

Part 2 Inside the Atom

Name:

Due Date:

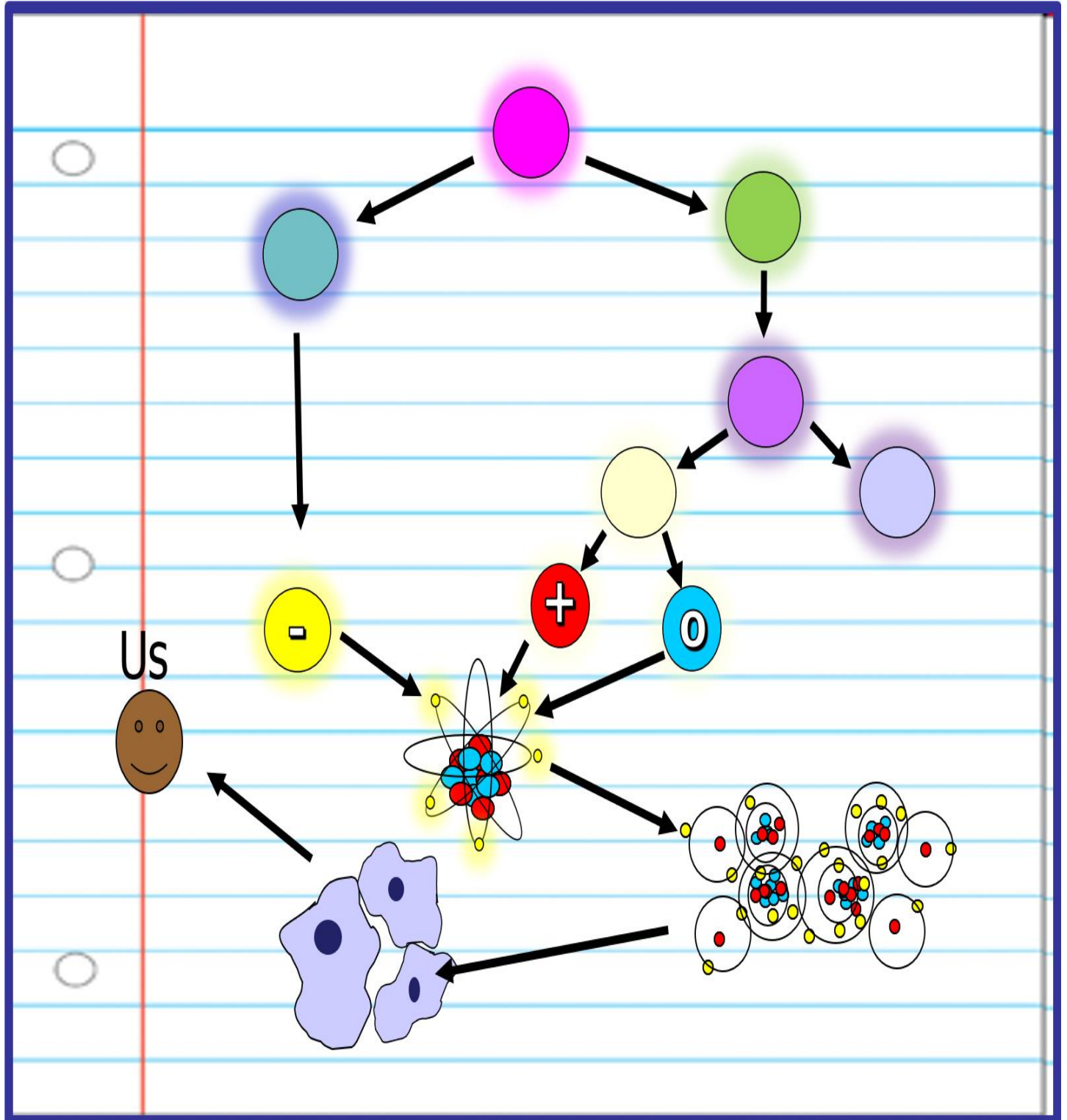
Part 1 Lesson 1

Most of an atom is mostly _____ space, electrons orbit far away from the nucleus.

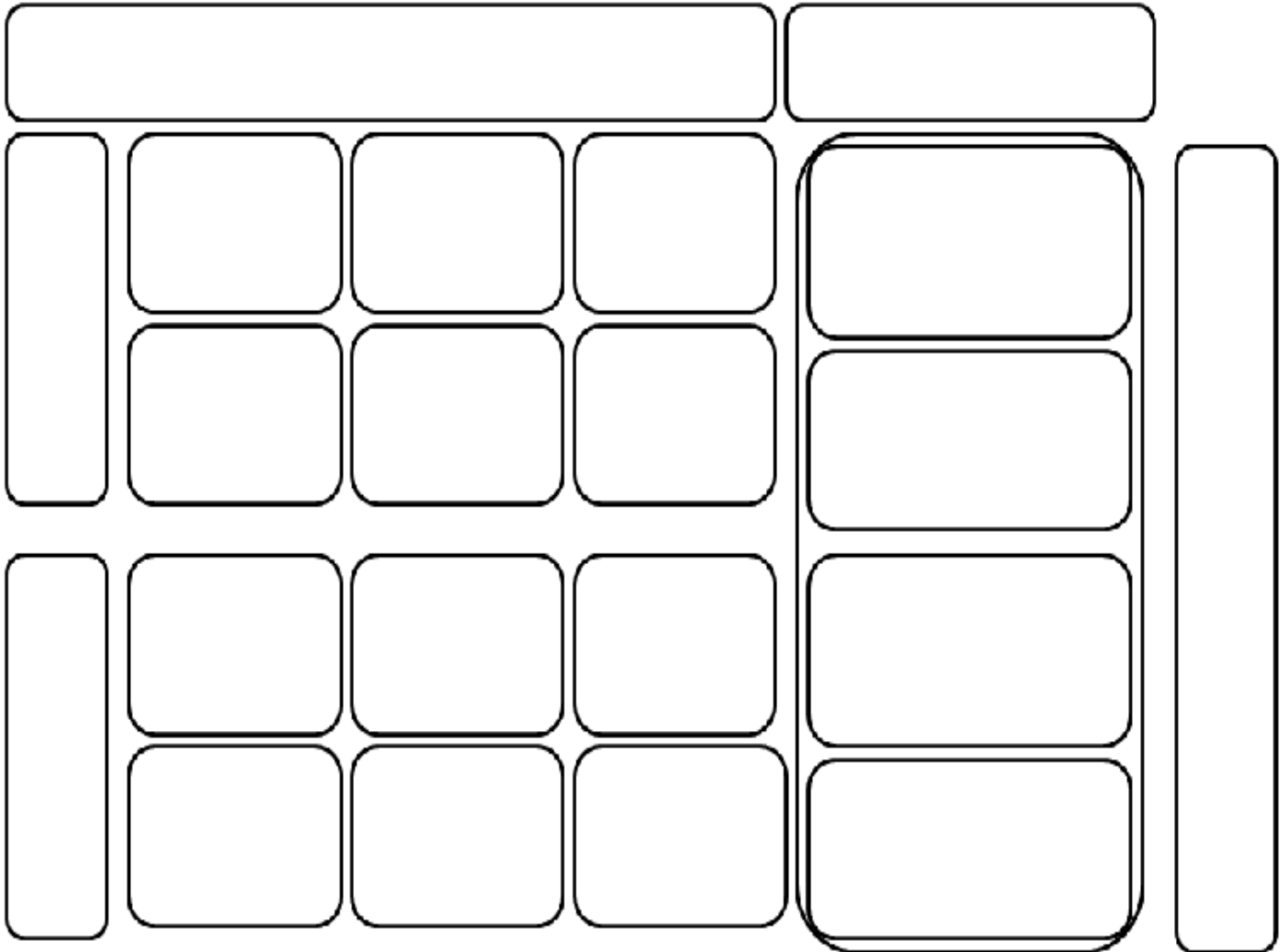
_____ Electrons = Mass of 1 proton.

1 Neutron = little bit more mass than a proton.

Complete the flow chart as described in the slideshow.



Please complete the blank standard model in particle physics below. Colored pencils can help improve your model.



Which is a Fermion? and which is a Boson?

