Life on Earth

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Life: What is it?

- From people, to microbes, to tree, to GATORS
Life: What is it?

- **Things with the ability to reproduce AND the ability to evolve and adapt**
- Why both of these?
- Flames can spread or “reproduce”, but they aren’t alive
- Crystals (i.e. salt) can also spread or grow, but they aren’t alive either
- Only living things evolve – meaning develop adaptations to their environment that improve their ability to continue
Quick Aside on “evolution”

• In this instance, we mean “evolution” with a little “e”
• Meaning … not necessarily the origin of species (“Evolution” with a big “E” – though that is related)
• Rather, the short timescale adaptation to environment
• Note that “evolution” is a VERY well-established fact – all sorts of living critters evolve on easily-observed timescales:
  • For instance, antibiotic-resistant microbes (like resistant tuberculosis)
  • If you don’t believe in “evolution” … well, good luck (you’ll need it!)
Life: What’s it Made of?

- Constituent elements of humans: H (61%), O (26%), C (10.5%), N (2.4%), Ca (0.23%), P (0.13%)
- Sun: H (91%), He (9%), O (0.08%), C (0.033%), Ne (0.011%), N (0.010%), …
- Earth crust: O (47%), Si (28%), Al (9.1%), Fe (5%), …
- Earth atmosphere: N (78%), O (21%), Ar (0.9%), C (0.04%), ..
- Hydrogen in us is mostly in H₂O (water)
- Carbon – a key ingredient(!!)
Why Carbon?

• For any element, its distribution and structure of electrons determines many of its properties (i.e. color and chemical properties)
• Electrons are distributed in discrete shells (quantum physics)
• Carbon has a very “normal-looking” electron structure
• 6 electrons:
  • Inner shell is “full” with 2 electrons
  • Outer shell is exactly half-full with 4 electrons (shell needs 8 electrons to be “full”)
Why Carbon?

• It turns out that this normal-ish structure has very special properties for chemical bonding.
• In chemical bonding, atoms “share” some electrons in their outermost shell to try to reach a “full shell” (8 for Carbon).
• For instance, Carbon can bond with another Carbon atom ⇒ each atom gets to feel like it has 8 electrons and is happy 😊.

![Diagram of atomic structure showing bonding between carbon atoms.](image)
Why Carbon?

- Or, Carbon can bond with 4 Hydrogen atoms
- Hydrogen only has the innermost shell $\Rightarrow$ needs 2 electrons “shared” to feel full; Carbon shares a total of 8 in its outer shell
- (This is the gas called “methane”)
Why Carbon?

• Or, Carbon can bond with 2 Oxygen atoms
• Oxygen has 6 outer shell electrons
• (This is the gas called “Carbon dioxide” or CO₂ – our favorite greenhouse gas!)
Why Carbon?

- Or, Carbon can bond with 1 Nitrogen and 1 Hydrogen atoms
- Nitrogen has 5 outer shell electrons
- (This is “Hydrogen Cyanide” or CNH – deadly poison!)
Why Carbon?

- There are other possibilities too!
- **Long story short:** Carbon is incredibly diverse in its ability to form chemical bonds with other elements
- Of ALL the other elements in the periodic table (almost 100 naturally-occurring ones), only Silicon has similar “talent” for chemical bonding
Carbon chains

- Carbon is also virtually unique for its ability to form long “chains” of molecules
- For instance, carbon “nanotubes” and “buckyballs” – only recently discovered in nature
- Fantastic material strength and electrical properties
Carbon chains

• Carbon and Hydrogen can also form long chains
• These might be just CH, or might include other elements – usually dangling off the ends of the CH “chain”
• These are generically called “hydrocarbons”
• Here are a few recognizable examples
Carbon chains

- Other chains including other elements and double bonds
- This one, for instance, is a lipid
- AKA “fat”
- The energy your body stores goes into that double bond near the lower right
- “Burning fat” means breaking that double bond to release energy

In reverse, eating chocolate cake means “augmenting my personal allocation of double carbon bonds” (sounds nicer that way)
Carbon chain vocabulary

• “Monomers” are chemical units (small molecules) which can be joined together to make a long chain
• “Polymers” are the larger, more complex molecules (i.e. chains) which are made up of multiple monomers

• Side Note:
  • This diversity is why “organic” (meaning, “carbon”!) chemistry is SO complex !!
Important Polymers

• We already saw some (i.e. lipid = fat)
• Other important ones include “amino acids” (lots more about these to come!)
• Note Alanine = amino acid
Alanine: Isomerism

- Alanine comes in 2 “flavors” -- Levo & Dextro
- (L = “left-handed”; D = “right-handed”)
- You cannot rotate one of these to match the other – same chemical components, but different structure (below)

- **Note that essentially ALL life on Earth uses L, not D (!!!)**
- Why?
As we’ll see in a few minutes, photosynthesis is the fundamental energy source for (almost) all life on Earth.

Here’s that pesky Sun again!

Plants pull water (H₂O) from underground, plus CO₂ from the atmosphere.

Add some sunlight and photosynthesis turns that energy into chemical bonds (sugars).

Oxygen is released to the air as a waste byproduct.
Photosynthesis Details

- More detailed picture (quick! Copy this all down!)
- Note presence of ADP and ATP
Photosynthesis (Less) Detail

- “Chlorophyll” is the main light absorber, and is what gives plants their typical green color
- Chlorophyll exists inside plant cells in structures called “chloroplasts”
Energy Cycle of Life

Almost all life on Earth gets in energy (ultimately) from the Sun!

Energy from the Sun is taken up by the plants, which absorb that energy in their chloroplasts.

Plants can reuse these products with the input of energy from the Sun.

In the process, they convert the highly ordered sugars into carbon dioxide and water, a disordered form.

Animals use the sugars to produce their own "energy currency" through the mitochondria.

The energy occurs for animal life processes.
Sugars & Metabolism

- Sugar is a chemical compound; chemical reactions can break down a sugar and release energy; ADP and ATP cycles, etc.
- The point: Carbon is critical for metabolism of life on Earth!
Carbon & Reproduction

• Carbon, hydrocarbons make up amino acids
• These are the basic building blocks of proteins (structural parts of living things)
• Amino acids are also building blocks of Deoxyribonucleic Acid (DNA)
• This is the key to reproduction (a defining characteristic of life!)
DNA

- Critical for **ALL** life on Earth
- Structure of DNA (Crick & Watson Nobel prize):
  - Double helix structure
  - Ladder-like
  - Amino acids are “rungs” (nucleotides)
  - Base pairs (A-T and C-G)
DNA

DNA ("zipper" view)
DNA

- DNA structure is key to DNA replication
- Enzymes make the helix “unzip”
- A only matches T; C only matches G (and vice versa)
- So, add new nucleotides to the mix, and they bond to the only possible matches
- Voila ⇒ you get 2 identical DNA strands!!
DNA & Genetic Coding

• There are 20 amino acids which humans use to build ALL of the proteins/structures in the body
• DNA nucleotide sequences are used as a code with a “triplet” package:
  • i.e. AAA in a row means one amino acid
  • ACA means another acid
  • GCC means yet another amino acid
• Some triplet sequences also mean “start” a structure and some mean “stop” the structure
• So … DNA is literally a set of instructions on how to build a living creature, one protein at a time
## Genetic Code

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