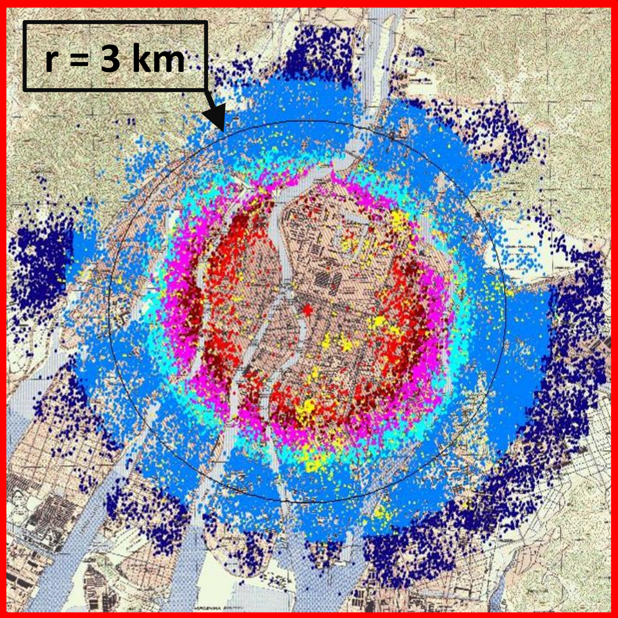


- 1920s
  "Radium Girls" de wijzerplaat ververs
  (lick, dip, paint)



Atomic Bomb Damage of Hiroshima





- korte termijn effecten (1):
  - explosie 50% energie
  - hitte 35% energie
  - straling 15% energie
  - houten structuren verbrand < 2.0 km
  - massale destructive schokgolf < 2.5 km

- korte termijn effecten (2):
  - Hiroshima: 110.000 -140.000 doden
    30%-40% van de populatie
  - mortaliteit >60% binnen 1 km

Radiation exposure How does it compare?

Exposure measured in mSv

mSv	Description
10,000	Fatal within weeks — LD100
6,000	Typical dosage recorded in those Chernobyl workers who died within a month
5,000	Single dose which would kill half of those exposed to it within a month
1,000	Single dose which could cause radiation sickness, nausea, but not death
400	Max radiation levels recorded at Fukushima plant 14 March, per hour
350	Exposure of Chernobyl residents who were relocated
100	Recommended limit for radiation workers every five years
10	Dose in full-body CT scan
9	Airline crew NYC -Tokyo polar route, annual
2	Natural radiation we're all exposed to, per year
1.02	Radiation per hour detected Fukushimia site, 12 March
0.4	Mammogram breast x-ray
0.1	Chest x-ray
0.01	Dental x-ray