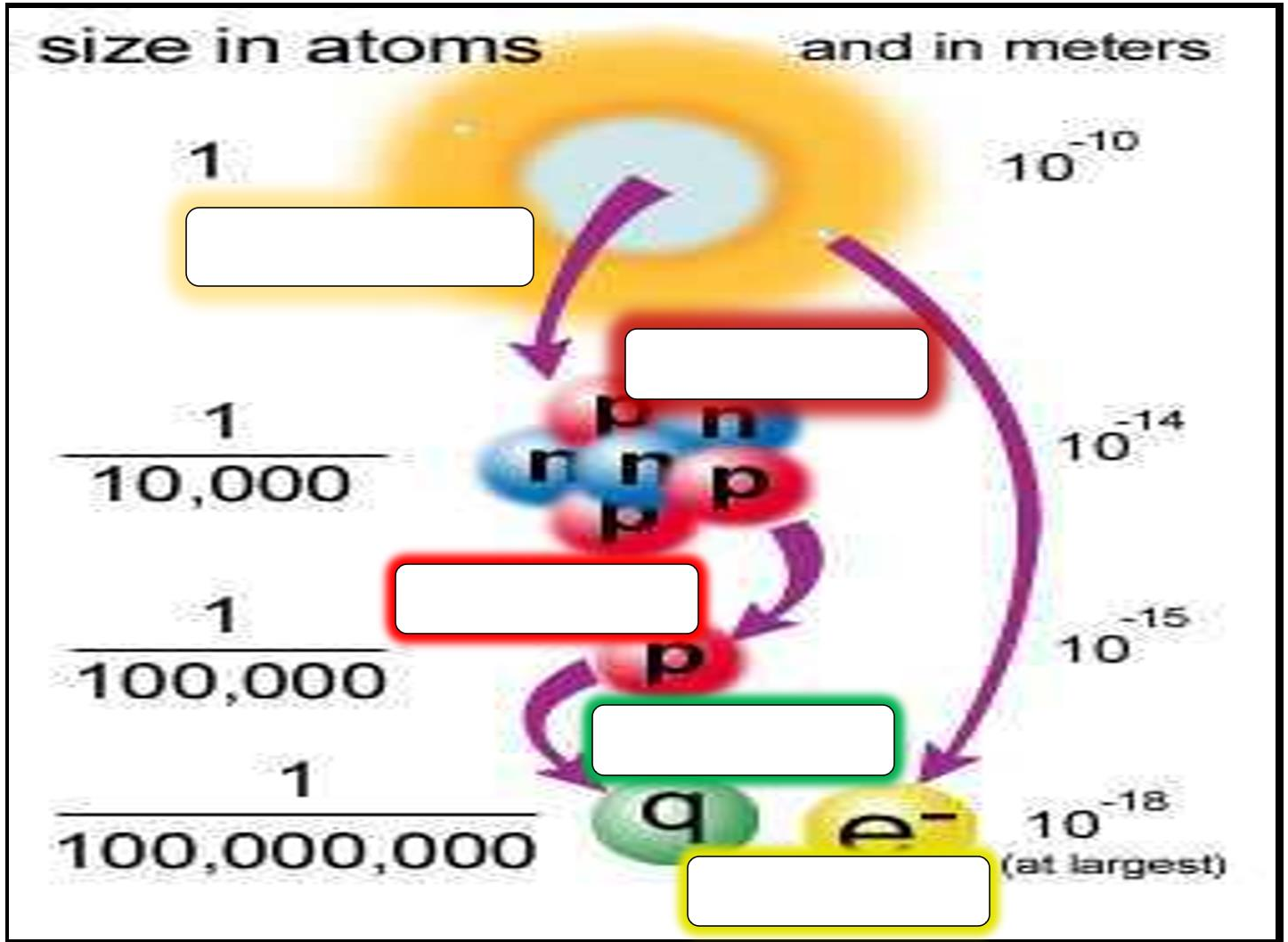
A _____ is a particle which has an integer spin (0, 1, 2...). All the force carrier particles and mesons.

A _____ is any particle that has an odd half-integer (like $1/2$, $3/2$, and so forth) spin. Quarks and leptons, as well as most composite particles, like protons and neutrons.

The _____ Boson Particle: One of the 17 fundamental particles in the Standard Model.

- The other 16 are the 6 quarks, 6 leptons, the photon, gluon, W, and Z bosons.
- These 17 particles are the ones responsible for all the forces in nature except gravity.
- The Higgs is currently being studied and until recently was only theoretical.
- The very massive Higgs Boson explains why the other elementary particles, except the photon and gluon, are massive. Also why the photon has no mass.

Please describe some relative size of particles in comparison to each other. Word Bank: Quark, Proton, Nucleus, Electron, Atom



Please put the following in the correct box according to their size.

Atom	Electron	Quark	Proton	Neutron	Molecule	Nucleus
Smallest -----> Largest						

Part 2 Lesson 2

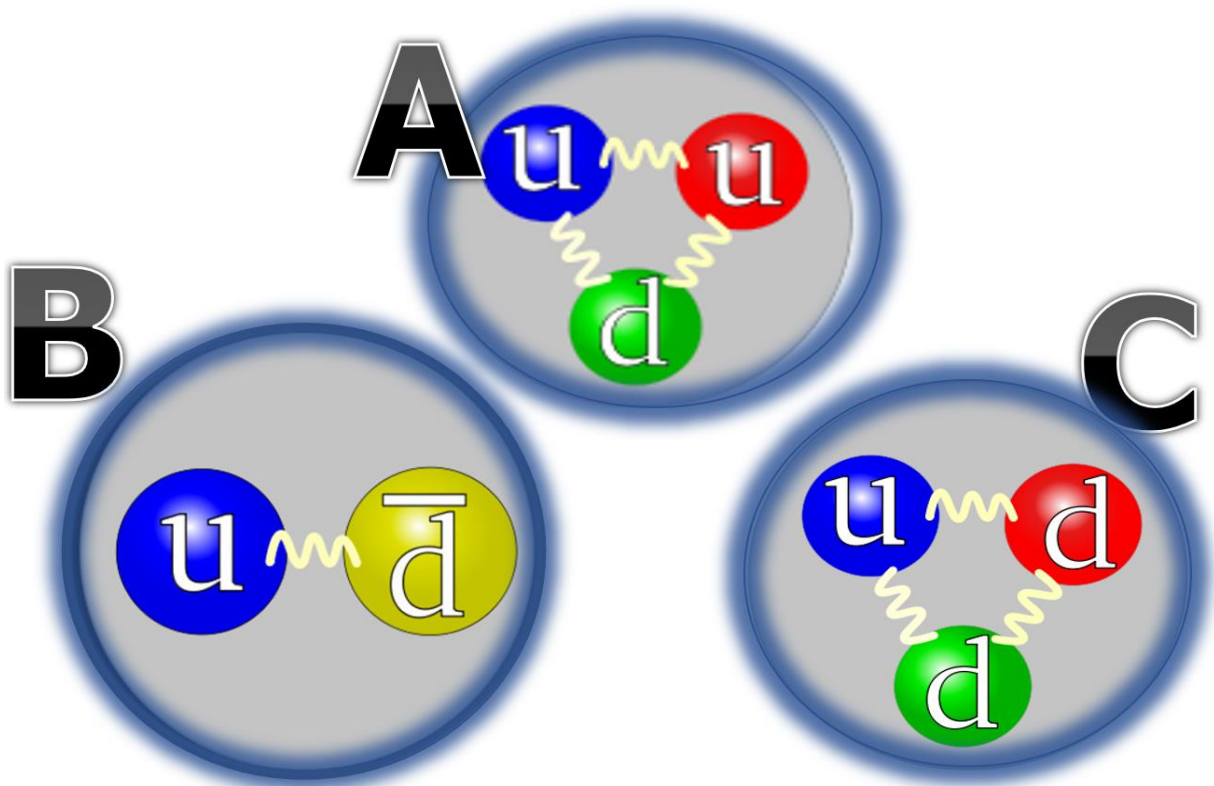
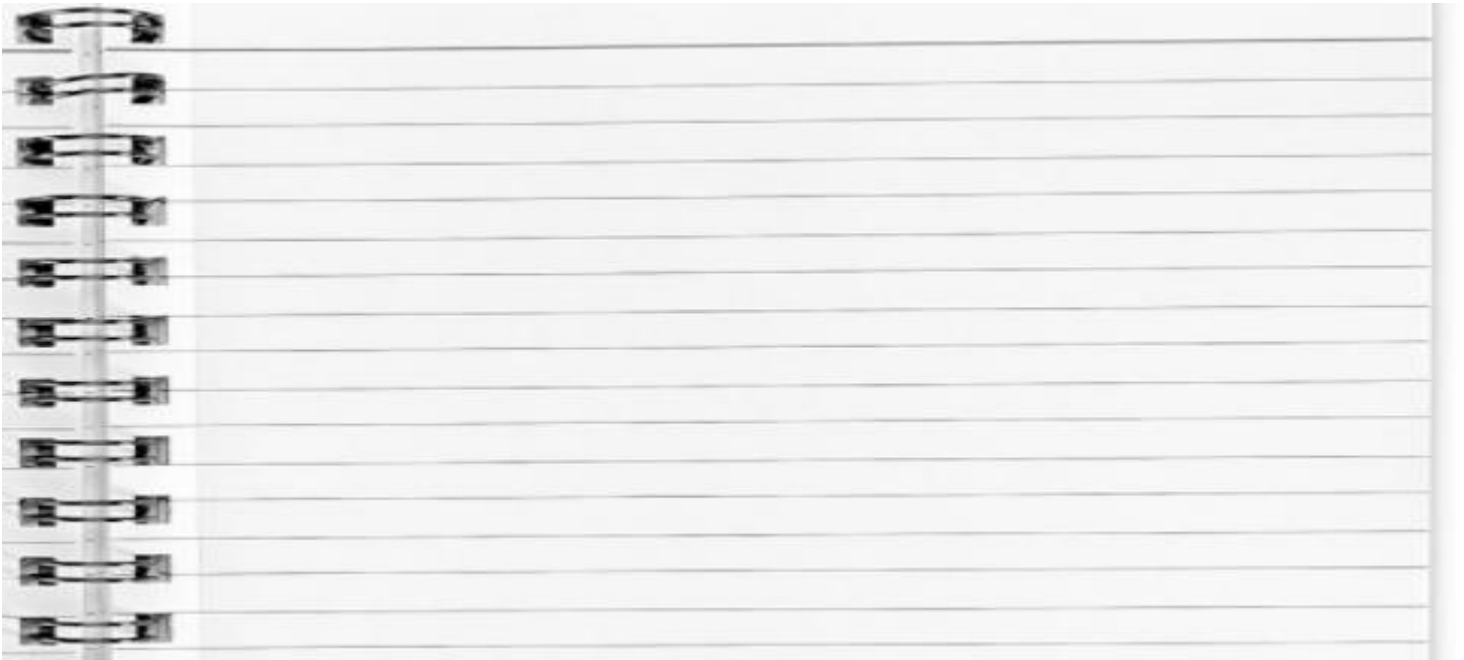
Physicists have discovered that protons and neutrons () are composed of even smaller particles called .

