

**ASTROBIOLOGY**  
**FIELD GUIDE**



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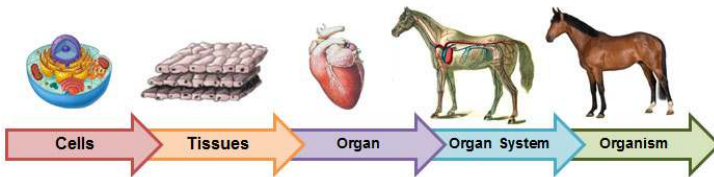
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# Chapter 1 - What are signs of life?

How can you tell if something is living? While there are over 100 characteristics of living things, the following are **8 key traits** to look out for.

## 1. Living things are organized.

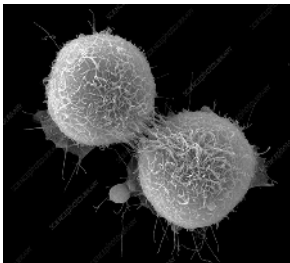
- This means that living things are **made up of one or more cells**.
- In more complex organisms, cells come together to make tissues, tissues come together to make organs, and organs come together to make systems.



## 2. Living things grow.

## 3. Living things reproduce.

- A simple bacterial cell, for example, makes an identical copy of itself through the process of **mitosis**.
- A more complex living thing such as a mammal creates a new organism through the process of **sex**.



mitosis

4. **Living things die.**

5. **Living things move.**

6. **Living things process energy.**

- For example, humans eat and **convert food into energy** to power the body.



7. **Living things get rid of waste.**

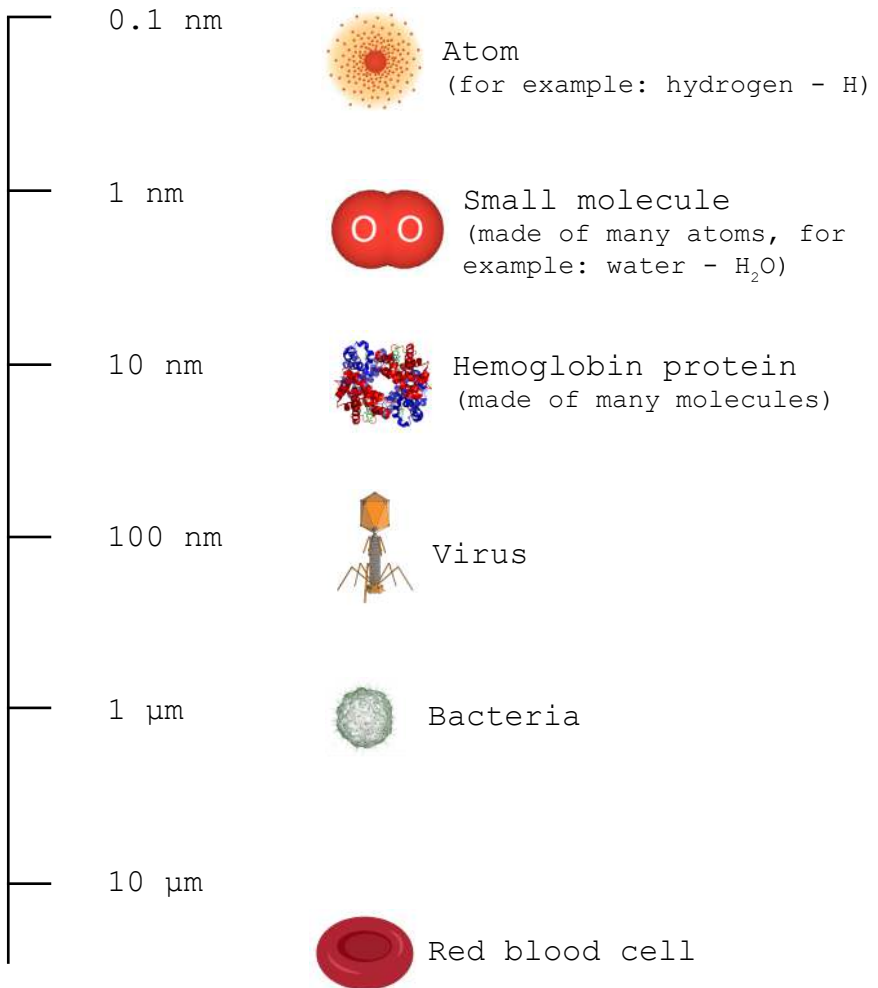
- For example, mammals produce feces and expel carbon dioxide from their lungs.