SOURCE: WNA, RADIOLOGYINFO.ORG, REUTERS

Biologic Effects based on Hiroshima/Nagasaki

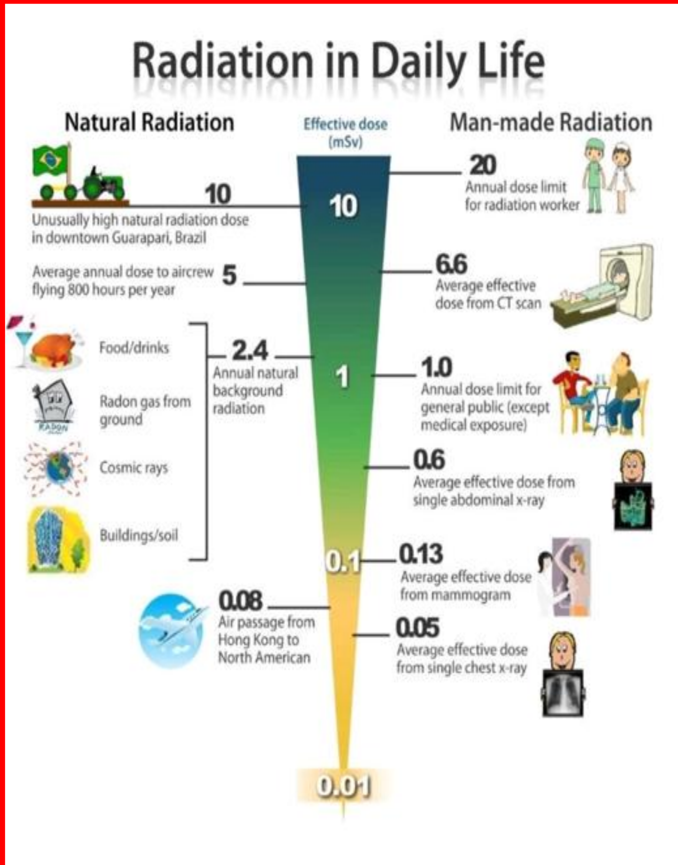
DETERMINISTISCHE EFFECTEN

- Stralingsziekte
  - "Beenmerg" Syndroom
  - "Darm" Syndroom
  - "Hersen" Syndroom

STOCHASTISCHE EFFECTEN

- Risico op kanker

Radiation in Daily Life I

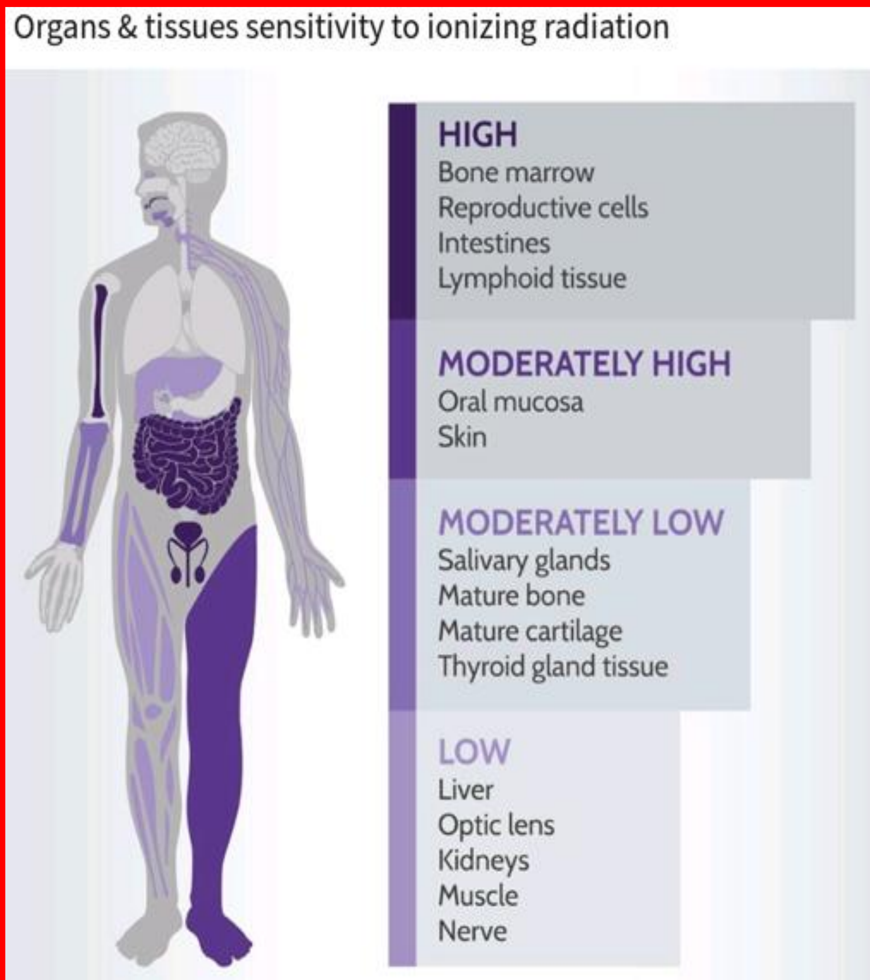


Public exposure to natural radiation[e]