Just bigger than an .

: A composite particle made of quarks held together by the strong force.

The proton and neutron are (family of hadrons) which are made of three quarks.

Which two are hadrons / in the family of baryons and which is a Meson Which is the Proton, and which is the Neutron? Explain and label the picture below.



The proton consists of ____ up quarks and ____ down quark (if you sum up the electrical charges / spin of this combination you get +1, the charge of the proton).
 $2/3 + 2/3 + -1/3 =$

The neutron is a combination of ____ down quarks and ____ up quark (and again, if you combine the electrical charges, they sum up to zero: it's therefore electrically neutral)
 $-1/3 + -1/3 + 2/3 =$

What is the Spin on the three below. Word Bank:

Hadron: A composite particle made of _____ held together by the _____ force. The proton and neutron are _____ (family of hadrons) which are made of three quarks.

Meson: Subatomic particles composed of one quark and one _____ quark, bound together by the strong interaction.

- Mesons are Bosons.
- They mediate the nuclear (or strong) interaction between nucleons.
- Keeps the nucleus together!

Gluons: Holds _____ together (Boson).

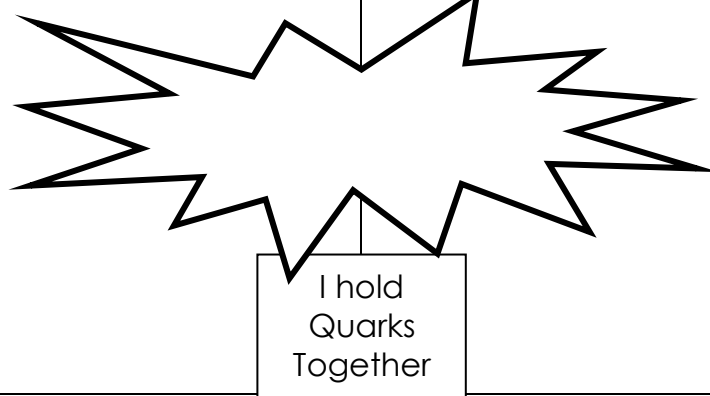
Color Force: The force between quarks is called the color force. The color force involves the exchange of gluons and is so strong that the quark-antiquark pair production energy is reached before quarks can be separated.

The Proton is composed of two up quarks, one down. (Fermion)

A neutron is composed of two down quarks and one up quark. (Fermion)

Please name and accurately show the fundamental particles that make up a proton.

Please name and accurately show the fundamental particles that make up a neutron.



Up Quarks carry a $\frac{2}{3}$ Charge, and a down quark carries a $-\frac{1}{3}$ charge. What is the charge of the Proton and Neutron below.

Proton	Neutron
<p style="text-align: center;">up up $+\frac{2}{3}e$ $+\frac{2}{3}e$ down $-\frac{1}{3}e$</p>	<p style="text-align: center;">up down $+\frac{2}{3}e$ $-\frac{1}{3}e$ down $-\frac{1}{3}e$</p>
$\frac{2}{3} + \frac{2}{3} - \frac{1}{3} = \boxed{}$	$\frac{2}{3} - \frac{1}{3} - \frac{1}{3} = \boxed{}$

A particle accelerator is a machine that uses electromagnetic fields to propel charged particles.

- The particles reach extremely high speeds and energies, and to contain them in well-defined beams.




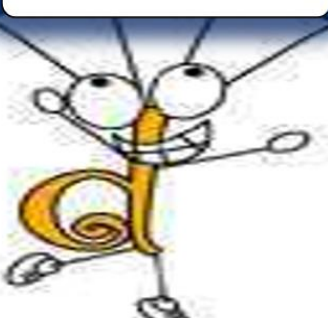


Part 2 Lesson 3 Particles

Particle: A tiny piece of anything.

An atom or nucleus.

Elementary particle, quark, gluon.

Name the _____ of quarks below. Word Bank: Charm, Strange, Bottom, Down, Top, Up

$\left(\frac{2}{3}\right)$ <input type="text"/>  Gen I $\left(-\frac{1}{3}\right)$	$\left(\frac{2}{3}\right)$ <input type="text"/>  Gen II $\left(-\frac{1}{3}\right)$	$\left(\frac{2}{3}\right)$ <input type="text"/>  Gen III $\left(-\frac{1}{3}\right)$
<input type="text"/> 	<input type="text"/> 	<input type="text"/> 

A lepton is an elementary particle of half-integer spin that does not undergo strong interactions.

The 6 Leptons

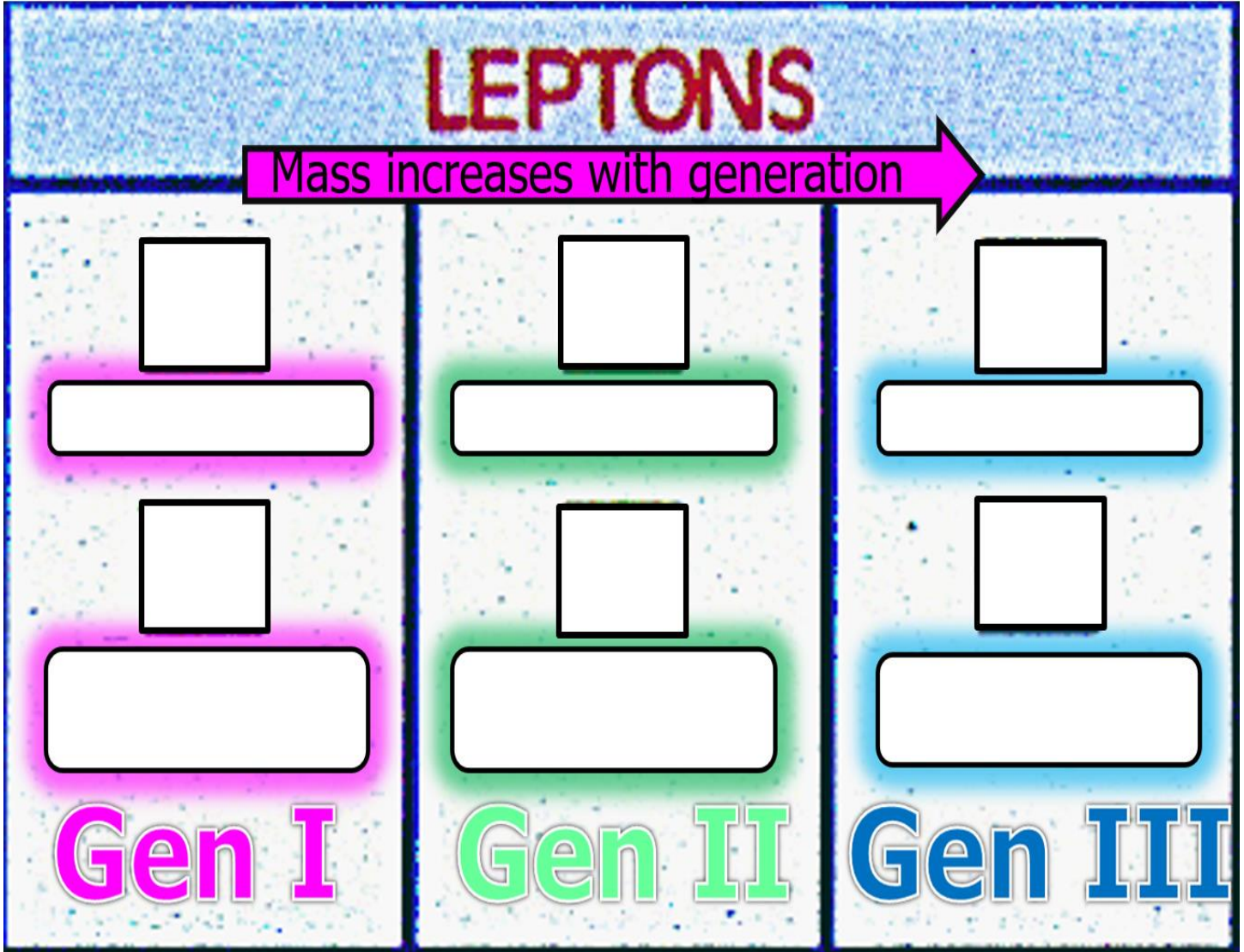
Electron

Muon

Tau

3 types of Neutrinos

Please name the Leptons below: Tau Neutrino 0, Electron -1, Tau -1, Muon -1, Electron Neutrino 0, Tau Neutrino 0



The Neutrino

- Neutrinos have no electrical or _____ charge, they almost never _____ with any other particles.
 - Most neutrinos pass right through the earth without ever interacting with a single atom.

