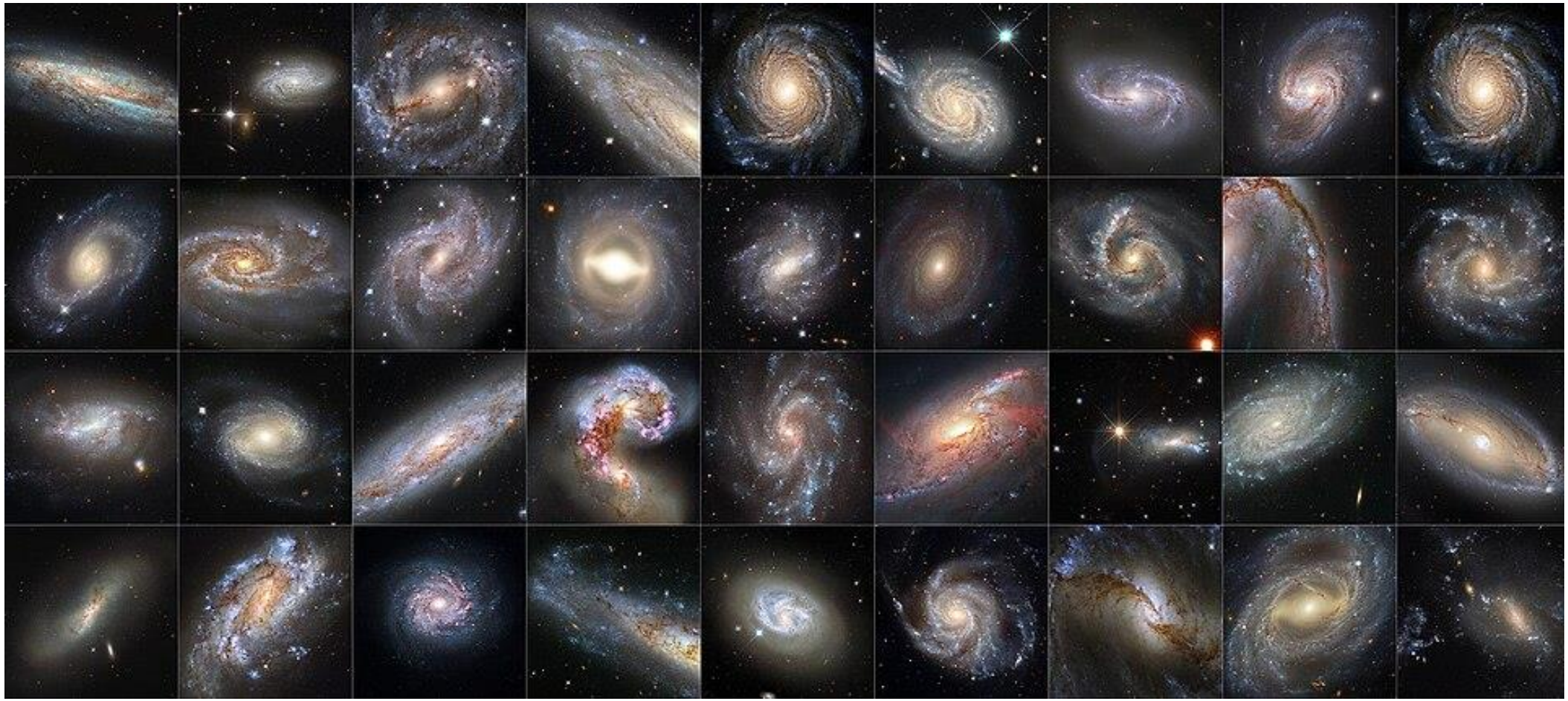
Pale Blue Dot: A Vision of the Human Future in Space

- 1990 photograph of Earth taken by the Voyager 1 spacecraft from 3.7 billion miles away

Galaxies : 2 trillion



1. THE BIG PICTURE – FROM UNIVERSE TO APPLE

Universe

↓

Milky Way Galaxy

↓

Solar System

↓

Earth

↓

Ecosystem (forest)

↓

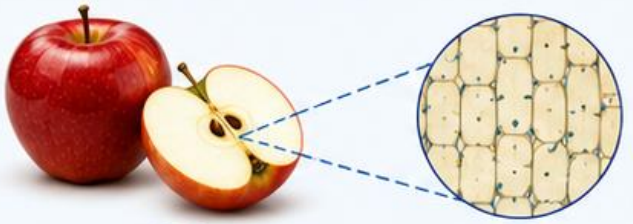
Apple Tree (organism)

