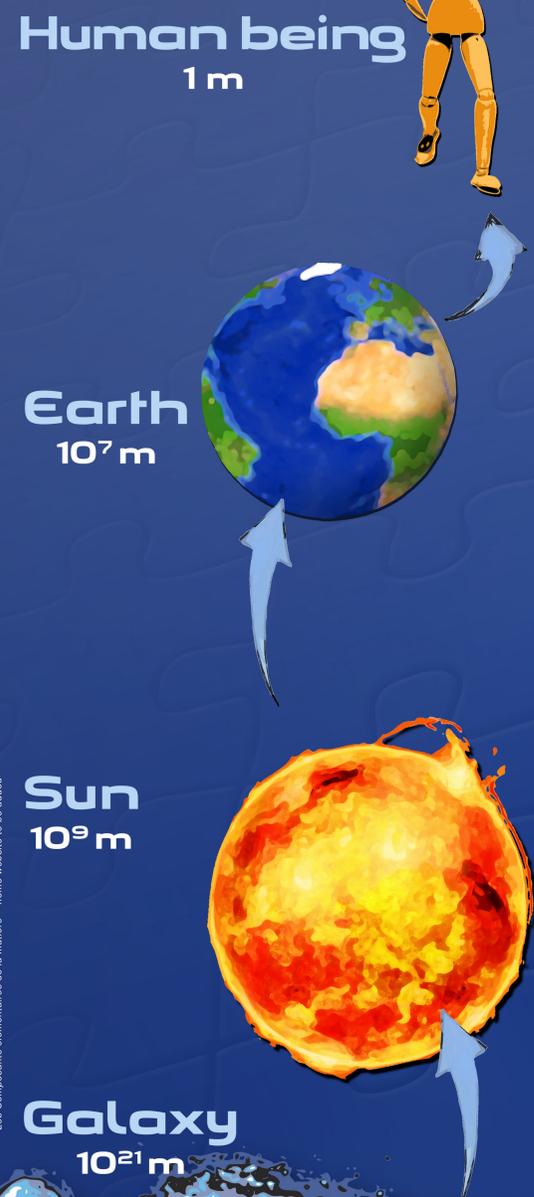
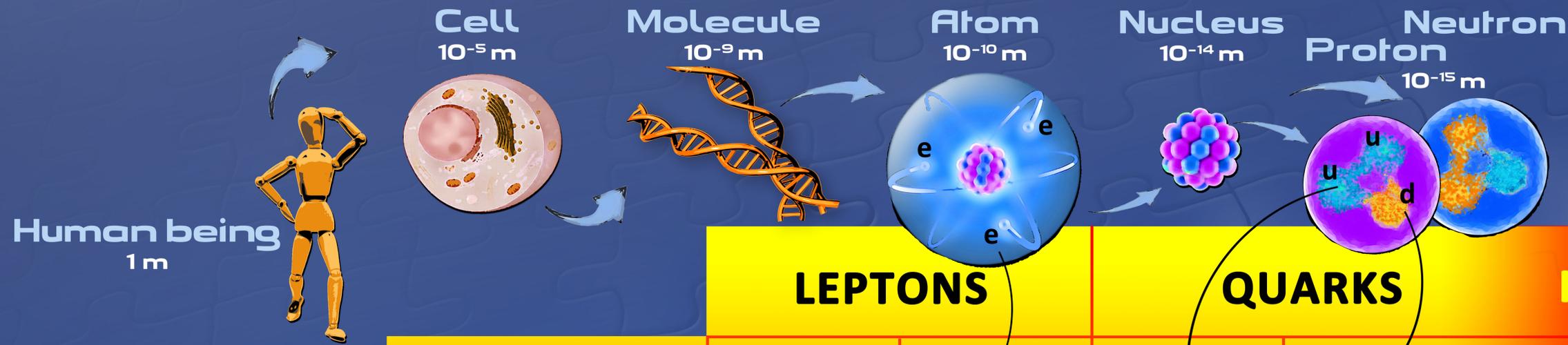