Source of exposure		Annual effective dose (mSv) Average	Typical range
Cosmic radiation	Directly ionizing and photon component	0.28	
	Neutron component	0.10	
	Cosmogenic radionuclides	0.01	
	Total cosmic and cosmogenic 16%	*0.39*	*0.3–1.0*[e]
External terrestrial radiation	Outdoors	0.07	
	Indoors	0.41	
	Total external terrestrial radiation 20%	*0.48*	*0.3-1.0*[e]
Inhalation	Uranium and thorium series	0.006	
	Radon (Rn-222)	1.15	
	Thoron (Rn-220)	0.1	
	Total inhalation exposure 53%	*1.26*	*0.2-10*[e]
Ingestion	K-40	0.17	
	Uranium and thorium series	0.12	
	Total ingestion exposure 16%	*0.29*	*0.2-1.0*[e]
Total	*Public exposure to natural radiation 100%*	*2.4 mSv*	**1.0-13**

Radiation in Daily Life II

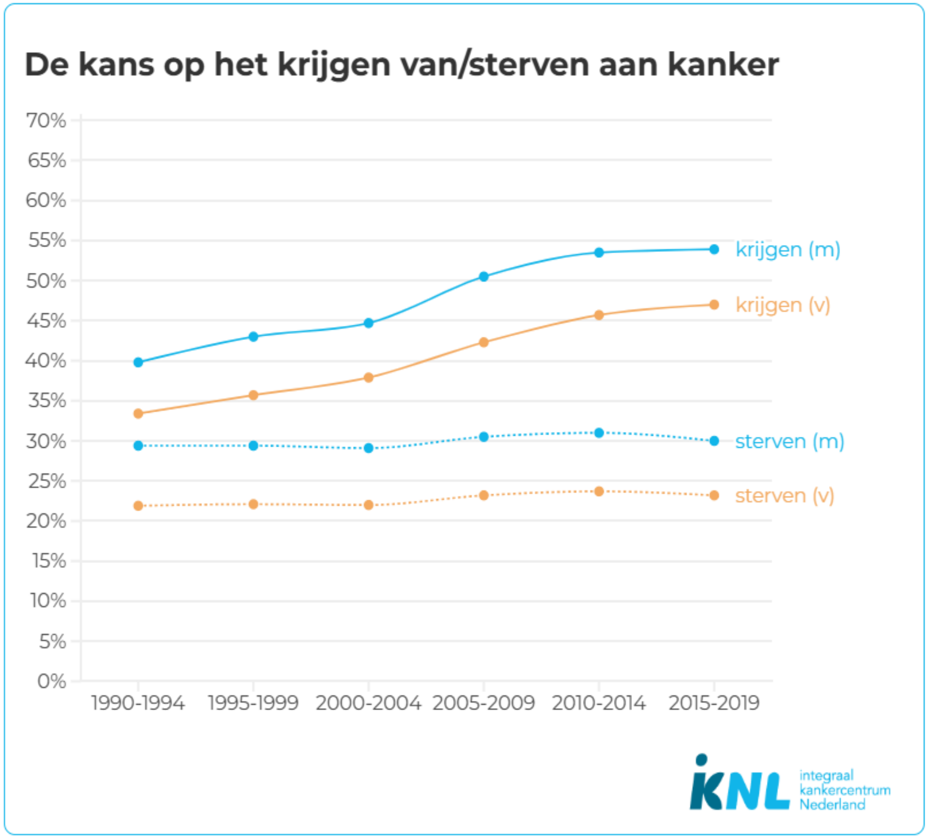
Radiation Dose from Medical Examinations