Part 2 Lesson 4 Fundamental Forces

All visible matter in the universe is made from the first generation of matter particles -- up quarks, down quarks, and electrons. This is because all second and third generation particles are unstable and quickly decay into stable first generation particles.

Everything is made of...

- 6 quarks that make Protons and Neutrons
- 6 leptons. The best-known lepton is the electron.
- Force carrier particles.



What am I and all matter made of?
A correct answer dives deep into the recipe of the universe.

Describe the recipe of the Universe.

A science-themed worksheet with a brown table background. On the table are several items: a green box labeled 'Leptons' with a lightning bolt and 'Collect all 6!'; a blue box labeled 'Quarks' filled with colorful spheres; a rack with four test tubes labeled 'EM', 'Weak', 'Strong', and 'Gravity'; and four empty lined boxes for writing (two green, one blue, one purple).

Leptons
Collect all 6!

EM
Weak
Strong
Gravity

Quarks

Force Carrier Particles: Particles communicate with one another through force carriers. Force carriers are particles that act like messages exchanged between other particles. Scientists have discovered force carriers for three of the four known forces: electromagnetism, the strong force and the weak force. Still looking for the graviton

Provide some information about the fundamental forces below as described in the slideshow

The image is a worksheet for a slideshow about force carrier particles. It features a cartoon man with glasses balancing two apples on his head, a lightning bolt, a man lifting a barbell with quark symbols, and a woman lifting a barbell. There are five lined boxes for notes: a red-bordered box next to the man, a yellow-bordered box next to the lightning bolt, a black-bordered box next to the woman, a black-bordered box next to the man with the barbell, and a green-bordered box next to the woman with the barbell.

Which quark integer spin is a proton and which is a neutron. Please Label the charge.

$$-1/3 + -1/3 + 2/3 = \underline{\hspace{2cm}} \text{ (___ Charge)}$$

$$2/3 + 2/3 + -1/3 = \underline{\hspace{2cm}} \text{ (___ Charge)}$$

Fill in the blanks.

H _____: A composite particle made of quarks held together by the strong force. The proton and neutron are **b** _____ (family of hadrons) which are made of three quarks.

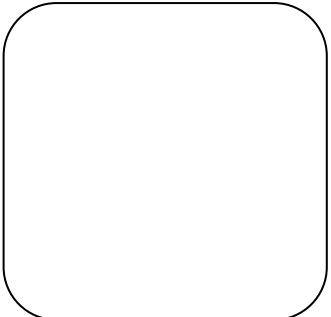



F _____ are particles that have an odd half integer spin (like $1/2$, $3/2$, and so forth) such as the proton, **n** _____, and electron. **B** _____ are particles that have integer spin (0,1,2...) and not constrained by the Pauli exclusion principle. All the force carrier **p** _____ and mesons are bosons.

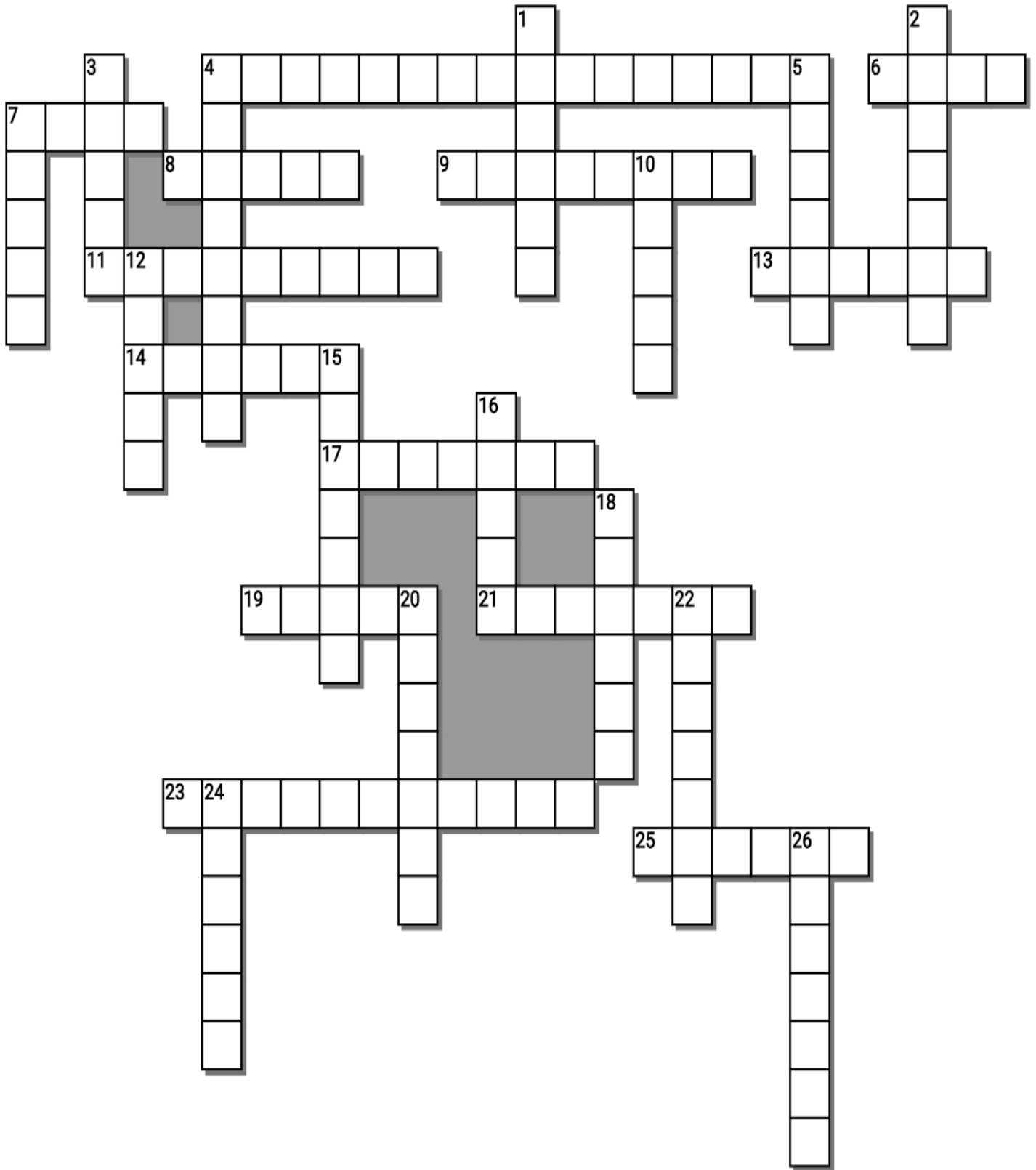
Meson: Subatomic particles composed of one quark and one **a** _____, bound together by the **s** _____ interaction.

When two quarks are close to each other they exchange **g** _____. This creates a very strong **c** _____ force field that binds the quarks together. This helps keep the nucleus together.

Name the Four Fundamental Forces Based on their Description Below. An awesome answer will also include each forces corresponding boson particle.

Word Bank: Gravity, Strong Force, Weak Force, Electromagnetism

<p>This force is responsible for the binding together of nucleons and controls their stability, it is known as the strong nuclear force. The strongest force.</p> 	<p>The forces that occur between electrically charged particles. In electromagnetic theory these forces are explained using electromagnetic fields. Much stronger than gravity and has an infinite range.</p> 	<p>The natural phenomenon by which physical bodies appear to attract each other with a force proportional to their masses. Weakest force but has an infinite range.</p> 	<p>A force between elementary particles that causes certain processes that take place with low probability, as radioactive beta-decay and collisions between neutrinos and other particles. Short range and only dominate only on sub atomic particles</p> 
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Possible Answers

ACCELERATOR, BOSON, CARRIER, CHARGE, COLOR, ELECTROMAGNETISM, ELECTRON, EMPTY, FERMION, GLUON, GRAVITY, HADRON, HIGGS, LEPTON, MATTER, MESON, MODEL, MUON, NEUTRINOS, NEUTRON, NEUTRON, NUCLEUS, PARTICLE, PROTON, QUARKS, STRANGE, STRONG, WEAK

Note: #3 Down should be boson, and #2 Down should be fermion – Sorry ☹️, it was a late night making this puzzle.