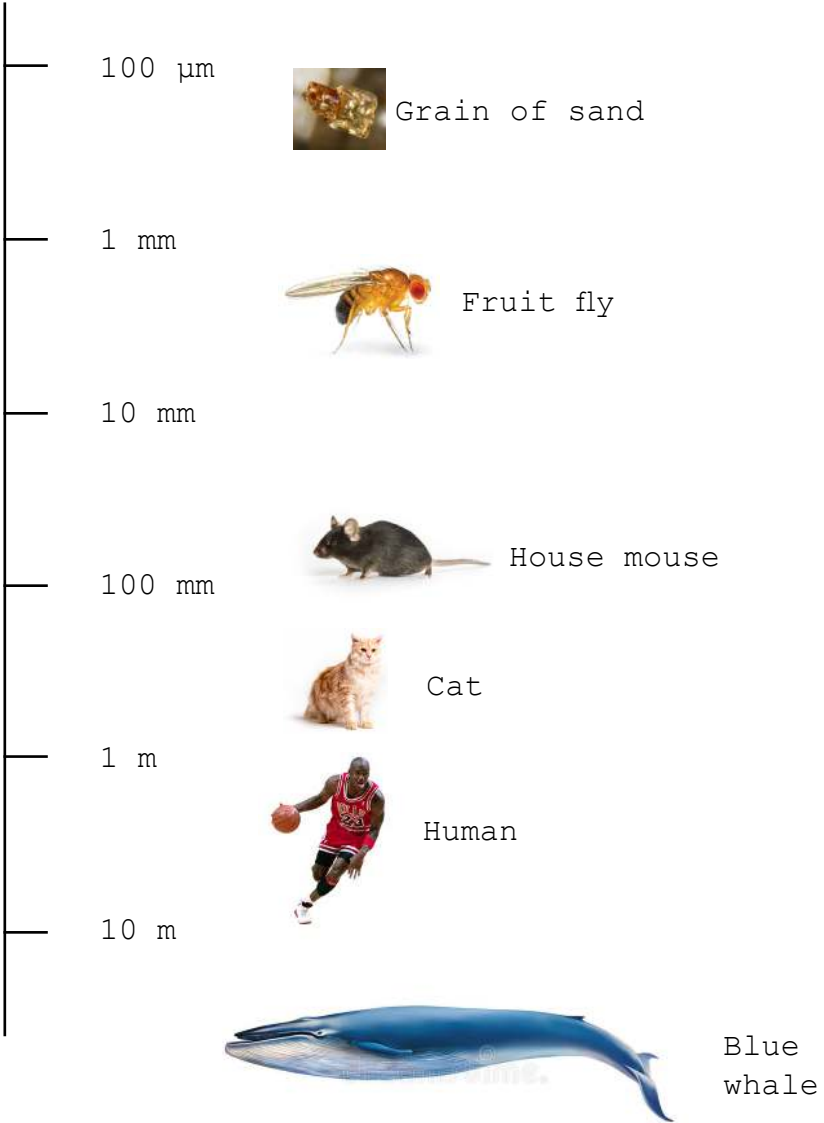
8. **Living things are sensitive to their environment.**

- For example, some plants grow towards light.

# Chapter 2 - What does life look like?

Living things come in all shapes and sizes. When looking for life outside of our own world, we must be careful to open our eyes to **the possibility of life looking different than what we are used to** in our every day lives.





# Chapter 3 - What are the requirements for life?

To the best of our knowledge, there are a few key ingredients that are absolutely required for life to exist. These are **3 elements** to look out for when searching for life outside of Earth.

## 1. Life requires a solvent

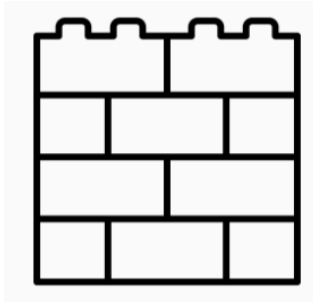
- A **solvent** is required to allow chemical reactions to take place within a living thing.
- The solvent used by all known living things on Earth is **water** ( $H_2O$ ).