Radiation Dose to Adults From Common Imaging Examinations

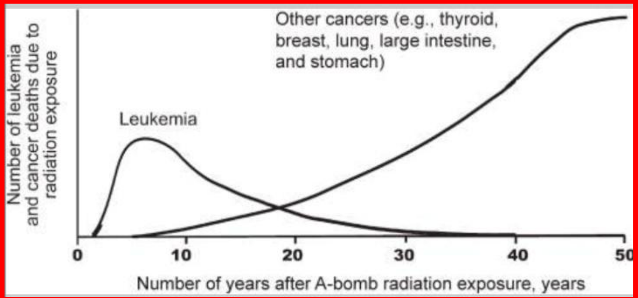
	Procedure	Approximate effective radiation dose	Comparable to natural background radiation for
ABDOMINAL REGION	Computed Tomography (CT) — Abdomen and Pelvis	10 mSv	3 years
	Computed Tomography (CT) — Abdomen and Pelvis, repeated with and without contrast material	20 mSv	7 years
	Computed Tomography (CT) — Colonography	6 mSv	2 years
	Intravenous Pyelogram (IVP)	3 mSv	1 year
	Barium Enema (Lower GI X-ray)	8 mSv	3 years
	Upper GI Study With Barium	6 mSv	2 years
BONE	Spine X-ray	1.5 mSv	6 months
	Extremity (hand, foot, etc.) X-ray	0.001 mSv	3 hours
CENTRAL NERVOUS SYSTEM	Computed Tomography (CT) — Head	2 mSv	8 months
	Computed Tomography (CT) — Head, repeated with and without contrast material	4 mSv	16 months
	Computed Tomography (CT) — Spine	6 mSv	2 years
CHEST	Computed Tomography (CT) — Chest	7 mSv	2 years
	Computed Tomography (CT) — Lung Cancer Screening	1.5 mSv	6 months
	Chest X-ray	0.1 mSv	10 days
DENTAL	Dental X-ray	0.005 mSv	1 day
HEART	Coronary Computed Tomography Angiography (CTA)	12 mSv	4 years
	Cardiac CT for Calcium Scoring	3 mSv	1 year
MEN'S IMAGING	Bone Densitometry (DEXA)	0.001 mSv	3 hours
NUCLEAR MEDICINE	Positron Emission Tomography — Computed Tomography (PET/CT)	25 mSv	8 years
WOMEN'S IMAGING	Bone Densitometry (DEXA)	0.001 mSv	3 hours
	Mammography	0.4 mSv	7 weeks

Risk of Cancer/Dying in a Lifetime



Het risico op kanker ten gevolge van ioniserende straling is:

