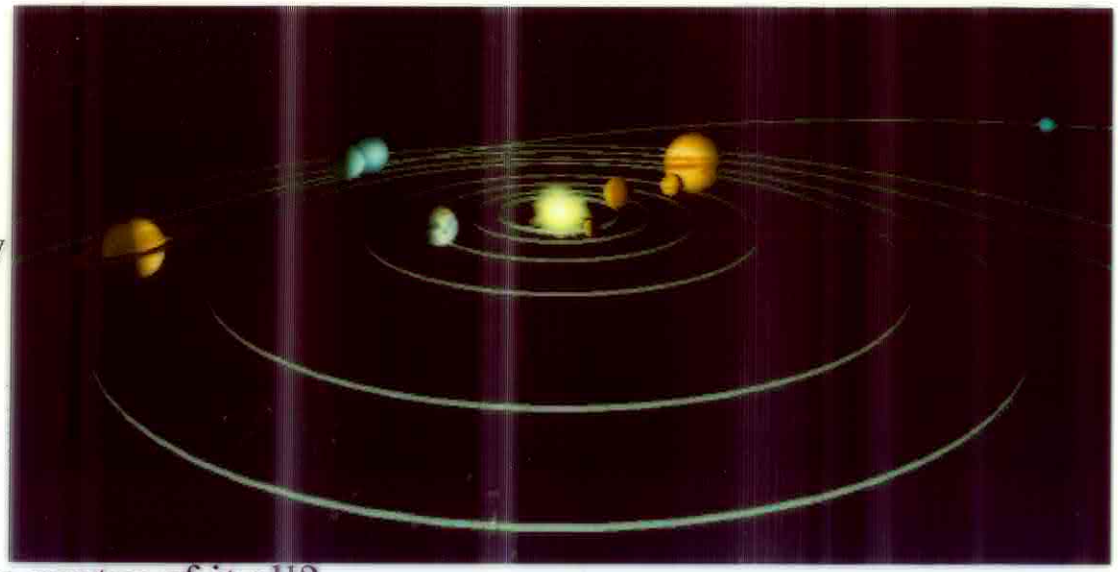
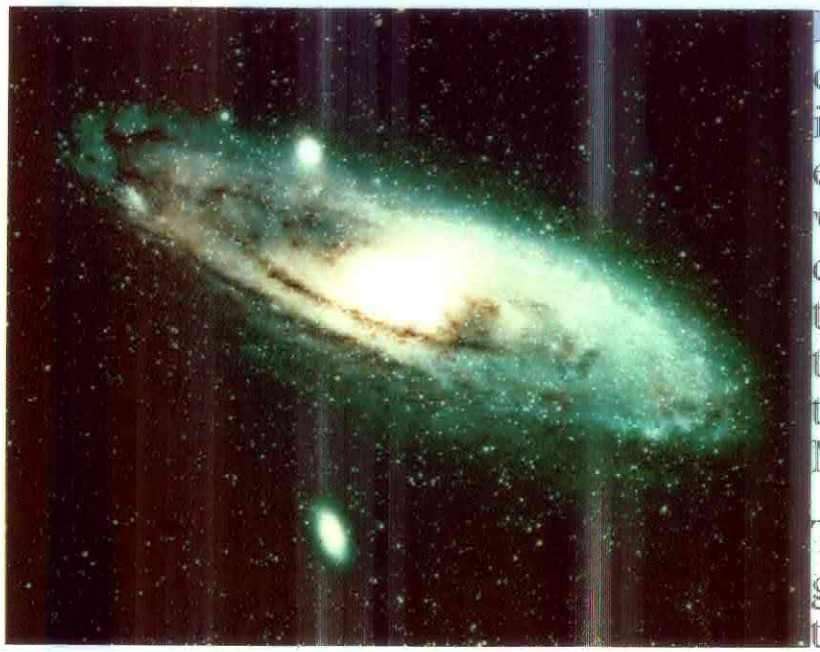
What about our "location"?



We may be tiny and we may have had little impact on the course of Cosmic evolution, but are we not at the center of it all?

Indeed, as we shall learn in a bit more detail, it was commonly believed that we, human beings, were at the center of creation. That the entire Universe revolved around us. The dynamic duo, Copernicus and Galileo, were the first to seriously call into question this assumption. They showed that rather than being at the center of the cosmos, the earth was but one small planet in orbit around the sun.