## 2. Living things require building blocks

- Living things are made up of **matter**.
- Matter is, for the most part, **made up of atoms and molecules**. (Molecules are combinations of atoms).
- If certain atoms and molecules are not present in a living thing's environment, it cannot grow, reproduce, etc.
- See Chapter 4 to further understand how living things use building blocks.



## 3. Living things require an energy source

- Most of the characteristics of living things described in Chapter 1 cannot occur if there is no available **energy**.
- Energy is often **contained within certain types of molecules** (for example: sugar).
- See Chapter 5 to further understand how living things process energy.



# Chapter 4 - What are the building blocks that make up living things?

## HIGH SCHOOL SCIENCE ALERT!

**Don't freak out.** You might remember seeing this in high school. Maybe it wasn't your thing or you don't remember it.

It's not as bad as it seems. Everything you need to know is on this page.

Living things are **made** from different atoms and molecules.

Here is the **periodic table of elements**. It shows all of the possible types of **atoms** known to exist in the universe.

Highlighted in **red** are the **6 most common atoms** (building blocks) found in living things on Earth.

1 IA		2 IIA		3 IIIB		4 IVB		5 VB	
1 H Hydrogen 1.008									
3 Li Lithium 6.94	4 Be Beryllium 9.012								
11 Na Sodium 22.990	12 Mg Magnesium 24.305								
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942					
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906					
55 Cs Cesium 132.905	56 Ba Barium 137.327	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948					
87 Fr Francium 223	88 Ra Radium 226	89-103 Actinides	104 Rf Rutherfordium 261	105 Db Dubnium 262					
		57 La Lanthanum 138.905	58 Ce Cerium 140.12	59 Pr Praseodymium 140.908					
		89 Ac Actinium 227	90 Th Thorium 232.04	91 Pa Protactinium 231.04					

- Carbon is **found in most molecules** within living things.
- It is for this reason that we describe all living things on Earth as being "**carbon-based**".

- In theory, we might find living things that **do not make use of carbon**.
- Instead, they **could make use of other atoms** that have similar properties to carbon (highlighted in **blue**).
- Examples include silicon (commonly found in sand) or germanium.

Atomic Number → **1** ← Symbol

Name → **Hydrogen** ← Atomic Weight

Mass per shell → **1.008**

Category in the metal-metalloid-nonmetal trend (color of background)

- Blue: s-block metals
- Green: d-block transition metals
- Yellow: p-block nonmetals
- Purple: metalloids
- Orange: f-block lanthanides and actinides
- Light blue: noble gases
- Grey: unknown chemical properties