~ 5 % per Sievert

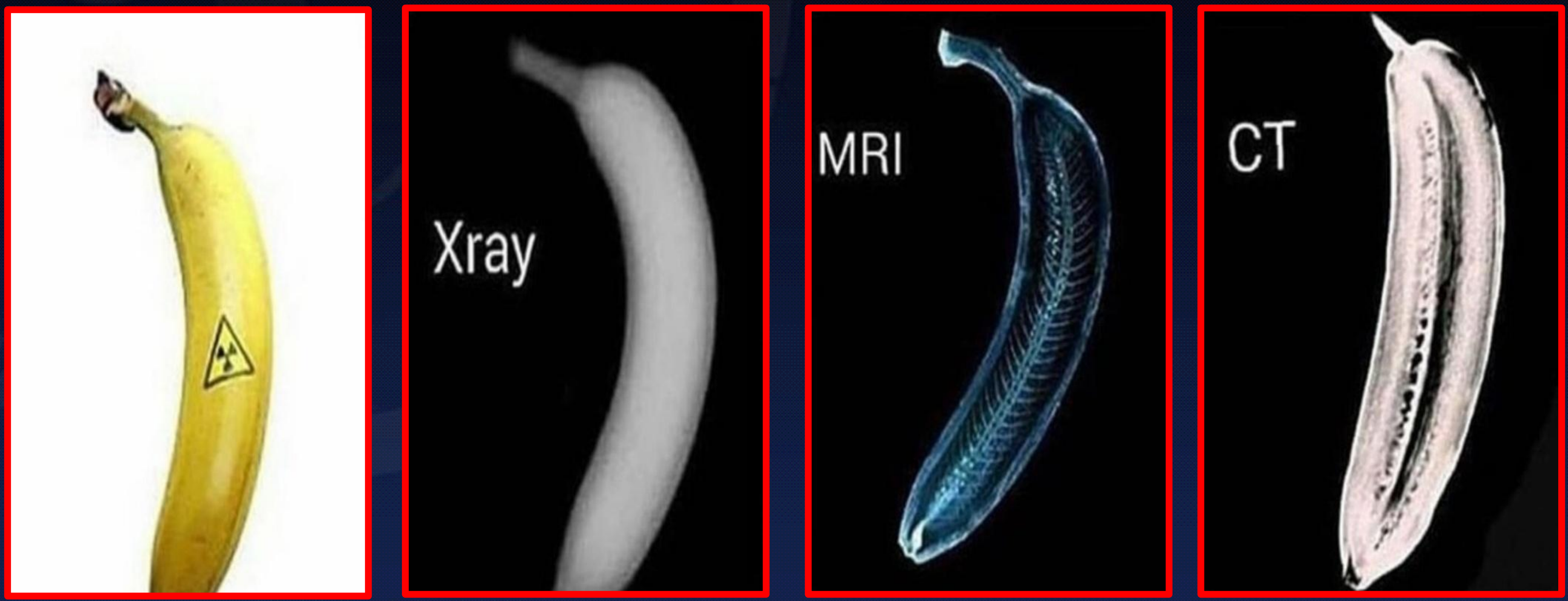


https://www.ntvg.nl/artikelen/ontwikkeling-van-de-kans-op-kanker-1990-2019

Non-Medical Imaging

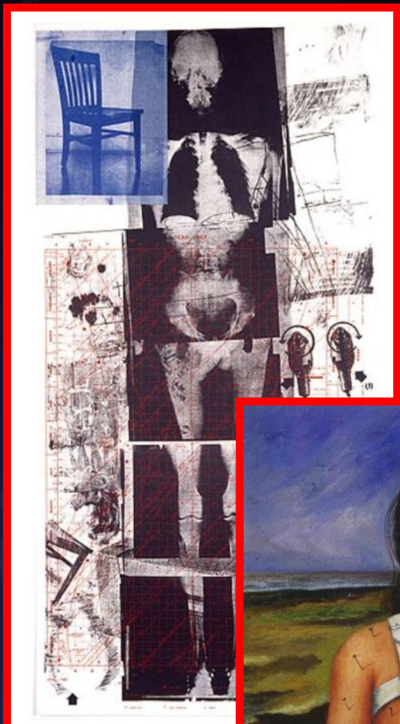
- Drug- and Human Trafficking
- Baggage Screening
- Art Objects

