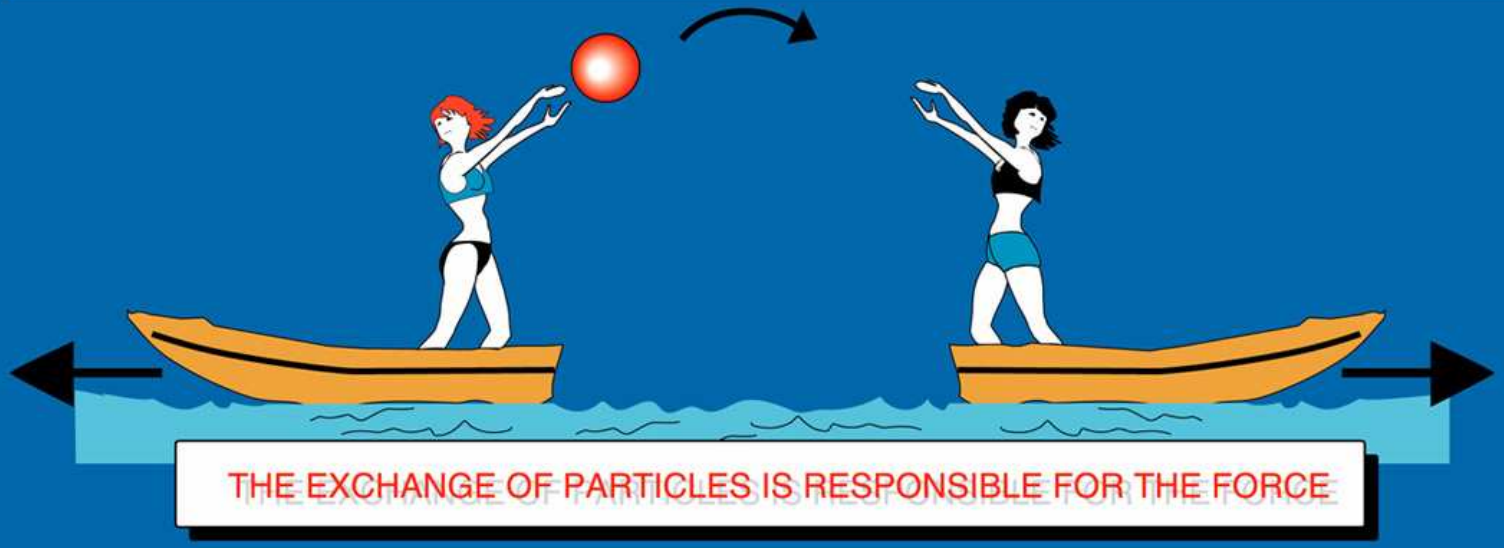
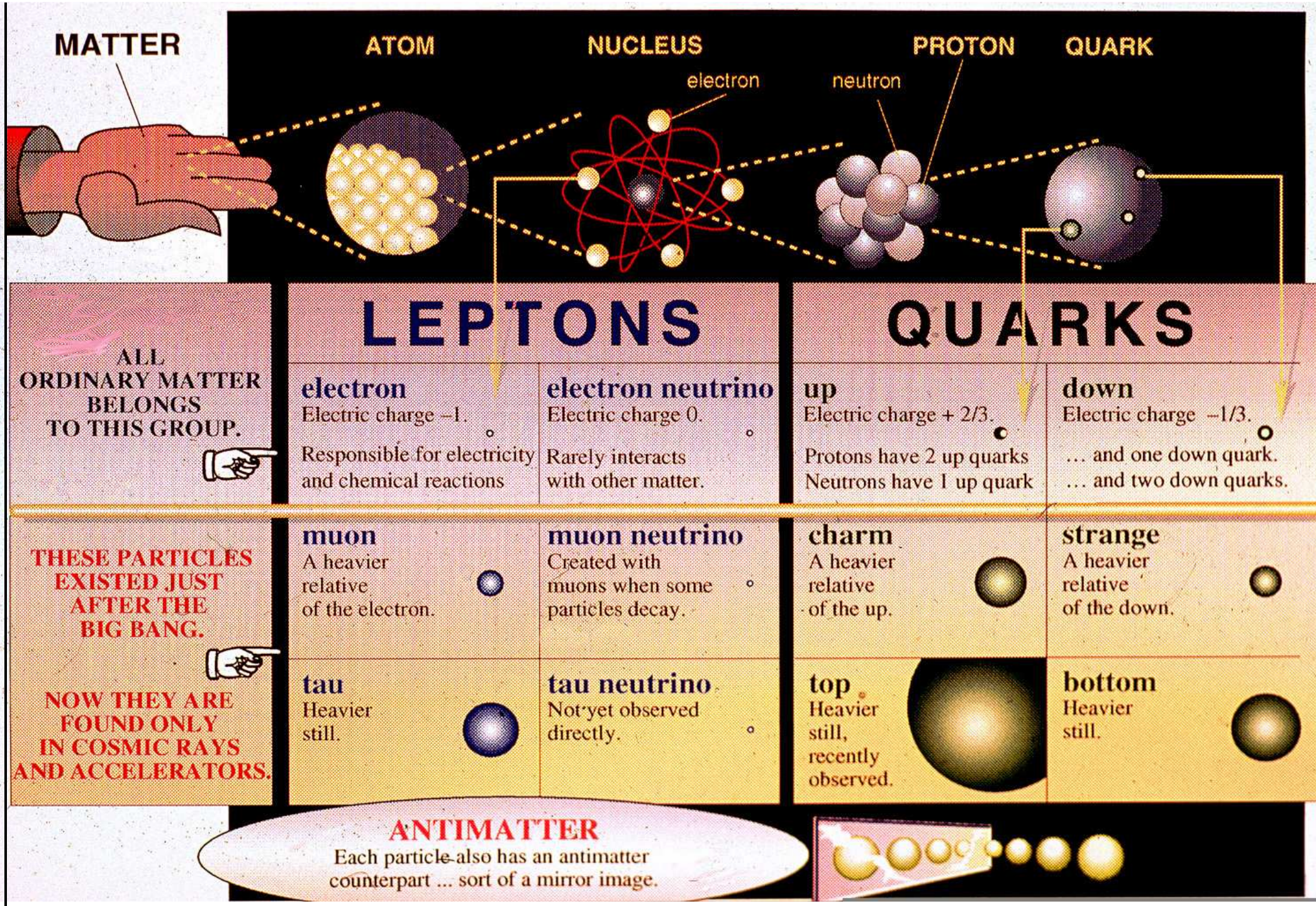
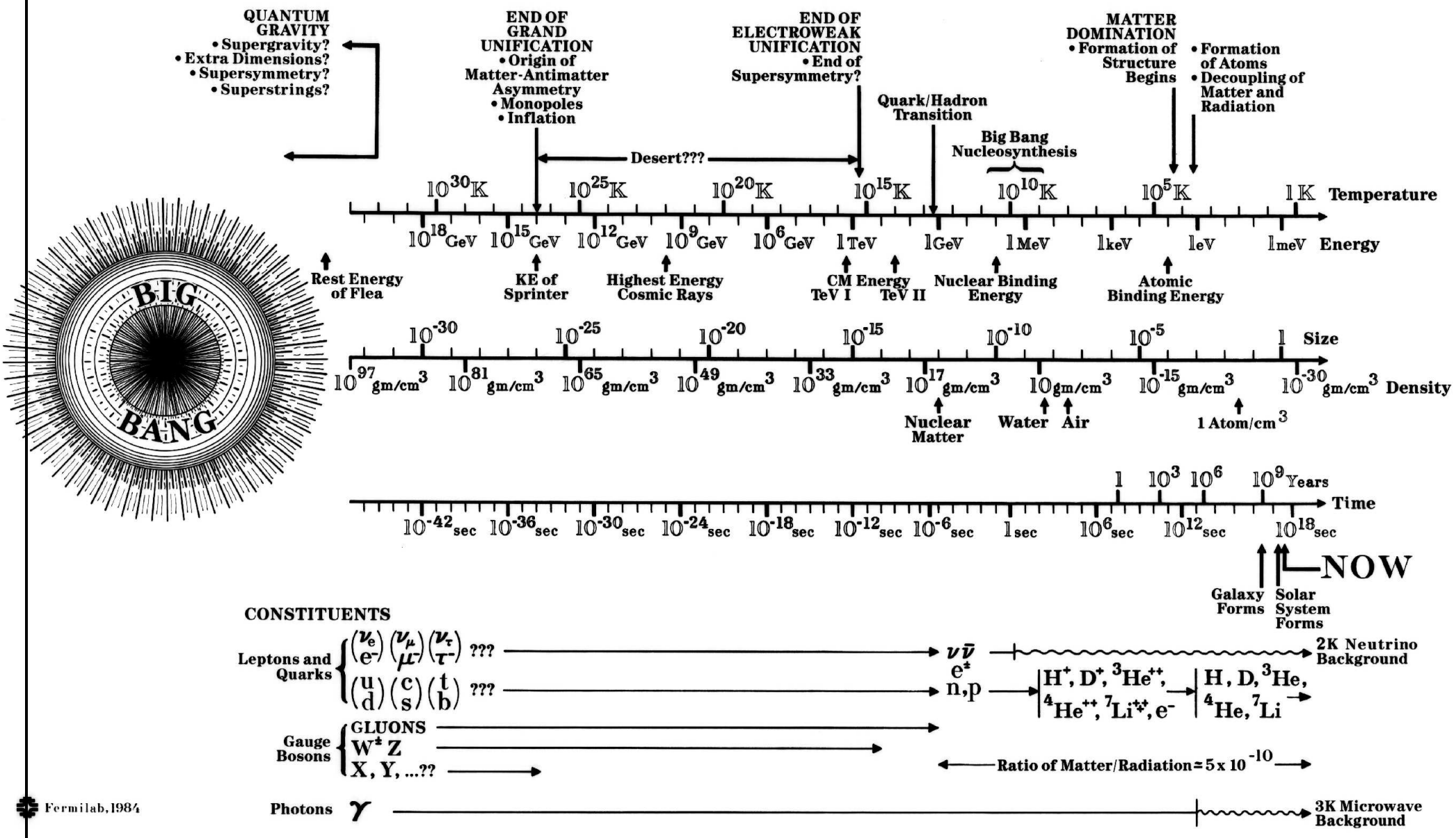
The forces in Nature

TYPE	INTENSITY OF FORCES (DECREASING ORDER)	BINDING PARTICLE (FIELD QUANTUM)	OCCURS IN :
STRONG NUCLEAR FORCE	~ 1	GLUONS (NO MASS)	ATOMIC NUCLEUS
ELECTRO -MAGNETIC FORCE	~ 10^{-3}	PHOTONS (NO MASS)	ATOMIC SHELL ELECTROTECHNIQUE
WEAK NUCLEAR FORCE	~ 10^{-5}	BOSONS Z^0 , W+ , W- (HEAVY)	RADIOACTIVE BETA DESINTEGRATION
GRAVITATION	~ 10^{-38}	GRAVITONS (?)	HEAVENLY BODIES




MATTER
ATOM
NUCLEUS
electron
PROTON
neutron
QUARK
ALL ORDINARY MATTER BELONGS TO THIS GROUP.
