How to Create a Universe

In 10 Easy Steps

BY

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Table of Contents

Forward

Some people think about it for only a few minutes while others spend their entire lives and careers searching for an answer to the most basic of all questions "Who am I and where did I come from?" The fact that the question itself can be examined from a variety of viewpoints depending on your own personal position in time and space only adds to the complexity of any given response.

The truth is that the entire list of all the individual events that had to occur, in precise order, just so that you could be reading this passage now is an incredibly lengthy mixture of natural physical laws, random probabilities, a dash of luck and, some would say, at least one miracle.

My hope is that dividing up this list into 10 distinct steps I can show you how reality for you has been constructed and perhaps give you a workable recipe in case you wish to create your own universe some day.

The creation of our universe and all that followed is indeed a truly unique event in our lives but one thing we can all agree on is that if it had never occurred none of us would be here now.

Another thing we know for certain is that nothing can be known for certain. And it is only after decades of research and data analysis undertaken by a multitude of dedicated men and women following strict rules and procedures that true scientific laws, principles and theories are generally accepted as valid. This is called the Scientific Method and it is the means by which all our knowledge of the physical world has come to be known.

The threshold between what came before the Big Bang and what came after will always be a dividing line as it may truly be impossible to ever know the precise circumstances that sparked the initiation of our own reality.

Albert Einstein once said "...Time is created by the relationship of the changes in things that happen...". It is difficult to argue with such a simple yet profound idea. Whatever came before this dividing line is left for each individual to contemplate in their own way. This narrative will start at the first instant of creation, known popularly as The Big Bang, and describe step by step the creation of atoms, elements, compounds, cells, life, organisms, intelligence and humans. I hope you will enjoy reading it as much as I've enjoyed discovering it.

Step 1: Getting Started

The first thing needed to get our universe underway is a tremendous amount of energy - more energy than all the output that has ever been produced by every power plant on earth; more energy than the entire output of every one of the billions of stars in our galaxy over its entire lifespan of billions of years. Here is how our own universe got started.

Approximately 13.8 billion years ago, in the first instant after the initiation of the Big Bang, there was only heat energy so vast that we can barely provide a common reference point in human terms by referring to the temperature of this spark as many millions of trillions of degrees.

This initial energy level was so high that the fabric of space itself began forming, expanding outward in all directions faster than anything has ever travelled since. At this stage time itself was born to ever tick persistently forward until space itself no longer exists. This initial super rapid expansion of space is called Inflation and it allowed the temperature of the energy spark to fall from many millions of trillions degrees to only a few thousand trillion degrees in less than 1 trillionth of a sec. While again this temperature may seem incomprehensibly high it was the start of an unstoppable process that eventually led to humans populating the planet Earth.

As space continued expanding in the first billionth of a second, temperatures dropped to a few hundred trillion degrees allowing for a multitude of physical particles of matter to be formed, perhaps the most significant of which we call Quarks, As the temperature fell into the range of a few hundred billion degrees, three individual Quarks became stuck close together by an attraction we call the Strong Nuclear Force forming two larger particles, possibly more familiar to the reader, called a Proton and a Neutron. The main differences between these two newly formed larger particles arose from the fact that the three Quarks that they were composed of were themselves slightly different from each other resulting in a proton having a positive electrical charge and being slightly lighter than the neutrally charged neutron.

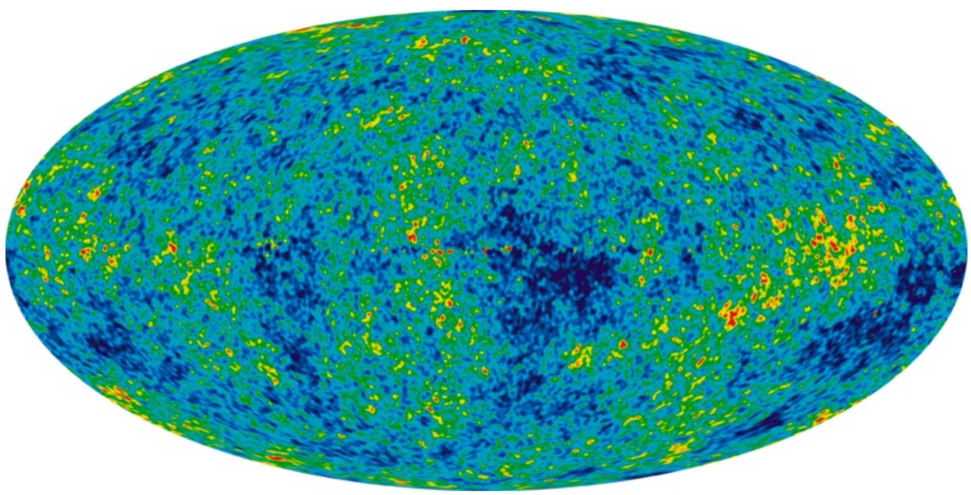
Within the first few seconds or so, space had cooled to a few hundred million degrees and countless protons and neutrons were whizzing around as the space around them continued to expand and cool. Within a few minutes, space had expanded to the point where energy levels had dropped enough for that same Strong Nuclear Force to bind a single Proton and single Neutron together in a permanent configuration that we now call the Deuterium Nucleus, a form of Hydrogen still found in very small quantities today. Single protons alone continued to fly around in a configuration we now call the Hydrogen Nucleus.