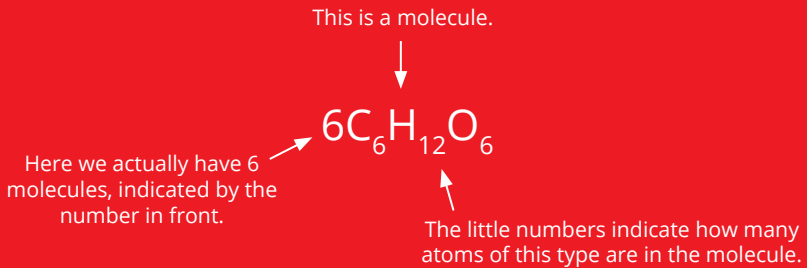
6 VIB		7 VIIB		8 VIIIB		9 VIIIB		10 VIIIB		11 IB		12 IIB		13 IIIA		14 IVA		15 VA		16 VIA		17 VIIA		18 VIIIA						
24 <b>Cr</b> Chromium 51.9961 24.951	25 <b>Mn</b> Manganese 54.938044 25.951	26 <b>Fe</b> Iron 55.845 26.967	27 <b>Co</b> Cobalt 58.933 27.957	28 <b>Ni</b> Nickel 58.693 28.67	29 <b>Cu</b> Copper 63.546 29.67	30 <b>Zn</b> Zinc 65.38 30.67	31 <b>Ga</b> Gallium 69.723 31.67	32 <b>Ge</b> Germanium 72.630 32.67	33 <b>As</b> Arsenic 74.9216 33.67	34 <b>Se</b> Selenium 78.9718 34.67	35 <b>Br</b> Bromine 79.904 35.67	36 <b>Kr</b> Krypton 83.798 36.67	37 <b>Rb</b> Rubidium 85.4678 37.67	38 <b>Sr</b> Strontium 87.62 38.67	39 <b>Y</b> Yttrium 88.905848 39.67	40 <b>Zr</b> Zirconium 91.224 40.67	41 <b>Nb</b> Niobium 92.90638 41.67	42 <b>Mo</b> Molybdenum 95.94 42.67	43 <b>Tc</b> Technetium 98.90625 43.67	44 <b>Ru</b> Ruthenium 101.07 44.67	45 <b>Rh</b> Rhodium 102.9055 45.67	46 <b>Pd</b> Palladium 106.42 46.67	47 <b>Ag</b> Silver 107.8682 47.67	48 <b>Cd</b> Cadmium 112.411 48.67	49 <b>In</b> Indium 114.818 49.67	50 <b>Sn</b> Tin 118.710 50.67	51 <b>Sb</b> Antimony 121.757 51.67	52 <b>Te</b> Tellurium 127.603 52.67	53 <b>I</b> Iodine 126.905 53.67	54 <b>Xe</b> Xenon 131.29 54.67
74 <b>W</b> Tungsten 183.84 74.67	75 <b>Re</b> Rhenium 186.207 75.67	76 <b>Os</b> Osmium 190.23 76.67	77 <b>Ir</b> Iridium 192.222 77.67	78 <b>Pt</b> Platinum 195.084 78.67	79 <b>Au</b> Gold 196.96657 79.67	80 <b>Hg</b> Mercury 200.59 80.67	81 <b>Tl</b> Thallium 204.38 81.67	82 <b>Pb</b> Lead 207.2 82.67	83 <b>Bi</b> Bismuth 208.9804 83.67	84 <b>Po</b> Polonium 209 84.67	85 <b>At</b> Astatine 210 85.67	86 <b>Rn</b> Radon 222 86.67	104 <b>Sg</b> Seaborgium 263 104.67	105 <b>Bh</b> Bohrium 264 105.67	106 <b>Hs</b> Hassium 265 106.67	107 <b>Mt</b> Meitnerium 266 107.67	108 <b>Ds</b> Darmstadtium 267 108.67	109 <b>Rg</b> Roentgenium 268 109.67	110 <b>Cn</b> Copernicium 269 110.67	111 <b>Nh</b> Nihonium 270 111.67	112 <b>Fl</b> Flerovium 277 112.67	113 <b>Mc</b> Moscovium 278 113.67	114 <b>Lv</b> Livermorium 279 114.67	115 <b>Ts</b> Tennessine 280 115.67	116 <b>Og</b> Oganesson 284 116.67					
60 <b>Nd</b> Neodymium 144.242 60.67	61 <b>Pm</b> Promethium 144.9127 61.67	62 <b>Sm</b> Samarium 150.36 62.67	63 <b>Eu</b> Europium 151.964 63.67	64 <b>Gd</b> Gadolinium 157.25 64.67	65 <b>Tb</b> Terbium 158.925 65.67	66 <b>Dy</b> Dysprosium 162.50 66.67	67 <b>Ho</b> Holmium 164.9303 67.67	68 <b>Er</b> Erbium 167.259 68.67	69 <b>Tm</b> Thulium 168.934 69.67	70 <b>Yb</b> Ytterbium 173.0547 70.67	71 <b>Lu</b> Lutetium 174.967 71.67																			
92 <b>U</b> Uranium 238.02891 92.67	93 <b>Np</b> Neptunium 237.048173 93.67	94 <b>Pu</b> Plutonium 244.06422 94.67	95 <b>Am</b> Americium 243.06136 95.67	96 <b>Cm</b> Curium 247.07724 96.67	97 <b>Bk</b> Berkelium 247.07724 97.67	98 <b>Cf</b> Californium 251.0832 98.67	99 <b>Es</b> Einsteinium 252.0832 99.67	100 <b>Fm</b> Fermium 257.103 100.67	101 <b>Md</b> Mendelevium 258.103 101.67	102 <b>No</b> Nobelium 259.103 102.67	103 <b>Lr</b> Lawrencium 260.103 103.67																			

# Chapter 5 - How do living things acquire and use energy?

## HIGH SCHOOL SCIENCE ALERT!

**Don't freak out.** You might remember seeing this in high school. Maybe it wasn't your thing or you don't remember it.

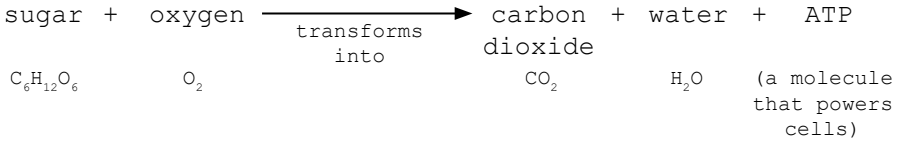
Here's what you need to remember:



So, here we have 6 identical molecules, each of which is made of 6 carbon (C) atoms, 12 hydrogen (H) atoms, and 6 oxygen (O) atoms connected together.