Andromeda: Sister Galaxy to the Milky Way



But, the sun must be at the center of the Universe? This idea was debunked during the early years of the 20th century, when it was discovered/realized that first, the sun was a smallish-average type, one of 100 billion stars that makes up our galaxy, the Milky Way.

The Milky Way is a disk galaxy, a spiral galaxy, with the the disk spanning 80,000 light years in diameter. Rather than being at the center of the galaxy, the sun was out in the "burbs", roughly 25,000 light years away.

And, the Milky Way galaxy is itself an average, medium-sized galaxy, occupying a rather non-descript neighbourhood in the Universe. It is one of the billions of galaxies in the Universe, all of which are moving away from each other due to the expansion of the Universe, none of which can truly be called the Center of the Universe.

In fact, if we must claim that we are special, then the one achievement that would allow us to make this claim legitimately is that we have have been able to reach our current level of understanding regarding the origins and the evolution of our Universe. That is truly incredible in the literal sense of the word.

The most incomprehensible thing about the Universe

is that it is comprehensible

Albert Einstein

COMPREHENSIBLE?

THERE IS METHOD IN THE MADNESS.

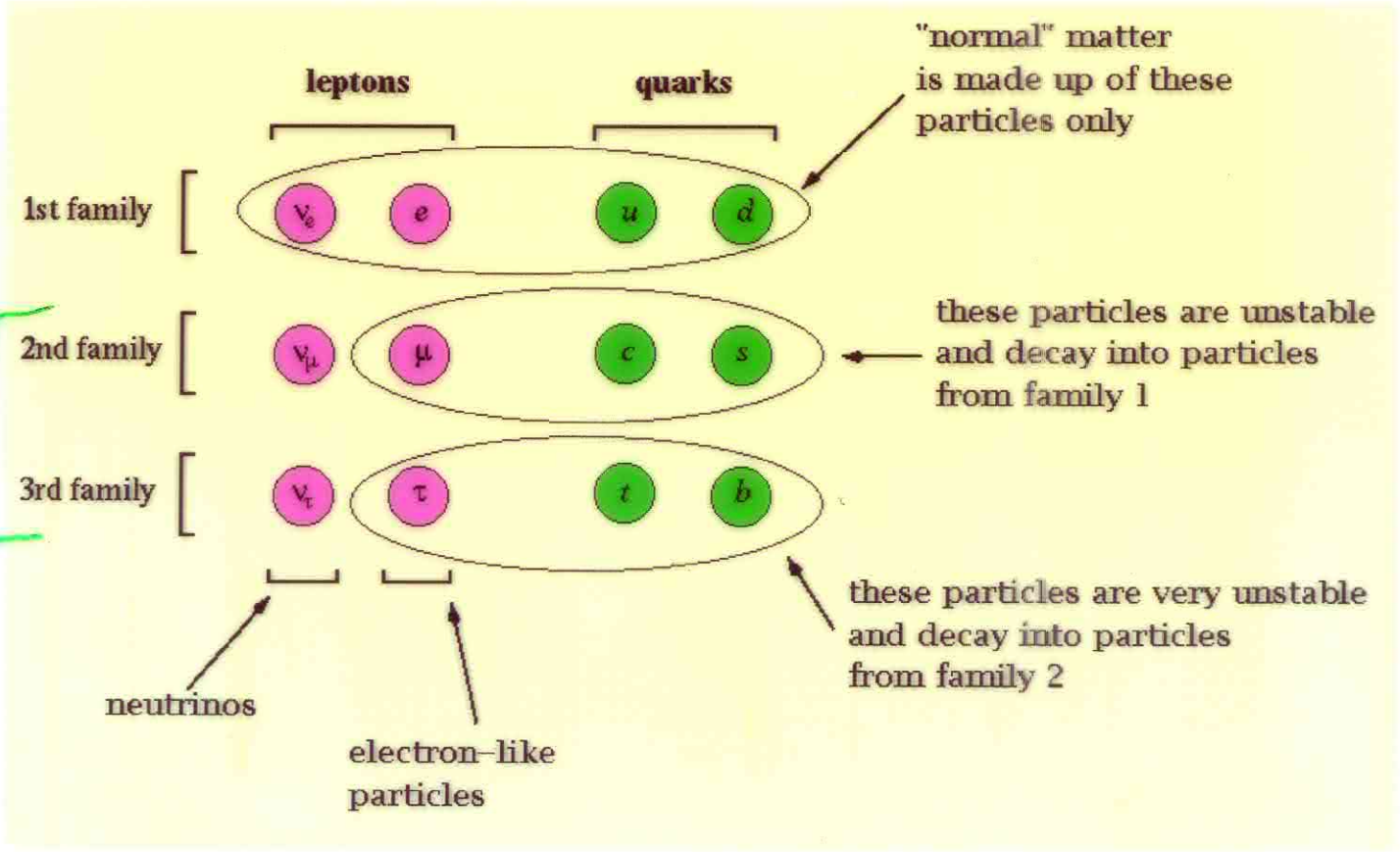
- NATURE'S RULES DON'T APPEAR TO BE ARBITRARY
- THEY ALL APPEAR TO BE LINKED IN AN ORGANIC WHOLE
- BASIC RULES & INGREDIENTS ARE SIMPLE & FEW
- BUT NOT SO SIMPLE THAT UNIVERSE IS DULL & STERILE