Across

4. The forces that occur between electrically charged particles. In electromagnetic theory these forces are explained using electromagnetic fields. Much stronger than gravity and has an infinite range.
6. A force between elementary particles that causes certain processes that take place with low probability, as radioactive beta-decay and collisions between neutrinos and other particles. Short range and only dominate only on sub atomic particles
7. The 6 Leptons Electron M_____ Tau 3 types of Neutrinos
8. Subatomic particles composed of one quark and one antiquark, bound together by the strong interaction.
9. A tiny piece of anything.
11. _____ have no electrical or strong charge, they almost never interact with any other particles.
13. A _____ is an elementary particle of half-integer spin that does not undergo strong interactions.
14. The _____ consists of two up quarks and one down quark (if you sum up the electrical charges / spin of this combination you get +1, the charge of the proton). $2/3 + 2/3 + -1/3 = +1$
19. Holds quarks together (Boson).
21. The most bizarre quark
23. A particle _____ is a machine that uses electromagnetic fields to propel charged particles.
25. The _____ Force: This force is responsible for the binding together of nucleons and controls their stability, it is known as the strong nuclear force. The strongest force.

Down

1. A composite particle made of quarks held together by the strong force.
2. A _____ is a particle which has an integer spin (0, 1, 2...). All the force carrier particles and mesons.
3. A _____ is any particle that has an odd half-integer (like 1/2, 3/2, and so forth) spin. Quarks and leptons, as well as most composite particles, like protons and neutrons.
4. Quarks are just bigger than the _____
5. All visible _____ in the universe is made from the first generation of matter particles – up quarks, down quarks, and electrons.
7. The Standard _____ of particle physics is the theory describing three of the four known fundamental forces (the electromagnetic, weak, and strong interactions, and not including the gravitational force) in the universe, as well as classifying all known elementary particles.
10. _____ Force: The force between quarks is called the color force. The color force involves the exchange of gluons and is so strong that the quark-antiquark pair production energy is reached before quarks can be separated.
12. Most of an atom is mostly _____ space
15. Electrons orbit far away from the _____.
16. The _____ Boson Particle: One of the 17 fundamental particles in the Standard Model.
18. Protons and Neutrons are composed of even smaller particles called _____
20. The neutron is a combination of _____ down quarks and _____ up quark (and again, if you combine the electrical charges, they sum up to zero: it's therefore electrically neutral) $-1/3 + -1/3 + 2/3 = 0$
22. The natural phenomenon by which physical bodies appear to attract each other with a force proportional to their masses. Weakest force but has an infinite range.
24. Up Quarks carry a $2/3$ C _____
26. A proton is just larger than a _____

Part 2 Inside the Atom

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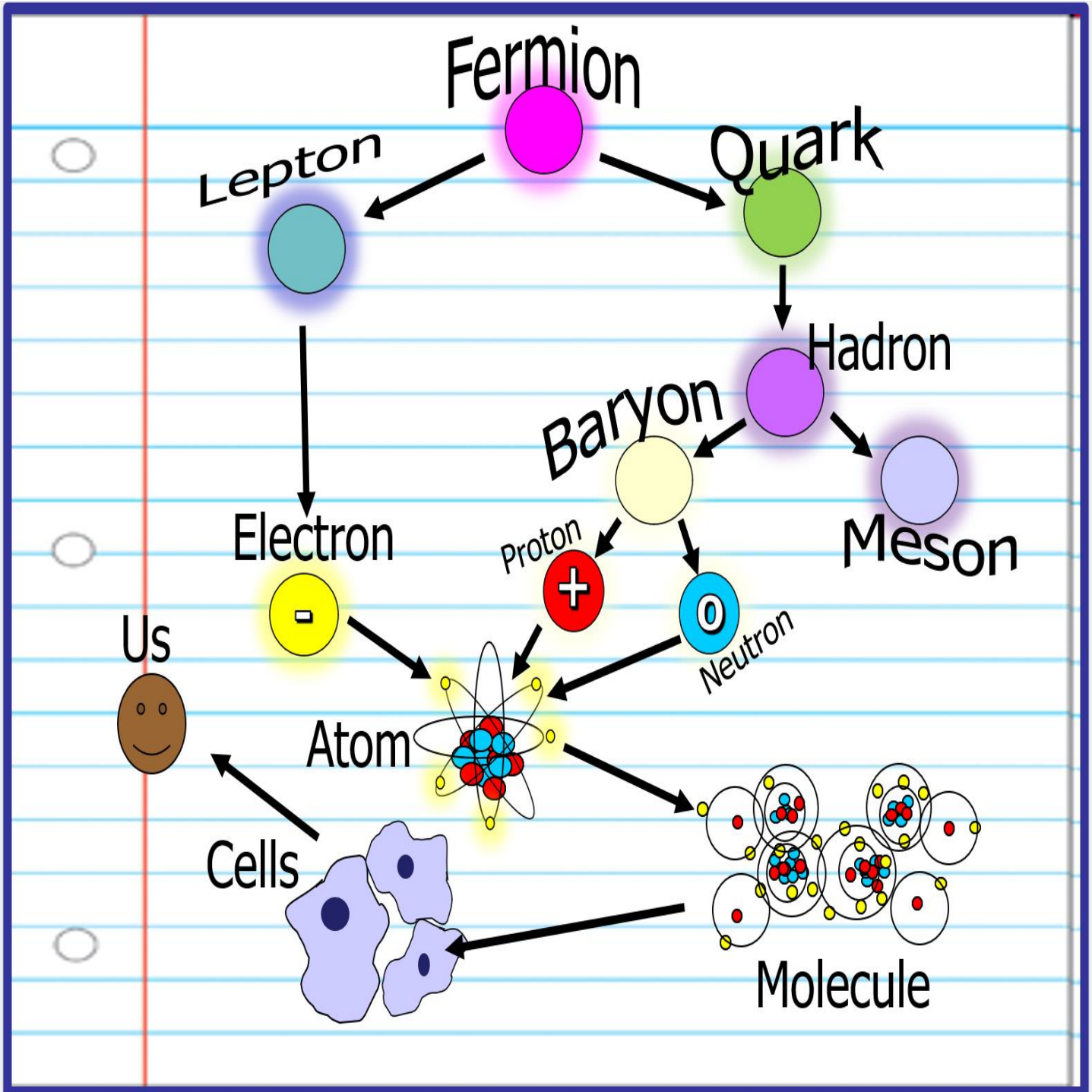
Part 1 Lesson 1

Most of an atom is mostly empty space, electrons orbit far away from the nucleus.

1836 Electrons = Mass of 1 proton.

1 Neutron = little bit more mass than a proton.

Complete the flow chart as described in the slideshow.



Please complete the blank standard model in particle physics below. Colored pencils can help improve your model.

Fermions

Bosons

Quarks

U

Up

C

Charm

T

Top

D

Down

S

Strange

B

Bottom

γ

EM

Photon

Z

Weak

Z Boson

W

Weak

W Boson

g

Strong

Gluon

Higgs Boson

Force Carrier Particles

Leptons

ν_e

Electron
Neutrino

ν_μ

Muon
Neutrino

ν_τ

Tau
Neutrino

e

Electron

μ

Muon

τ

tau

Which is a Fermion? and which is a Boson?

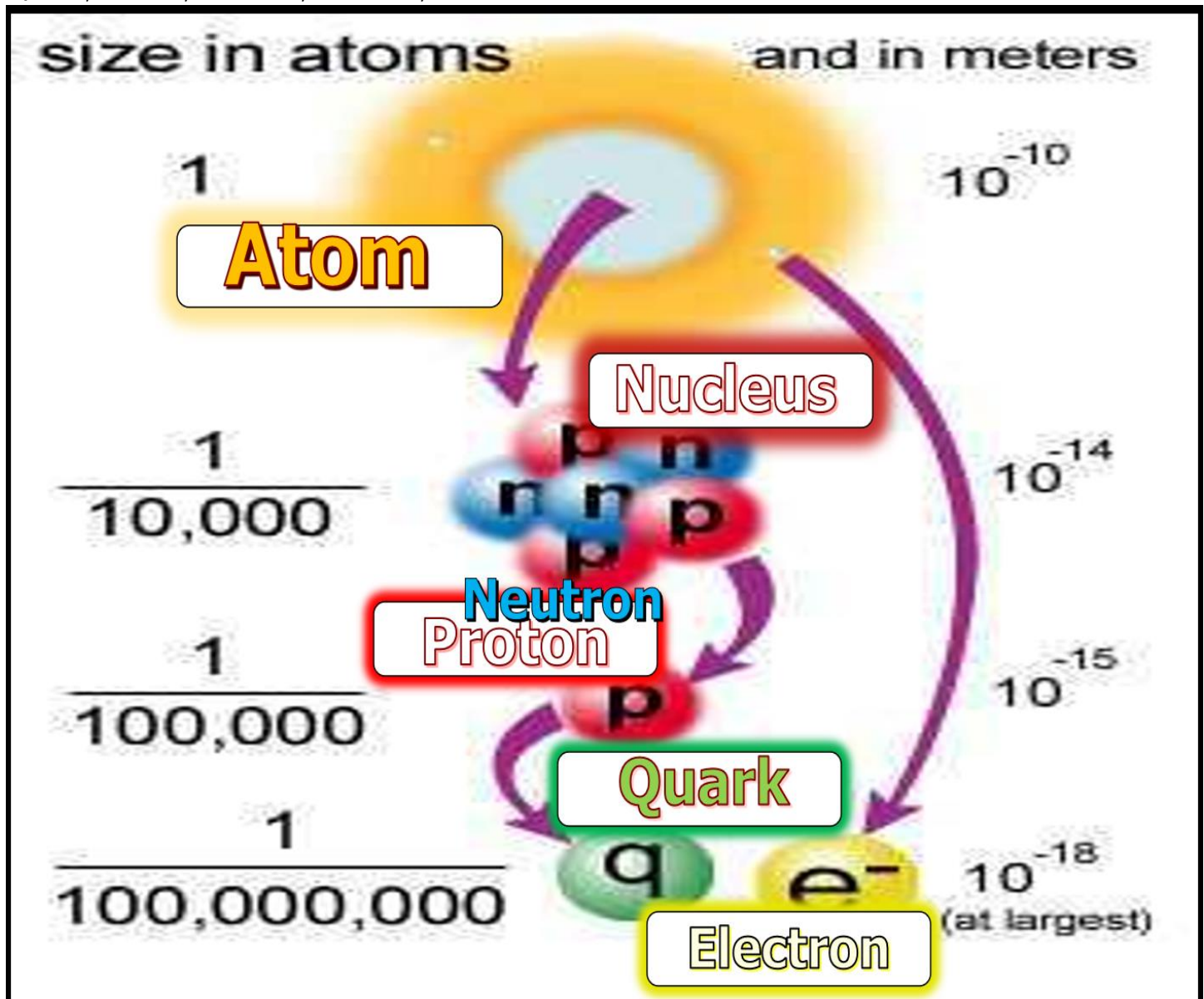
A **Boson** is a particle which has an integer spin (0, 1, 2...). All the force carrier particles and mesons.