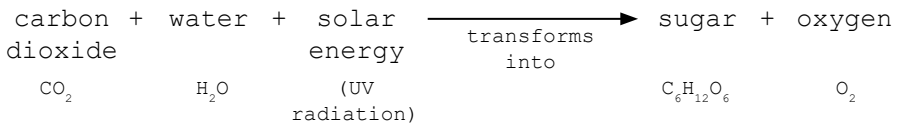
There are many known methods by which living things process energy. The following are **two of the most common energy processing methods** found on Earth.

# 1. Respiration



- Respiration allows the cells of living things to **convert sugars that they consume into usable energy.**
- **Almost all living things** made up of more than one cell use respiration.
- **Some living things made up of just one cell** (for example: bacteria) also make use of respiration.

# 2. Photosynthesis



- **Plants** are the main living things on Earth that make use of photosynthesis.
- Plants undergo **BOTH** respiration and photosynthesis.
- **When there is light available, photosynthesis occurs:** Photosynthesis allows a plant to use solar energy (UV radiation) to build its own sugar molecules.
- **When there is NO light available, respiration occurs:** Plants switch modes and use their newly built sugars in the process of respiration (previous page) to power their cells.
- Photosynthesis requires a special molecule called **chlorophyll**.

# Chapter 6 - How can we test for life?

Finding extraterrestrial life isn't necessarily as simple as looking for it with our eyes. A living thing might be too small to see, or too far away, or too different than what we expect to find. In addition to direct observation, we can also **infer (deduce)** the presence of life by looking at **traces (clues)** that a living thing leaves behind.

Here are examples of how we can infer life:

## 1. Detect waste products

- If we suspect, for example, that a living thing undergoes respiration (see Chapter 5), we can **assume that it would produce carbon dioxide** (CO<sub>2</sub>).
- We should thus **be on the lookout** for the presence of such waste products.

## 2. Detect a favourable environment

- As seen earlier, a living thing has a **checklist of requirements to live** (for example: a solvent like water, building blocks, an energy source).
- If we detect some of these required elements in an environment, we can infer that a living thing **might be able to live there**.
- Detecting a favourable environment, however, is **not proof** that a living thing lives there.

## 3. Miscellaneous traces of life

- Living things on Earth contain **genetic material** (for example: DNA, RNA) and **protein material**.
- Many living things on Earth have **electrical activity** (for example: the human heart's ECG electrical signal).

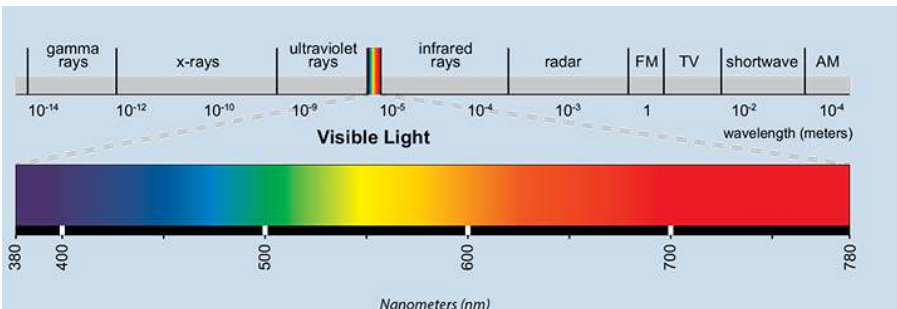
## 4. Observe with an alternative light source

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Here, all you need to know is that coloured light is associated to a specific wavelength. For example, the wavelength of yellow light measures about 580nm.