ORDINARY "EVERYDAY" STUFF ⇒ 4 PARTICLES

ENGAGING IN 4 DIFFERENT KINDS OF INTERACTIONS:

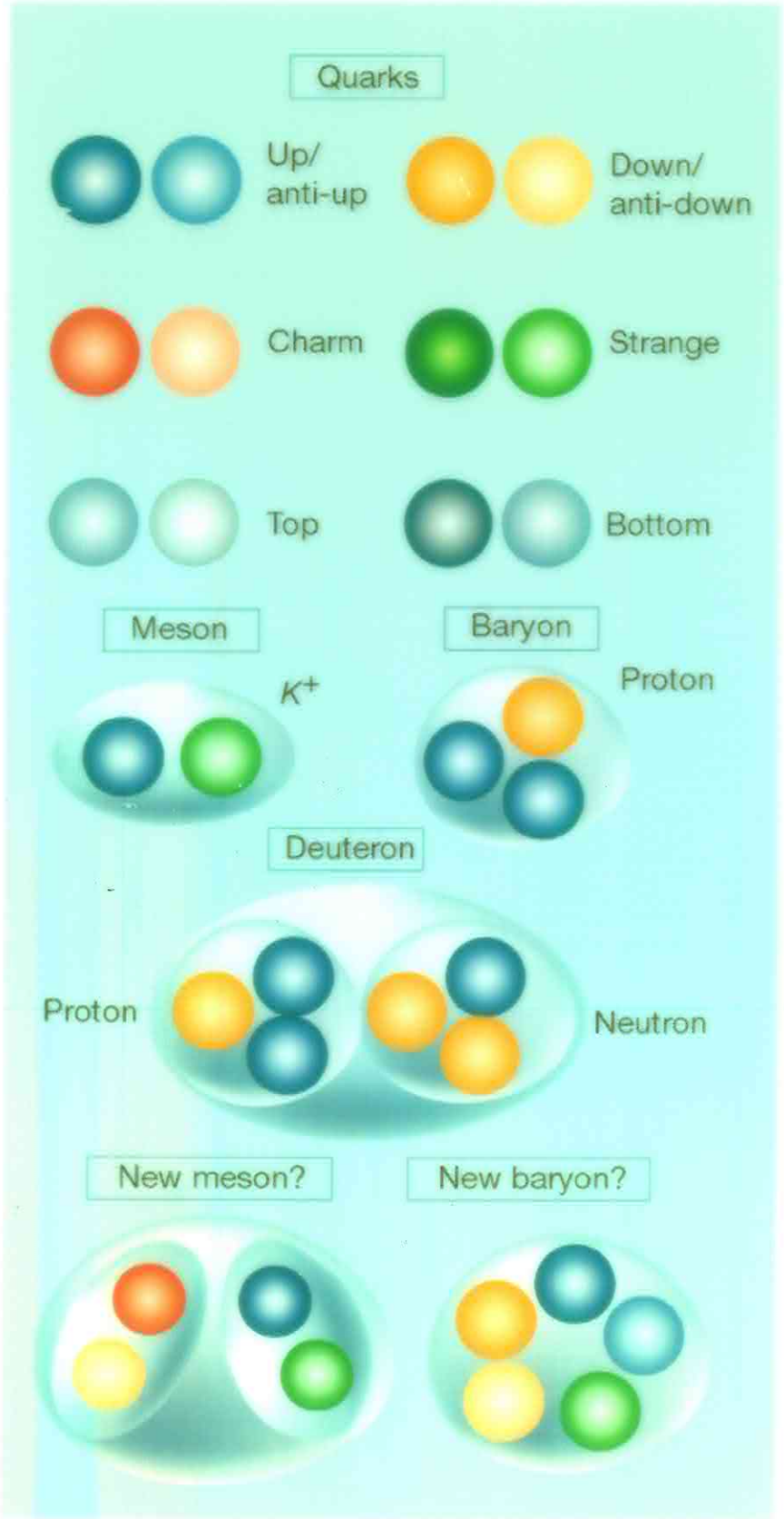
- ELECTROMAGNETIC } HUMAN SCALE
- GRAVITY
- STRONG } NUCLEAR
- WEAK

200-ODD ELEMENTS,
GAZILLION MOLECULES,
ETC.



→ CREATED IN HIGH ENERGY SITUATIONS:

SOLAR CORE
STELLAR EXPLOSIONS
BLACK HOLES
BIG BANG
COLLIDERS (PARTICLE)



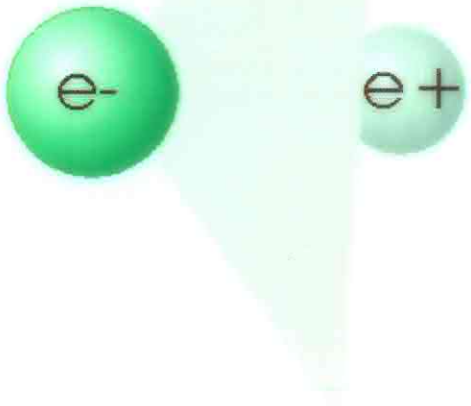
- ALL PARTICLES HAVE "MIRROR" PARTNERS
- ANTI-MATTER

[SEE NEXT PAGE]

What is Antimatter?

An interesting thing that has been discovered about matter particles, is that each one has a corresponding