A **Fermion** is any particle that has an odd half-integer (like 1/2, 3/2, and so forth) spin. Quarks and leptons, as well as most composite particles, like protons and neutrons.

The **Higgs** Boson Particle: One of the 17 fundamental particles in the Standard Model.

- The other 16 are the 6 quarks, 6 leptons, the photon, gluon, W, and Z bosons.
- These 17 particles are the ones responsible for all the forces in nature except gravity.
- The Higgs is currently being studied and until recently was only theoretical.
- The very massive Higgs Boson explains why the other elementary particles, except the photon and gluon, are massive. Also why the photon has no mass.

Please describe some relative size of particles in comparison to each other. Word Bank: Quark, Proton, Nucleus, Electron, Atom



Please put the following in the correct box according to their size.

Atom	Electron	Quark	Proton	Neutron	Molecule	Nucleus
Smallest -----> Largest						
Electron	Quark	Proton	Neutron	Nucleus	Atom	Molecule

Part 2 Lesson 2

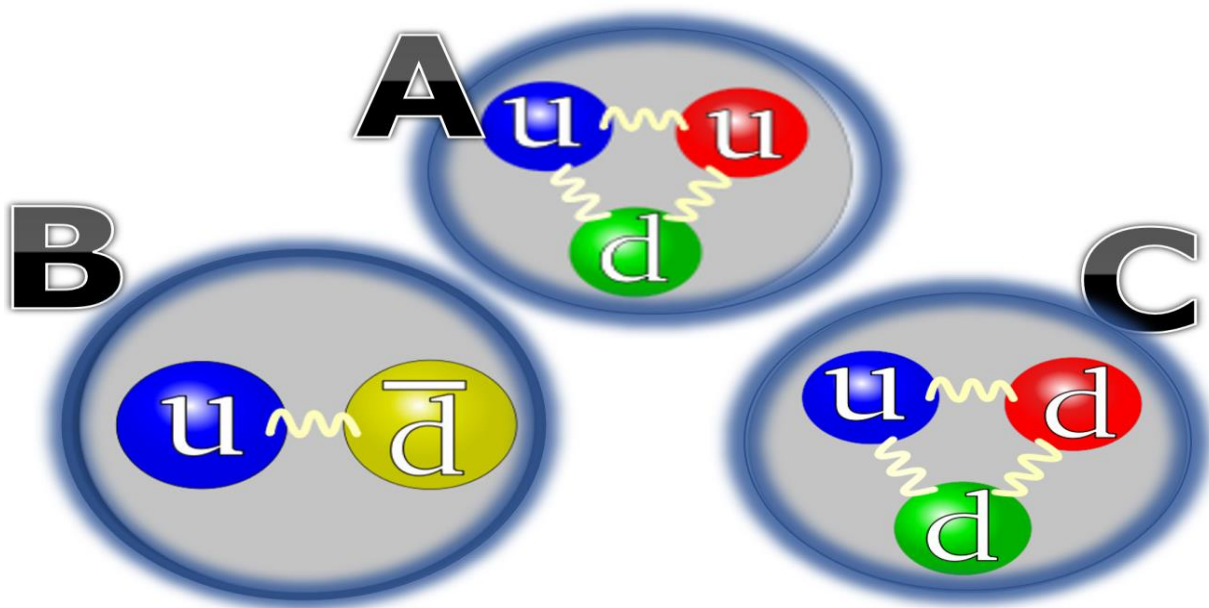
Physicists have discovered that protons and neutrons (**Hadrons**) are composed of even smaller particles called **Quarks**.

Just bigger than an **Electron**.

Hadron: A composite particle made of quarks held together by the strong force. The proton and neutron are **baryon** (family of hadrons) which are made of three quarks.

Which two are hadrons / in the family of baryons and which is a Meson Which is the Proton, and which is the Neutron? Explain and label the picture below.

A and C are hadrons (A is the Proton because it has two up quarks and one down quark. C is the Neutron because it has two down quarks and one up quark). B is a Meson made of one quark and one anti-quark



The proton consists of **2** up quarks and **1** down quark (if you sum up the electrical charges / spin of this combination you get +1, the charge of the proton).

$$\frac{2}{3} + \frac{2}{3} + -\frac{1}{3} = +1$$

The neutron is a combination of **2** down quarks and **1** up quark (and again, if you combine the electrical charges, they sum up to zero: it's therefore electrically neutral)

$$-\frac{1}{3} + -\frac{1}{3} + \frac{2}{3} = 0 \text{ Neutral}$$

What is the Spin on the three below. Word Bank:

Hadron: A composite particle made of **quarks** held together by the **strong** force. The proton and neutron are **baryons** (family of hadrons) which are made of three quarks.

Meson: Subatomic particles composed of one quark and one **anti** quark, bound together by the strong interaction.

- Mesons are Bosons.
- They mediate the nuclear (or strong) interaction between nucleons.
- Keeps the nucleus together!

Gluons: Holds **quarks** together (Boson).

Color Force: The force between quarks is called the color force. The color force involves the exchange of gluons and is so strong that the quark-antiquark pair production energy is reached before quarks can be separated.

The Proton is composed of two up quarks, one down. (Fermion)

A neutron is composed of two down quarks and one up quark. (Fermion)

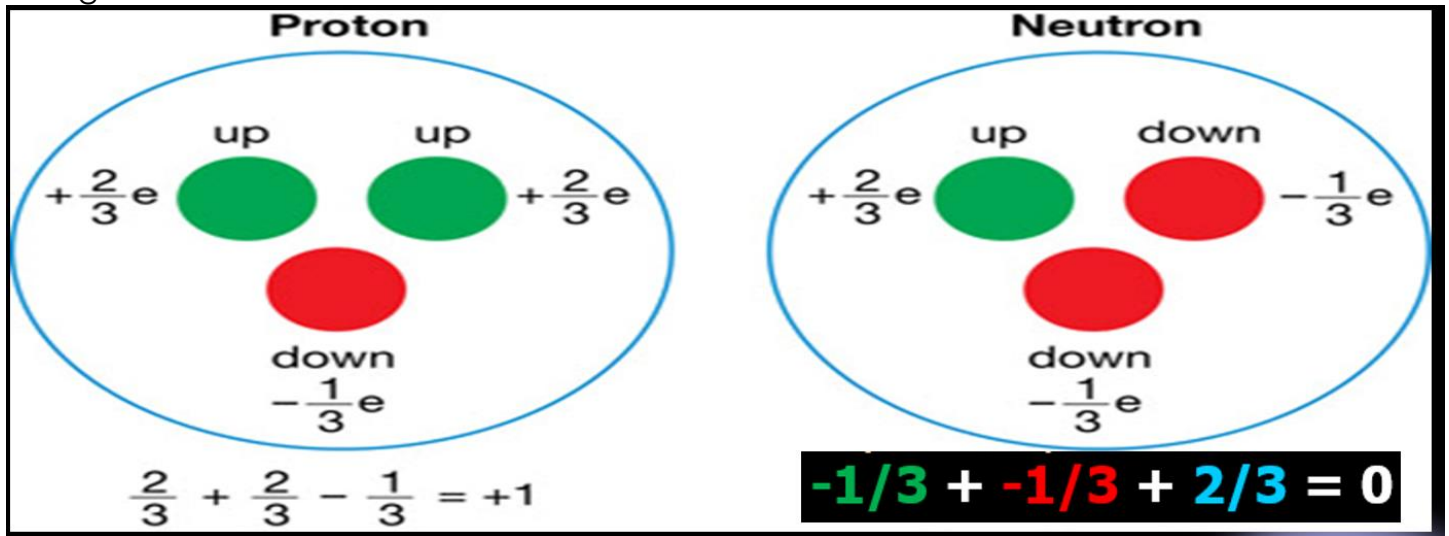
Please name and accurately show the fundamental particles that make up a proton.