- Our human eyes **can only see light (a.k.a. radiation) in the visible spectrum.**
- If we use special tools to look at different types of light, we might be able to **spot traces of life** that we might not otherwise be able to see with our eyes.
- Shining **UV light** on an object, for example, can make certain biological molecules **fluoresce.**
- When something fluoresces, it means that it can absorb UV light (in other words, it has an **excitation wavelength of 390nm**) and reflect back light in a wavelength that the human eye can see (in other words, it has an **emission wavelength between 400nm and 780nm**), thus making it visible to us.
- See the **glossary** for a list of common biological molecules that fluoresce.



The visible spectrum. These are the colours your eyes can see. Note that the visible spectrum is surrounded by other forms of radiation that our eyes cannot see.

# Chapter 7 - What are signs of intelligent life?

Although unlikely, we might encounter an extraterrestrial living thing that demonstrates intelligence and might even make use of advanced technology.

Be on the lookout for the following signs of intelligent life:

## 1. Communication

An intelligent living thing might attempt to communicate with us using some **type of language**:

- Their own language
- Our own language
- Music
- Symbols
- Mathematics (a universal language)

Its language could be conveyed by **speaking directly** with us, or it might encode whatever it has to say on some **form of media**. It could:

- Broadcast a message using **radio waves** or some other form of radiation
- Record a message on **physical media** (for example: vinyl disc)
- Encode a message within **biological molecules** (for example: genetic material). This is an effective way to store and possibly even hide a large quantity of data

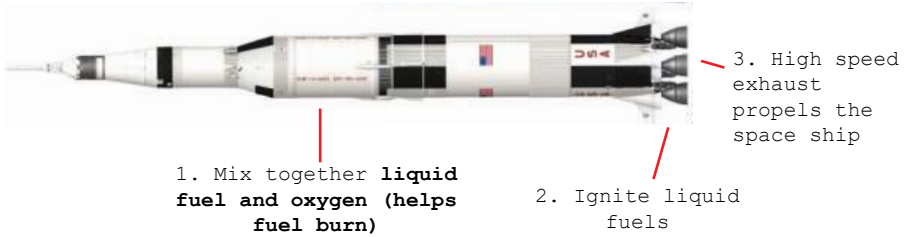
Though we might not understand their language, we should be on the lookout for **patterns** or any **signal that does not appear to be noise**.



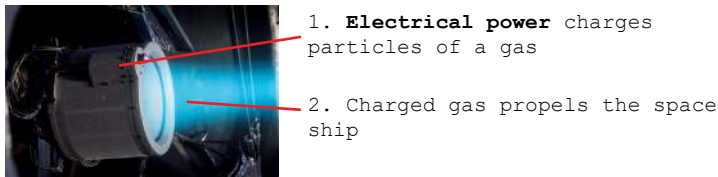
## 2. Space travel

Here are a few of the many theoretical ways an intelligent living thing might travel through space:

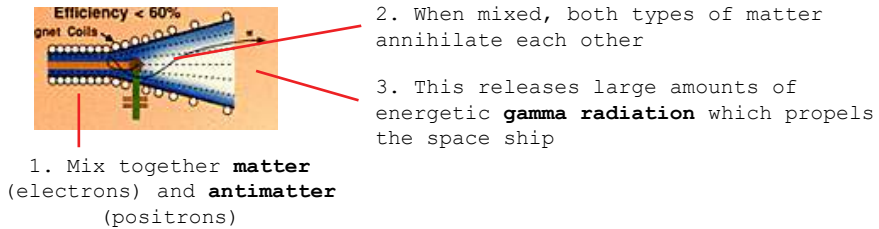
### Traditional rocket



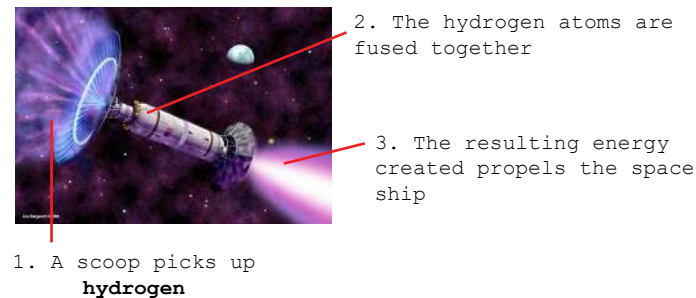
### Ion Engines



### Antimatter rockets



### Interstellar ramjets



# Glossary

## **Asteroid**

- A rocky object found in outer space.
- They are typically made of clay, silicon, and a variety of metals such as nickel and iron.