Non-Medical Imaging

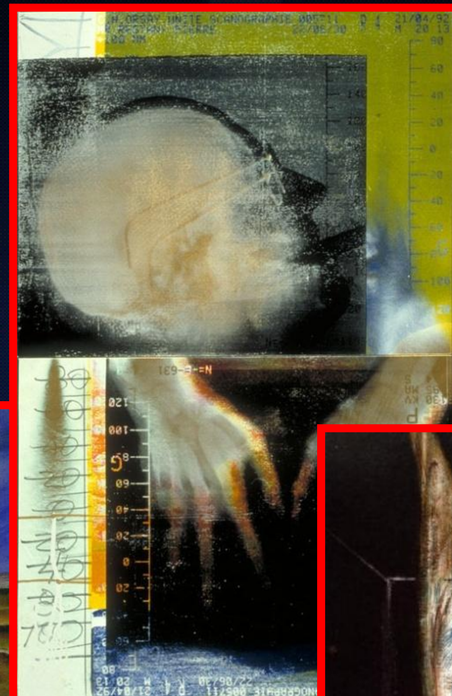


Non-Medical Imaging and the Arts

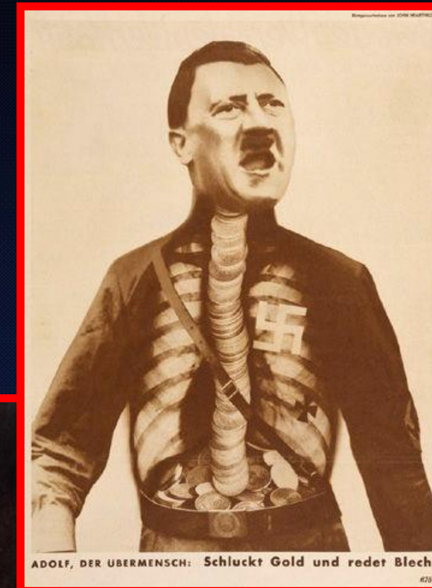
Rauschenberg

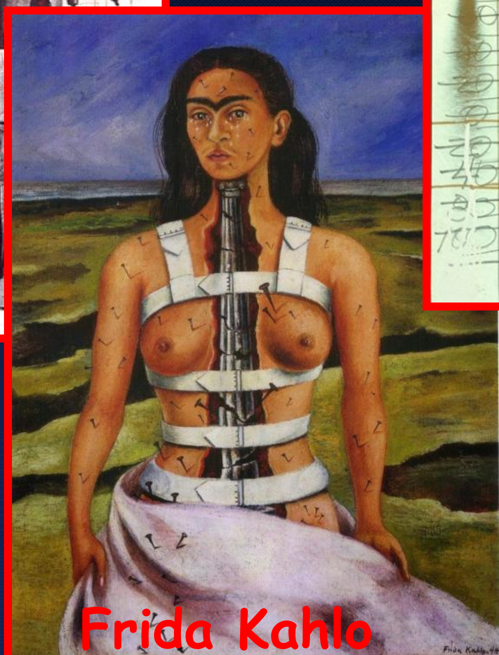


Steve Miller



Heartfield





Frida Kahlo

Francis Bacon

Some Medical Related Topics

"Your cat scan looks fine, your pet scan looks fine, your MRI looks fine, but your insurance reimbursement doesn't look fine."

- Preventive Whole-Body Scan?
- Unjustified use of Medical Procedures
- Overall Increase of Collective Dose
- Personalised Medicine
- Health Insurance costs

Some Medical Related Conclusions

- Medical Imaging is a non-invasive (mostly diagnostic) practice.
- Medical Imaging is team work and needs highly qualified personnel. (High Tech and Multi-Discipline)
- Medical Imaging Modalities are complementary.
- Medical Imaging has a spin off in many domains.
- Overall Increase of Collective Dose
- Danger of Medicalization

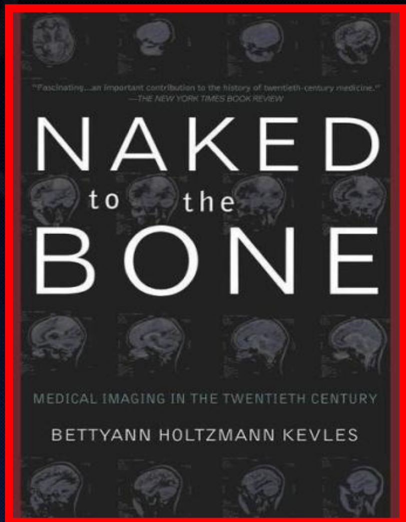
Some General Conclusions

Francisco de Holanda (1545)

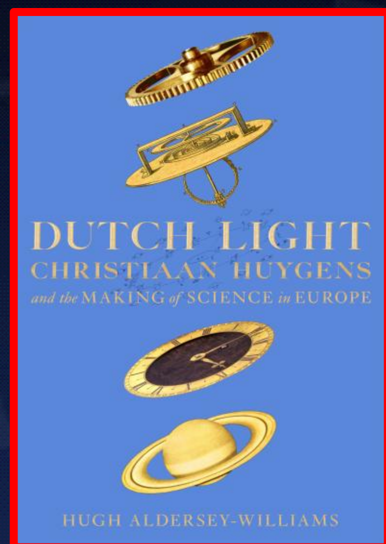
- Radiation is a General Natural Phenomenon all around in Time and Space.
- In Short:
  Radiation is Energy on the move.
- In Practice:
  Be aware of the distinction between Ionising and Non-Ionising Radiation

  Exposure to Ionising Radiation is basically not without Risk.