antiparticle. The term "anti" may be a bit decieving, as it is still real matter. The only difference between a particle and it's antiparticle is that an antiparticle has the opposite electrical charge.

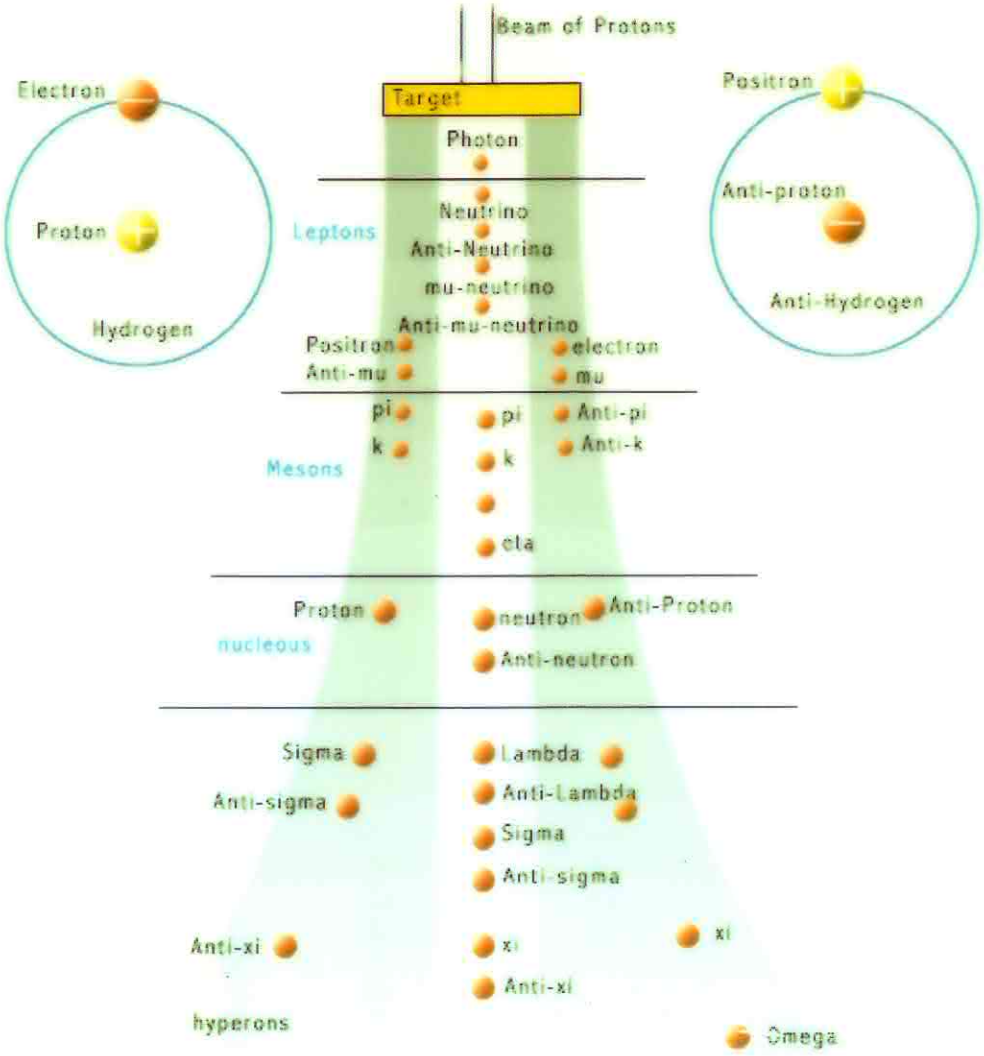
Think of it as a mirror image. In our experience left and right are the only things to reverse when looking in the mirror. Similarly, in the particle world, charge is what reverses when looking in the "mirror". It's mass, spin, and most (quarks have something called colour charge which is also changed in the "mirror") other properties are the same.