# Elementary constituents of matter



	LEPTONS		QUARKS		HIGGS BOSON H
<b>1<sup>st</sup> family</b> Components of everyday matter	$\nu_e$ electron neutrino $t = \infty$ $Q = 0$ $m < 2 \times 10^{-9} \text{ GeV}/c^2$	$e$ electron $t = \infty$ $Q = -e$ $m = 0.00051 \text{ GeV}/c^2$	$u$ up $t = \infty$ $Q = 2e/3$ $m = 0.002 \text{ GeV}/c^2$	$d$ down $t = 15 \text{ min}$ $Q = -e/3$ $m = 0.005 \text{ GeV}/c^2$	$t = 1.6 \times 10^{-22} \text{ s}$ $Q = 0$ $m = 125 \text{ GeV}/c^2$
<b>2<sup>nd</sup> family</b> A more massive copy of the 1 <sup>st</sup> family	$\nu_\mu$ muon neutrino $t = \infty$ $Q = 0$ $m < 2 \times 10^{-9} \text{ GeV}/c^2$	$\mu$ muon $t = 2.2 \times 10^{-6} \text{ s}$ $Q = -e$ $m = 0.106 \text{ GeV}/c^2$	$c$ charm $t = 10^{-12} \text{ s}$ $Q = 2e/3$ $m = 1.3 \text{ GeV}/c^2$	$s$ strange $t = 10^{-10} \text{ s}$ $Q = -e/3$ $m = 0.1 \text{ GeV}/c^2$	<p>The Higgs boson is the manifestation of the Higgs field. Through its interaction with the elementary constituents of matter, this field is responsible for their masses. It also brings about the splitting between the electromagnetic and weak forces.</p>
<b>3<sup>rd</sup> family</b> A more massive copy of the 1 <sup>st</sup> and 2 <sup>nd</sup> families	$\nu_\tau$ tau neutrino $t = \infty$ $Q = 0$ $m < 2 \times 10^{-9} \text{ GeV}/c^2$	$\tau$ tau $t = 2.9 \times 10^{-13} \text{ s}$ $Q = -e$ $m = 1.78 \text{ GeV}/c^2$	$t$ top $t = 3 \times 10^{-25} \text{ s}$ $Q = 2e/3$ $m = 173 \text{ GeV}/c^2$	$b$ beauty / bottom $t = 1.5 \times 10^{-12} \text{ s}$ $Q = -e/3$ $m = 4.2 \text{ GeV}/c^2$	

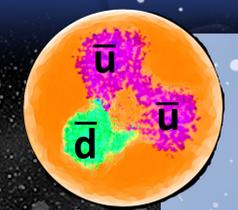
## FUNDAMENTAL INTERACTIONS

RANGE	Interaction	Mediator	Effects
$10^{-17} \text{ m}$	Weak Interaction	Z, W <sup>±</sup> Bosons	Radioactive decays $\beta^+$ and $\beta^-$ of unstable nuclei
Infinite	Electromagnetic interaction	$\gamma$ Photon	Electricity, magnetism, atomic and molecular binding, chemistry
$10^{-15} \text{ m}$	Strong interaction	g Gluons	Binding of protons, neutrons and nuclei, nuclear energy
Infinite	Gravitation	Graviton (?)	Gravity, universal attraction, solar system, galaxies

Each fundamental interaction is mediated by the associated **particles**

The stars that populate the galaxies, including the Sun, make use of the four fundamental interactions:

- gravity shapes interstellar dust clouds into stars;
- the weak and strong interactions are required for the nuclear fusion reactions;
- the electromagnetic interaction is needed to emit light.



Antiproton

## ANTIMATTER

Each particle has an antiparticle. Their properties are almost the same. A particle and its antiparticle have equal masses but opposite charges.

Bruno Mazoyer - ILL, Orsay, 2014, adapted from the French poster "Les Composantes élémentaires de la matière" - alone website to be added