## **Atom**

- One of the smallest pieces that makes up matter.
- Examples include Hydrogen and Carbon.
- When atoms are combined together, they make molecules.

## **Bacteria**

- A type of single-cell living thing that is found everywhere around the world.
- Too small to see with the naked eye.

## **Carbon (C)**

- An atom that forms a carbon dioxide molecule ( $\text{CO}_2$ ) when combined with two oxygen atoms.
- Carbon dioxide prevents combustion reactions.

## **Cell**

- Made from proteins, fats, sugars, genetic material, and water.
- Arguably, the smallest possible object that can be considered living.
- Examples include white blood cells in your body and bacterial cells (small living things made of just one cell) found in yogurt.

## **Exoplanet**

- A.k.a. Extrasolar planet.
- A planet that is not part of our solar system.

## Fluorescent biological molecules (examples)

Molecule	Excitation wavelength	Emission wavelength
collagen	315-400nm	420-510nm
chlorophyll	315-400nm	700nm
flavin	315-400nm	520-540nm
melanin	315-400nm	430-540nm
NADH	315-400nm	450nm

## Genetic material

- DNA and RNA molecules.
- Found inside the cells of living things.
- Most commonly used to tell cells what proteins to make.

## Germanium (Ge)

- An atom that has similar properties to carbon.

## Hypothesis (plural: hypotheses)

- A sort of guess as to either:
  - What you think will happen during an experiment.
  - Why you think an experiment produced a certain result.

## Mammal

- A complex living thing made up of trillions of cells.
- Reproduction involves two mammals procreating to form a new living thing. This new living thing acquires half of its genetic material from one parent and half from the other.
- At a cellular level, reproduction does not involve mitosis. It involves a slightly different process called meiosis.

## Metabolism

- Chemical reactions in a living thing that gives cells the energy needed to function and create new molecules.
- These chemical reactions need outside energy (for example: sugar molecules) to take place.

## Meter (m)

- A unit of measurement.
- At microscopic levels, we use smaller units of measurement such as the millimeter (**mm**; 1 m = 1000 mm), micrometer (**µm**; 1 mm = 1000µm), and nanometer (**nm**; 1 µm = 1000 nm).

**Meteorite**

- A space rock that has survived its fall to Earth.
- As they are falling to Earth, they are called meteors.

**Mitosis**

- A process by which living things like bacteria reproduce.
- During mitosis, a cell makes an identical copy (a clone) of itself.

**Molecule**

- Made up of atoms connected together.
- Examples include hemoglobin, DNA, sugar (glucose).
- When combined, molecules can make proteins.

**Negative control**

- An experiment that we know will not produce any result.
- Negative controls are used to show you what it is supposed to look like if an experiment does not produce a result.

**Oxygen (O)**

- An atom that forms an oxygen molecule ( $O_2$ ) when combined with another oxygen atom.
- Oxygen molecules promote combustion reactions.

**Positive control**

- An experiment that we know will produce an intended result.
- Positive controls are used to make sure that the experimental method is working correctly.

**Proteins**

- Made up of molecules connected together.
- Many types of proteins are found inside cells or make up the structure itself of the cells of living things.

**Scanning electron microscope (SEM)**

- A type of microscope that can see objects that measure only a few nanometers (nm) in length.

**Sequencing (genetic material)**

- A technique used to read the genetic code of DNA molecules.

**Silicon (Si)**

- An atom that has similar properties to carbon.
- Forms silica molecule (silicon dioxide -  $\text{SiO}_2$ , a.k.a. sand), when combined with oxygen.

**Slingshot**

- A.k.a. Gravity assist.
- When a fast moving object (for example: an asteroid) comes in close proximity to a large object in space (for example: a planet), the gravity of the large object can pull on the fast moving object and slightly alter its trajectory.

**Spectrum (plural: spectra)**

- A series of colours that is observed when light (for example: light from a star) passes through an object (for example: the atmosphere of a planet).
- These colours can be studied to identify what atoms and molecules are present in the object being studied.

**Solvent**

- A liquid that allows chemical reactions to occur.
- Water ( $\text{H}_2\text{O}$ ) is the solvent used in all biological chemical (biochemical) reactions in living things on Earth.

**Theory**

- An explanation for an observed phenomenon.
- Creating a theory requires evidence.
- Evidence comes from performing multiple experiments and having tested multiple hypotheses.

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