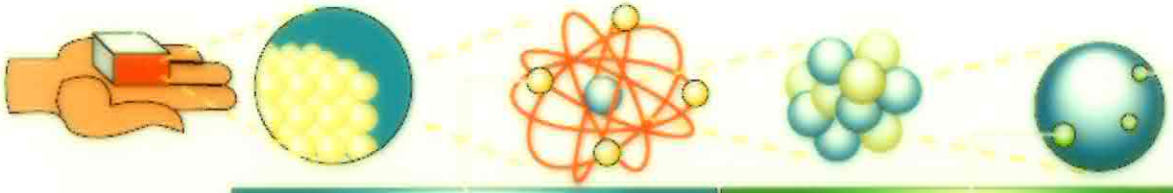


In general, an antiparticle is the particles name with "anti" in front of it. For example, the antiparticle of the proton is the antiproton. An exception to this rule is the electron, whose antiparticle is known as the positron.

An interesting fact about antimatter is that all of the universe is made up of matter as opposed to antimatter. This is somewhat of a mystery.

On to Quarks.


Beam of Protons
Target
Photon
Electron
Proton
Hydrogen
Positron
Anti-proton
Anti-Hydrogen
Leptons
Neutrino
Anti-Neutrino
mu-neutrino
Anti-mu-neutrino
Positron
Anti-mu
electron
mu
pi
k
Mesons
pi
k
eta
Anti-pi
Anti-k
Proton
nucleous
neutron
Anti-neutron
Anti-Proton
Sigma
Anti-sigma
Lambda
Anti-Lambda
Sigma
Anti-sigma
Anti-xi
hyperons
xi
Anti-xi
xi
Omega



Mass Particles

All ordinary particles belong to this group

Those particles only existed just after the Big Bang. Now they are found in cosmic rays or produced in scientific laboratories such as CERN.

LEPTONS		QUARKS	
Electron Responsible for electricity and chemical reactions It has a charge of -1 Its anti-particle, the positron,has a charge of +1	**Electron Neutrino** Particle with no electric charge, and possibly no mass. Billions fly through your body every second.	**Up** It has an electric charge of +2/3. Protons contain 2, neutrons contain 1.	**Down** It has an electric charge of -1/3 Protons contain 1, neutrons contain 2.
Muon It is heavier than the electron. It lives for two millionths of a second It has a charge of ±1	**Muon Neutrino** Created along with muons when some particles decay. It has no electric charge.	**Charm** Discovered in 1974. It is heavier than the Up. It has a charge of +2/3	**Strange** Discovered in 1963. It is heavier than the Down. It has a charge of -1/3
Tau Heavier still; it is extremely unstable. It was discovered in 1975. It has a charge of ±1	**Tau Neutrino** Discovered in 2000. It has no electric charge.	**Top** Heavier still. Discovered in 1995. Electric charge +2/3	**Bottom** Heavier still; measuring bottom quarks is an important test of electroweak theory. Discovered in1977. Electric charge -1/3

Force Particles

These particles transmit the four fundamental forces of nature. Gravitons have so far not been discovered.

Gluons
Carriers of the strong force between quarks

Felt by: quarks and gluons

The explosive release of nuclear energy is the result of the strong force.