Please name and accurately show the fundamental particles that make up a neutron.

Gluon

I hold Quarks Together

Up Quarks carry a $\frac{2}{3}$ Charge, and a down quark carries a $-\frac{1}{3}$ charge. What is the charge of the Proton and Neutron below.



A particle accelerator is a machine that uses electromagnetic fields to propel charged particles.

- The particles reach extremely high speeds and energies, and to contain them in well-defined beams.

Part 2 Lesson 3 Particles

Particle: A tiny piece of anything.

An atom or nucleus.

Elementary particle, quark, gluon.

Name the **Flavors** of quarks below. Word Bank: Charm, Strange, Bottom, Down, Top, Up

<p>$(\frac{2}{3})$ up</p> <p>Gen I</p> <p>$(-\frac{1}{3})$ down</p>	<p>$(\frac{2}{3})$ charm</p> <p>Gen II</p> <p>$(-\frac{1}{3})$ strange</p>	<p>$(\frac{2}{3})$ top</p> <p>Gen III</p> <p>$(-\frac{1}{3})$ bottom</p>
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A lepton is an elementary particle of half-integer spin that does not undergo strong interactions.

The 6 Leptons

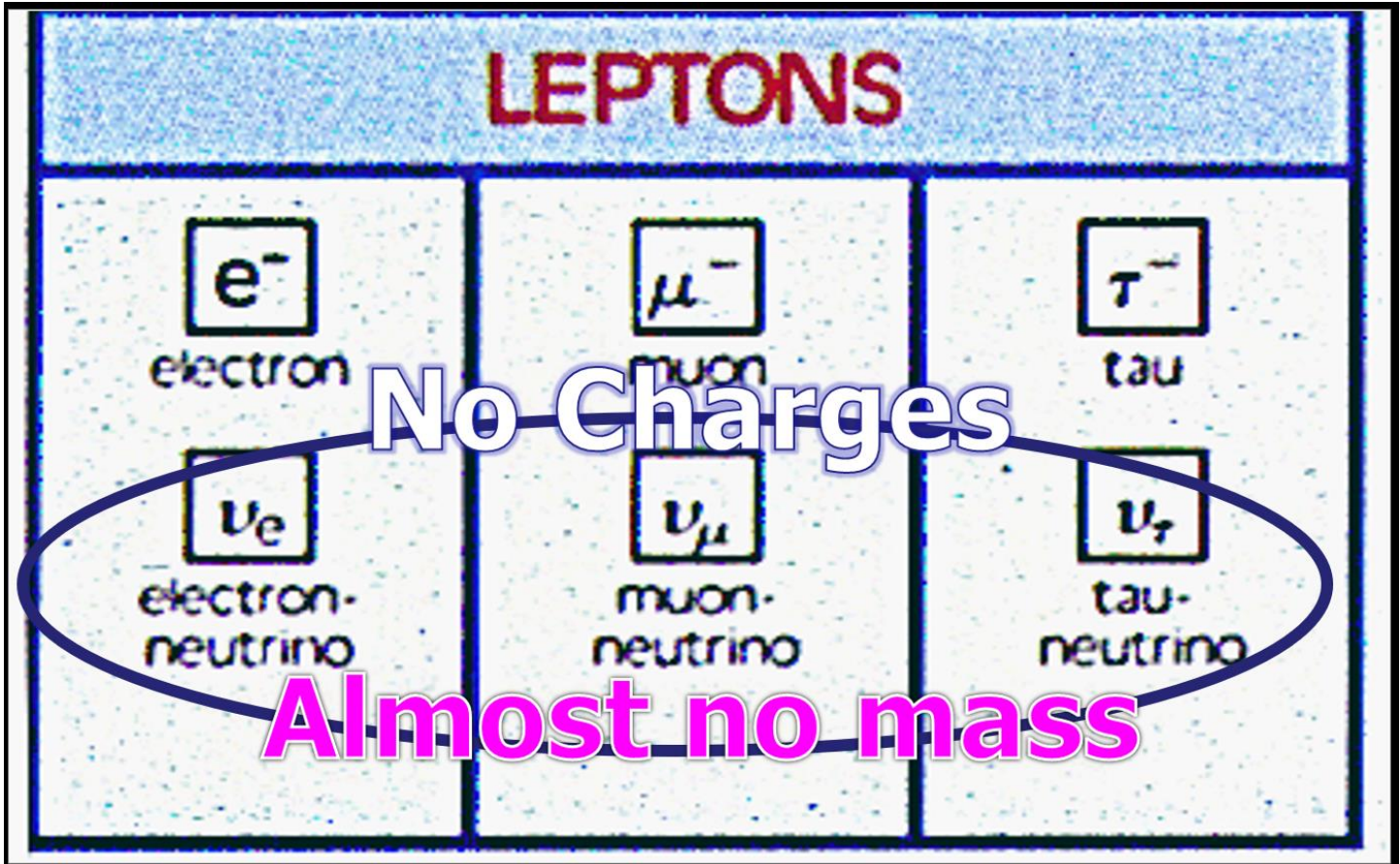
Electron

Muon

Tau

3 types of Neutrinos

Please name the Leptons below: Tau Neutrino 0, Electron -1, Tau -1, Muon -1, Electron Neutrino 0, Tau Neutrino 0



The Neutrino

- Neutrinos have no electrical or **strong** charge, they almost never **interact** with any other particles.
 - Most neutrinos pass right through the earth without ever interacting with a single atom.


Part 2 Lesson 4 Fundamental Forces

All visible matter in the universe is made from the first generation of matter particles -- up quarks, down quarks, and electrons. This is because all second and third generation particles are unstable and quickly decay into stable first generation particles.

Everything is made of...

6 quarks that make Protons and Neutrons

6 leptons. The best-known lepton is the electron.
Force carrier particles.

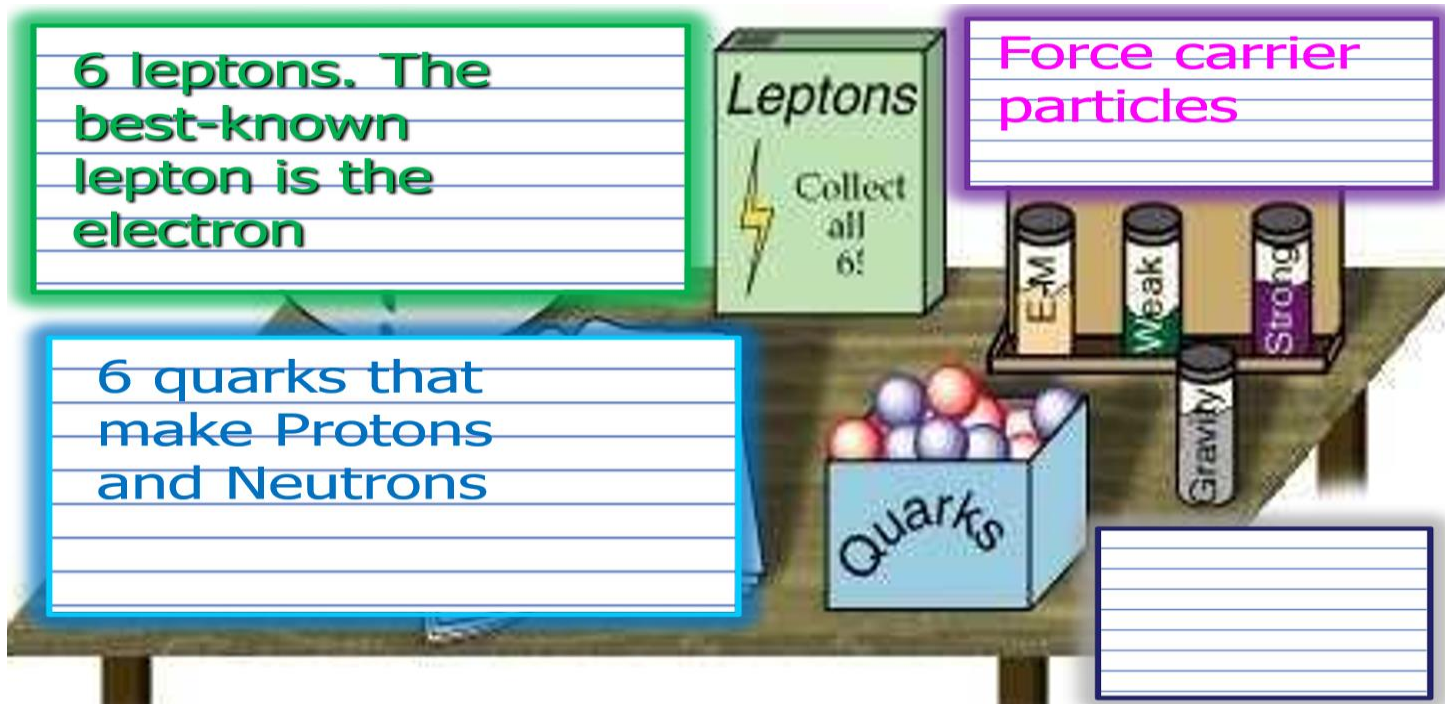


What am I and all matter made of?
A correct answer dives deep into the recipe of the universe.