↓

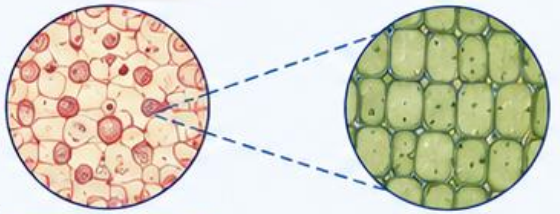
Apple (the fruit)

2. ZOOMING IN – FROM APPLE TO ATOMS

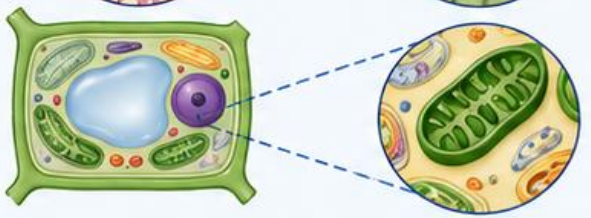
Apple



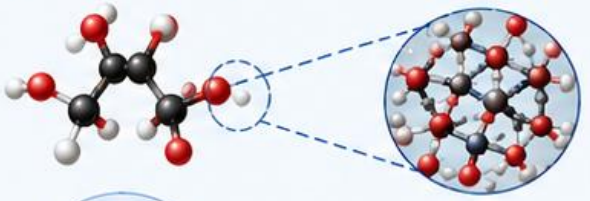
Plant tissues (flesh)



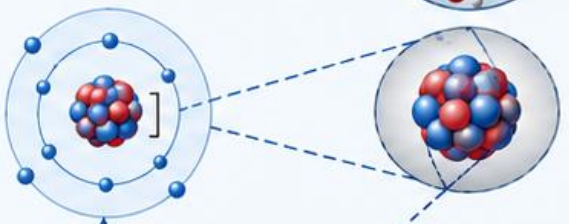
Plant cell



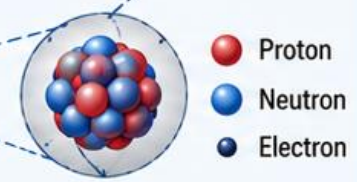
Molecules (e.g., sugar)



Atom (e.g., carbon)

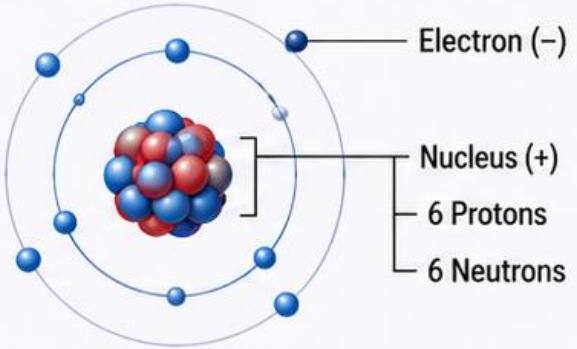


Subatomic particles

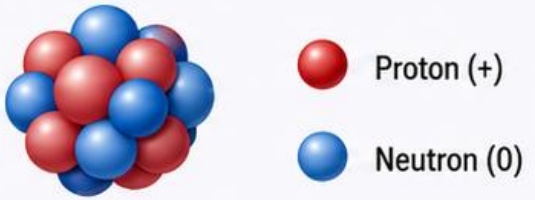


3. THE SMALLEST BUILDING BLOCKS

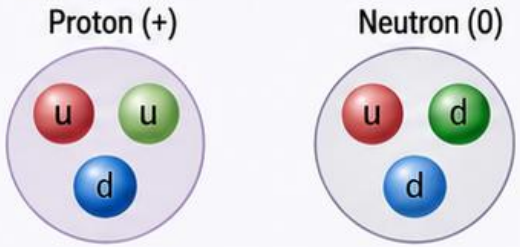
Atom (e.g., Carbon)



Nucleus



Proton and Neutron (Quarks)

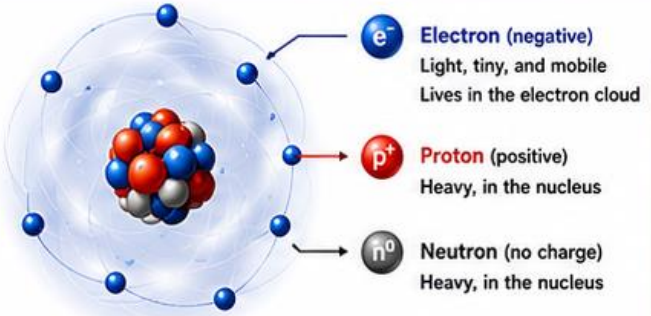


u = up quark d = down quark

∿∿ = gluons (force particles) holding quarks together

1. WHY DO WE CARE ABOUT ELECTRONS?

Electrons are the part of the atom that interacts with the outside world.