Photons
Particles that make up light. They carry the electromagnetic force

Felt by: charged particles

Electricity, magnetism and chemistry are all the results of electromagnetic force.

Intermediate vector bosons
Carriers of the weak force

Felt by quarks and leptons

Some forms of radio-activity are the result of the weak force.

Gravitons
Carriers of gravity

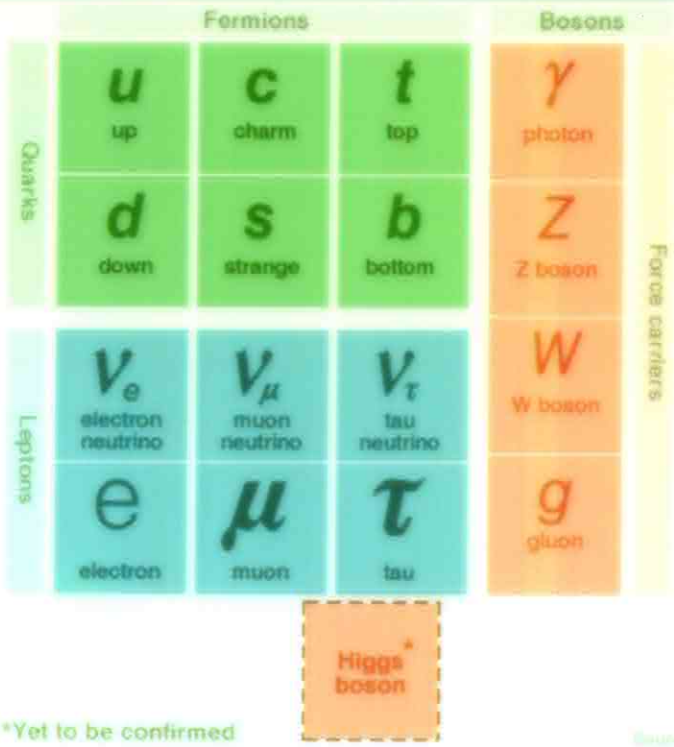
Felt by: all particles with mass

All the weight we experience is the result of the gravitational force.

ANTIMATTER: Each particle also has an antimatter counterpart... sort of a mirror image.

* ANTI-MATTER PARTICLES ARE NOT "FUNDAMENTAL"

THE STANDARD MODEL



- The Standard Model is a theory devised to explain how sub-atomic particles interact with each other
- There are 16 particles that make up this model (12 matter particles and 4 force carrier particles). But they would have no mass if considered alone
- The Higgs boson explains why these particles have mass. Particles acquire their mass through interactions with an all-pervading field, called the Higgs field, which is carried by the Higgs boson.
- There are now signs that the Standard Model will have to be extended by adding new particles that play roles in high-energy reactions.

PARTICLES (SOME) HAVE MASS, OTHERS DON'T.

⇒ HIGGS.

Particle	*Name*	*Feels These Forces*[a]	*Mediates These Forces*[b]	*Superpartner*
e, μ, τ	charged leptons (electron, muon, tau)	EM, W	—	sleptons $\tilde{e}, \tilde{\mu}, \tilde{\tau}$ (selectron, smuon, stau)
ν_e, ν_μ, ν_τ	neutrinos	W	—	sneutrinos $\tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$
u, c, t	up, charm, top quarks	EM, W, S	—	squarks $\tilde{u}, \tilde{c}, \tilde{t}$
d, s, b	down, strange, bottom quarks	EM, W, S	—	squarks $\tilde{d}, \tilde{s}, \tilde{b}$
γ	photon		EM	photino[d] $\tilde{\gamma}$
$W^\pm$	weak boson	EM, W	W	Wino[d] $\tilde{W}^\pm$
Z	weak boson	W	W	Zino[d] $\tilde{Z}$
g	gluon	S	S	gluino $\tilde{g}$
G	graviton	GR	GR	gravitino $\tilde{G}$
h	Higgs boson[c]	W	generates mass	higgsino[c] $\tilde{h}$

[a] All particles feel the gravitational force.

[b] EM = electromagnetic force, W = weak force, S = strong force, GR = gravitational force.

[c] Photons feel only the gravitational force, but they interact with all electrically charged particles.

[d] Mixtures of these particles form charginos and neutralinos (Appendix C).

[e] The additional Higgs bosons predicted by supersymmetry are not shown.

GRAND UNIFICATION → ANOTHER "MIRROR"

SHADOW PARTICLES