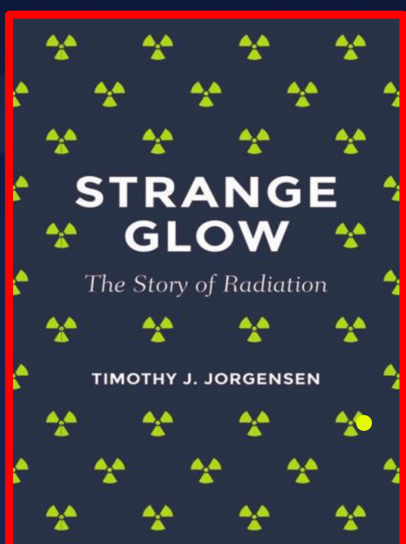
References



Naked to the Bone: Medical Imaging in the Twentieth Century (1997) - *B. Kevles*

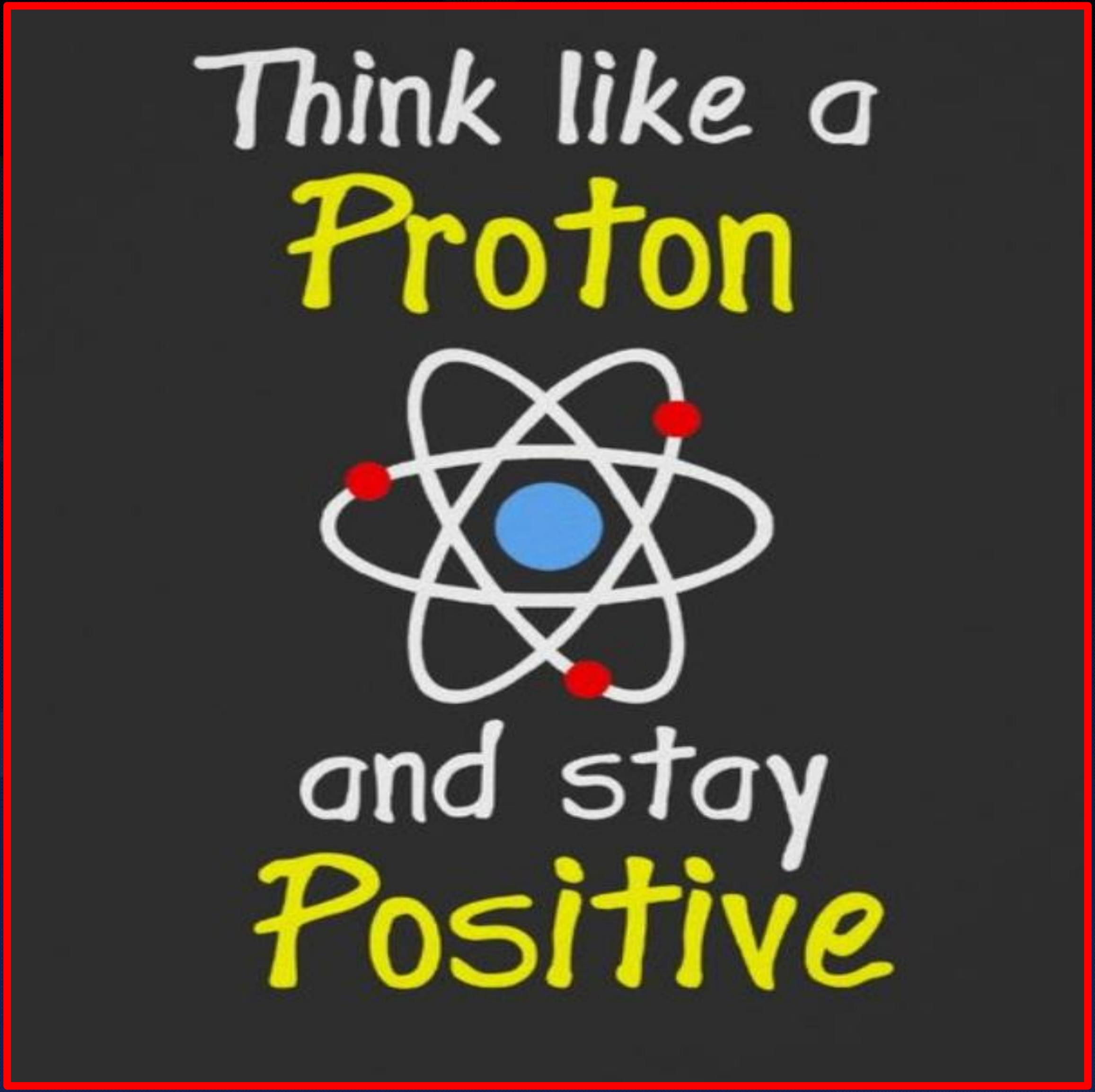


Dutch Light (2020) - *Hugh Aldersey-Williams*



Strange Glow (2020) - *Timothy J. Jorgensen*

- YouTube (DWDD Licht)
- http://www.unscear.org/
- https://www.iaea.org
- http://www.who.int


Think like a
Proton
and stay
Positive