LEPTONS
QUARKS
electron
Electric charge –1.
Responsible for electricity and chemical reactions
electron neutrino
Electric charge 0.
Rarely interacts with other matter.
up
Electric charge + 2/3.
Protons have 2 up quarks
Neutrons have 1 up quark
down
Electric charge –1/3.
… and one down quark.
… and two down quarks.
THESE PARTICLES EXISTED JUST AFTER THE BIG BANG.
NOW THEY ARE FOUND ONLY IN COSMIC RAYS AND ACCELERATORS.
muon
A heavier relative of the electron.
muon neutrino
Created with muons when some particles decay.
charm
A heavier relative of the up.
strange
A heavier relative of the down.
tau
Heavier still.
tau neutrino
Not yet observed directly.
top
Heavier still, recently observed.
bottom
Heavier still.
ANTIMATTER
Each particle also has an antimatter counterpart ... sort of a mirror image.


QUANTUM GRAVITY
• Supergravity?
• Extra Dimensions?
• Supersymmetry?
• Superstrings?
END OF GRAND UNIFICATION
• Origin of Matter-Antimatter Asymmetry
• Monopoles
• Inflation
END OF ELECTROWEAK UNIFICATION
• End of Supersymmetry?
Quark/Hadron Transition
Big Bang Nucleosynthesis
MATTER DOMINATION
• Formation of Structure Begins
• Formation of Atoms
• Decoupling of Matter and Radiation
Desert???
10^{30}K 10^{25}K 10^{20}K 10^{15}K 10^{10}K 10^{5}K 1K Temperature
10^{18}GeV 10^{15}GeV 10^{12}GeV 10^{9}GeV 10^{6}GeV 1TeV 1GeV 1MeV 1keV 1eV 1meV Energy
Rest Energy of Flea
KE of Sprinter
Highest Energy Cosmic Rays
CM Energy TeV I
TeV II
Nuclear Binding Energy
Atomic Binding Energy
BIG BANG
10^{-30} 10^{-25} 10^{-20} 10^{-15} 10^{-10} 10^{-5} 1 Size
10^{97} gm/cm^3 10^{81} gm/cm^3 10^{65} gm/cm^3 10^{49} gm/cm^3 10^{33} gm/cm^3 10^{17} gm/cm^3 10 gm/cm^3 10^{-15} gm/cm^3 10^{-30} gm/cm^3 Density
Nuclear Matter
Water
Air
1 Atom/cm^3
1 10^3 10^6 10^9 Years Time
10^{-42}sec 10^{-36}sec 10^{-30}sec 10^{-24}sec 10^{-18}sec 10^{-12}sec 10^{-6}sec 1sec 10^{6}sec 10^{12}sec 10^{18}sec
NOW
Galaxy Forms
Solar System Forms
CONSTITUENTS
Leptons and Quarks
$\begin{pmatrix}\nu_e\\e^-\end{pmatrix}\begin{pmatrix}\nu_\mu\\\mu^-\end{pmatrix}\begin{pmatrix}\nu_\tau\\\tau^-\end{pmatrix}$???
$\begin{pmatrix}u\\d\end{pmatrix}\begin{pmatrix}c\\s\end{pmatrix}\begin{pmatrix}t\\b\end{pmatrix}$???
$\nu\bar{\nu}$
$e^{\pm}$
n,p
$H^+, D^+, {}^3He^{++}, {}^4He^{++}, {}^7Li^{+++}, e^-$
H, D, ^{3}He, ^{4}He, ^{7}Li
2K Neutrino Background
Gauge Bosons
GLUONS
$W^{\pm}$ Z
X, Y, ...??
Ratio of Matter/Radiation = 5 x 10^{-10}
Photons γ
3K Microwave Background
Fermilab, 1984