- Everything is made of...
 - 6 quarks that make Protons and Neutrons
 - 6 leptons. The best-known lepton is the electron.
 - Force carrier particles.

	Long Range (Speed Of Light) No Mass	Short Range (Slower Than Light Speed) High Mass	Long Range (Speed Of Light) No Mass	Short Range (Slower Than Light Speed) High Mass
	Gravity	Weak	Electromagnetic	Strong
Carried By	Graviton (not yet observed)	W^+ W^- Z^0	Photon	Gluon
Acts on	All	Quarks and Leptons	Quarks and Charged Leptons and W^+ W^-	Quarks and Gluons

Describe the recipe of the Universe.



Force Carrier Particles: Particles communicate with one another through force carriers. Force carriers are particles that act like messages exchanged between other particles. Scientists have discovered force carriers for three of the four known forces: electromagnetism, the strong force and the weak force. Still looking for the graviton

Provide some information about the fundamental forces below as described in the slideshow

Gravity

The natural phenomenon by which physical bodies appear to attract each other with a force proportional to their masses. Weakest force but has an infinite range.

Electromagnetic

The forces that occur between electrically charged particles. In electromagnetic theory these forces are explained using electromagnetic fields. Much stronger than gravity and has an infinite range.

Strong

This force is responsible for the binding together of nucleons and controls their stability, it is known as the strong nuclear force. The strongest force.

Weak

A force between elementary particles that causes certain processes that take place with low probability, as radioactive beta-decay and collisions between neutrinos and other particles. Short range and only dominate only on sub atomic particles

Weak Force: Weakest of the forces but still stronger than gravity.

Which quark integer spin is a proton and which is a neutron. Please Label the charge.

$-1/3 + -1/3 + 2/3 =$ Neutron (0 Charge)	$2/3 + 2/3 + -1/3 =$ Proton (+1Charge)
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Fill in the blanks.

H Hadron: A composite particle made of quarks held together by the strong force. The proton and neutron are **Baryon** (family of hadrons) which are made of three quarks.

Fermions are particles that have an odd half integer spin (like $1/2$, $3/2$, and so forth) such as the proton,

Neutron and electron. **Baryons** are particles that have integer spin (0,1,2...) and not constrained by the Pauli exclusion principle. All the force carrier **Particles** and mesons are bosons.

Meson: Subatomic particles composed of one quark and one **Anti-Quark** bound together by the **STRONG** interaction.

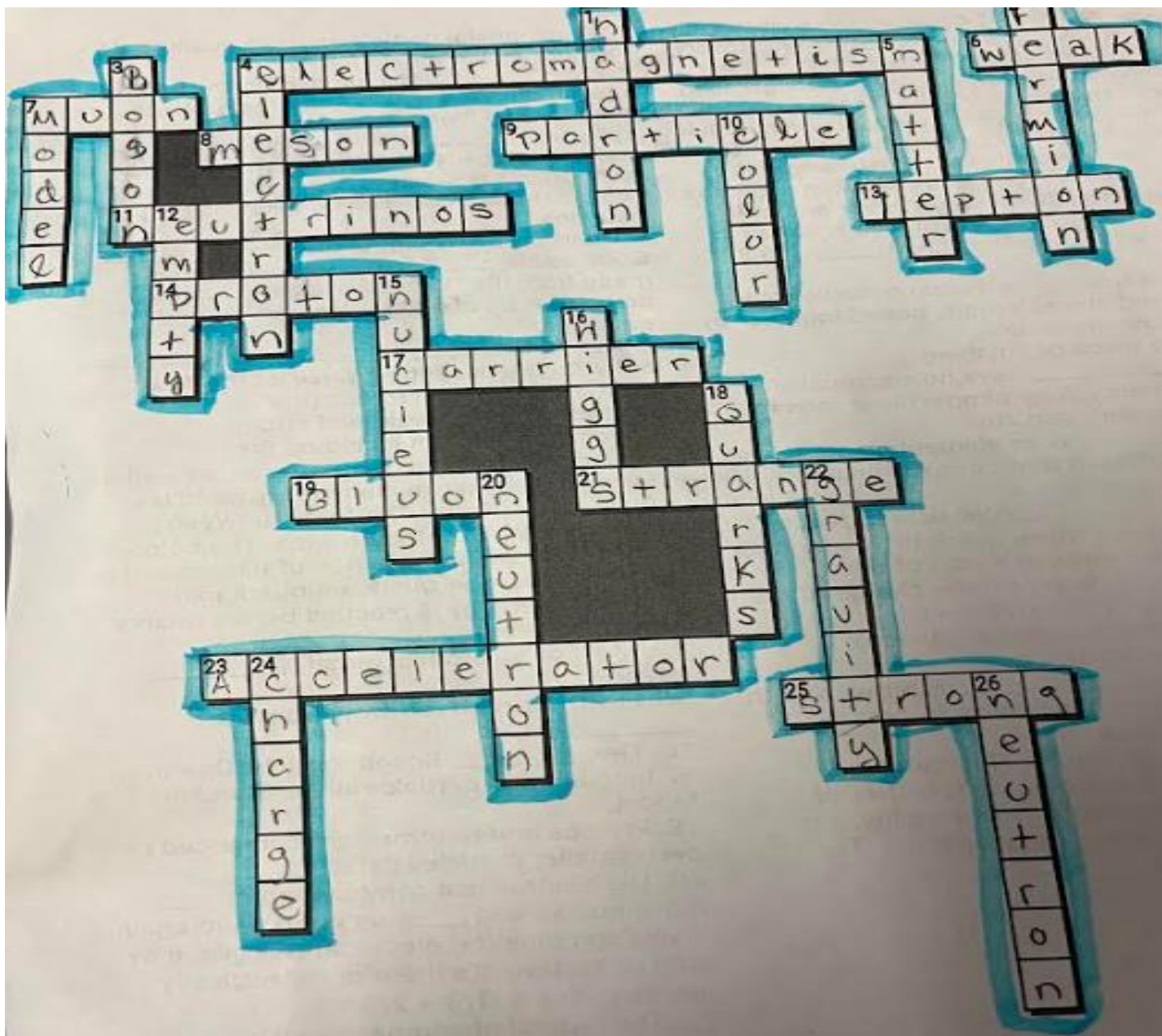
When two quarks are close to each other they exchange **gGluon**. This creates a very strong **Color** force field that binds the quarks together. This helps keep the nucleus together.

Name the Four Fundamental Forces Based on their Description Below. An awesome answer will also include each forces corresponding boson particle.

Word Bank: Gravity, Strong Force, Weak Force, Electromagnetism

Word Bank: Gravity, Strong Force, Weak Force, Electromagnetism

<p>This force is responsible for the binding together of nucleons and controls their stability, it is known as the strong nuclear force. The strongest force.</p> <p>STRONG FORCE</p>	<p>The forces that occur between electrically charged particles. In electromagnetic theory these forces are explained using electromagnetic fields. Much stronger than gravity and has an infinite range.</p> <p>Electro-magnetism</p>	<p>The natural phenomenon by which physical bodies appear to attract each other with a force proportional to their masses. Weakest force but has an infinite range.</p> <p>Gravity</p>	<p>A force between elementary particles that causes certain processes that take place with low probability, as radioactive beta-decay and collisions between neutrinos and other particles. Short range and only dominate only on sub atomic particles</p> <p>WEAK FORCE</p>
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Possible Answers

ACCELERATOR, BOSON, CARRIER, CHARGE, COLOR, ELECTROMAGNETISM, ELECTRON, EMPTY, FERMION, GLUON, GRAVITY, HADRON, HIGGS, LEPTON, MATTER, MESON, MODEL, MUON, NEUTRINOS, NEUTRON, NEUTRON, NUCLEUS, PARTICLE, PROTON, QUARKS, STRANGE, STRONG, WEAK

Note: #3 Down should be boson, and #2 Down should be fermion. And #26, the Neutron is in fact slightly more massive than the proton. - Sorry ☹️, it was a late night making this puzzle.

Across

4. The forces that occur between electrically charged particles. In electromagnetic theory these forces are explained using electromagnetic fields. Much stronger than gravity and has an infinite range.
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21. The most bizarre quark
23. A particle _____ is a machine that uses electromagnetic fields to propel charged particles.
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Down

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16. The _____ Boson Particle: One of the 17 fundamental particles in the Standard Model.
18. Protons and Neutrons are composed of even smaller particles called _____
20. The neutron is a combination of _____ down quarks and _____ up quark (and again, if you combine the electrical charges, they sum up to zero: it's therefore electrically neutral) $-1/3 + -1/3 + 2/3 = 0$
22. The natural phenomenon by which physical bodies appear to attract each other with a force proportional to their masses. Weakest force but has an infinite range.
24. Up Quarks carry a $2/3$ C _____
26. A proton is just larger than a _____