Electron (negative)
Light, tiny, and mobile
Lives in the electron cloud

Proton (positive)
Heavy, in the nucleus

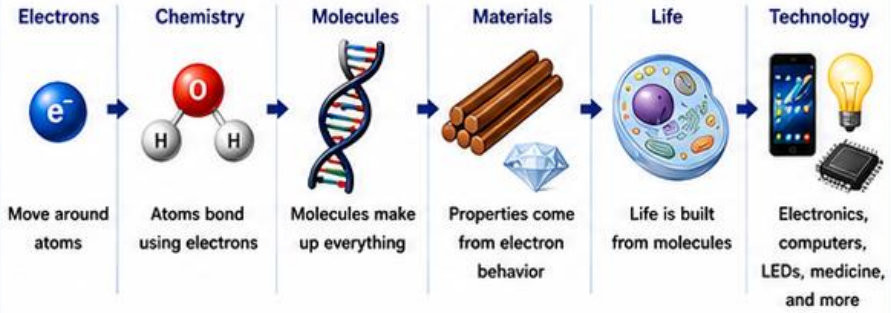
Neutron (no charge)
Heavy, in the nucleus

Big idea:

The nucleus is tiny and mostly sits still.

Electrons move around and determine how atoms interact, bond, and behave.

Electrons make the world we experience



Why not the others?

Protons (p^+)

- Give atoms their identity (how many).
- But they are locked in the nucleus and don't move around.
- So they don't do chemistry or carry electricity.

Neutrons (n^0)

- Add stability to the nucleus.
- But they have no electric charge.
- So they don't participate in chemical reactions or electric current.

Quarks (u,d,...)

- Build protons and neutrons.
- But quarks are trapped inside by the strong force.
- We never see quarks in everyday life.

Electrons are the active players that create chemistry, electricity, light, magnetism—and modern technology.

2. WHY IS THE ELECTRON NEGATIVE?

We don't know why. But we know what it means.

A. "Positive" and "negative" are just labels (conventions)

Convention A (what we use)
- electron (–)
- proton (+)

Physics would work exactly the same!

Convention B (equally valid)
- electron (+)
- proton (–)

B. Opposite charges attract. That's why atoms exist.

Opposite charges: attract

Electron is held by the proton.

Atoms are stable! ✓

Same charges: repel

They push apart.

No stable atom. ✗

C. What we know (measured)

Electron charge	$-e = -1.602 \times 10^{-19}$ C
Proton charge	$+e = +1.602 \times 10^{-19}$ C

Exactly equal in magnitude, opposite in sign.

D. What we don't know

Why nature chose this value or sign.

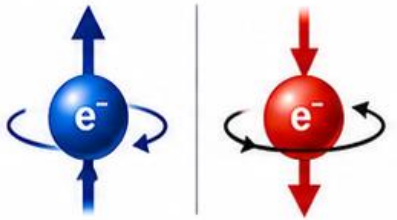
This is one of the deepest mysteries in physics.

Opposite charge makes atoms possible. Without it, there would be no chemistry, no life.

3. ELECTRON SPIN: THE QUANTUM SUPERPOWER

Spin is an intrinsic quantum property. It is not literal spinning.

A. Every electron has spin



Not a spinning ball!

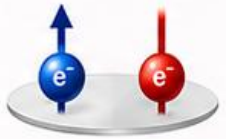
Spin is NOT the electron physically spinning.

It is an intrinsic quantum property.

B. Pauli Exclusion Principle

No two electrons can occupy the same quantum state.

Allowed (opposite spins)



One "seat" (orbital) can hold two electrons if their spins are opposite. ✓

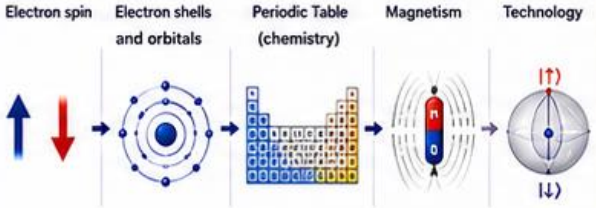
Not allowed (same spins)

One "seat" cannot hold two electrons with the same spin. ✗

Why this matters

- ✓ Allows many electrons to fill shells.
- ✓ Creates the structure of atoms.
- ✓ Leads to the periodic table.
- ✓ Enables the richness of chemistry.

C. Spin in action: from atoms to technology



- Magnetic storage (hard drives)
- MRI scans
- Spintronics (next-gen electronics)
- Quantum computing

Spin gives atoms structure, chemistry richness, magnetism—and powers many modern technologies.