Expansion and further cooling in the next few minutes allowed an opportunity, although rarely, for two protons and two neutrons to bind together to form the first Helium nuclei and in an even rarer configuration, three protons and three neutrons bound together to form the first Lithium nuclei. All three nuclei configurations retained a positive charge due to the presence of protons, the neutral neutrons having no impact on the electric charge of the nucleus. During these same first few seconds, a negatively charged particle we call the electron had also formed but energy levels were still so high that it continued to fly about on its own unencumbered by the positive charge of protons or other nuclei.

Things remained pretty much the same over the next 380,000 years as space continued to expand, time moved forward and energy levels eventually dropped to around 3,000 degrees.

At this point, it became possible for the negatively charged electron to become attracted to the positively charged Hydrogen, Helium and Lithium nuclei by what is called the Electromagnetic Force. The electron's rapid motion, however, prevented it from simply sticking to the nuclei and it eventually found a unique balance between moving toward the nuclei and moving away from the nuclei ending in an action we commonly described as orbiting and forming what we now call Hydrogen atoms, Helium atoms and Lithium atoms.

Below is a representation of the Universe about 380,000 years after the Big Bang that was created by specialized spacecraft scanning Space and reporting back on temperature differences that were found. The dark blues ares are the coldest while the yellow and red are the hottest although the difference in temperature between all three is less than a fraction of a degree.



The Universe as it appeared just 380,000 Years after the Big Bang

At long last we have reached the stage of matter best known to most people as the stable atom - a nucleus formed from a number of Protons and Neutrons which were themselves composed of Quarks all bound together by the Strong Nuclear Force and surrounded by Electrons held in place by the Electromagnetic Force. Still at this time 75% of the matter of the universe consisted of Hydrogen atoms with about 25% Helium atoms and a tiny dash of Lithium atoms.

There is one additional concept that should be understood before proceeding.

Because of the vast distances involved in exploring the expanding Universe, scientists have settled on light and it's incredible speed as a convenient method of expressing very large distances.

A light beam travels at approximately 300,000 Kilometres every second. Science, of course, knows this figure to a much higher degree of accuracy than this but it will suit our purpose best to round off the number to something easier to work with. At this velocity, a light beam will travel 18 million kilometres (11 million miles) in one minute and 1 billion 80 million kilometres (671 Million miles) in one hour. As far as that is, in one year a light beam can cover roughly 9 trillion, 460 billion, 800 million kilometres (about 6 trillion miles). Now that`s far.

It takes quite an imagination to conceive of distances on this scale and yet even these are but tiny specks on the ruler of distances across our Universe. In fact the Light Year, the distance light travels in one year, is the standard for measuring how far apart objects are in our universe. The nearest star to Earth, Alpha Centauri, is a mere 4 Light Years from Earth, since it took the light from that star 4 years to reach us while the Andromeda Galaxy is over 2.5 million Light Years away, light from that Galaxy having taken over 2.5 million years to reach Earth. Since it has taken the light from these objects that many years to reach us here on Earth we are actually observing them now as they actually were 4 years and 2.5 million years ago, respectively.

There some interesting implications from this fact. Although it may appear when we turn off a flashlight that the light disappears immediately that is only a result of our being extremely close to both the source of the light (the bulb) and the beam itself. Considering our distant neighbours, if some unexpected catastrophe should befall the star Alpha Centauri and it were to instantly stop emitting light right now, any light already emitted by the star would continue to travel out through space and it would take 4 years before we on Earth would become aware of any change. Similarly any dramatic change today in the Andromeda Galaxy would not become apparent to an Earth observer for another 2.5 million years.

This is one of the primary ways that scientists can say what happened so long ago. Powerful telescopes on the Earth, in orbit around it (like the Hubble Space Telescope) and aboard man-made satellites collect the light emitted by our distant relatives allowing us to observe the composition of the Universe as it was billions of years ago. At present the most distant objected detected directly by us is a Galaxy called UDFj-39546284 estimated to be some 13.37 billion Light Years away having been 'born' a mere 400 million years after the initial Big Bang. Along with observations of other objects between UDFj and Earth, we are able to form a picture of the development of the Universe from its very early days to the present.

2. Galaxies, Stars and Elements

Now that we have an expanding area of time and space filled with Hydrogen atoms and Helium atoms, it's necessary to begin making all the other things we find in our own universe; things like galaxies, stars, planets, moons, asteroids and even comets.

The primary force influencing the next stage of development is one we call Gravity.

Most of us have experienced the effect of gravity when we get some distance away from the Earth's surface and our support system at the time (whether that be a tree, a ladder, a stairway handrail etc.) is suddenly not available. Depending on our distance from the closest solid ground the consequences can range from minor bumps and bruises to life threatening injury. What is important to understand here is that gravity exists for any and all objects in space regardless of their size and its ultimate impact is to draw together any two physical bodies in space no matter how far apart they may be. The smaller the objects and the further apart they are the smaller the force of gravity between them is but it is never '0' so given no other interfering condition or force eventually any two objects will be drawn together in space.

Now it is also important to understand that the fabric of space itself exerts no gravity as it has no physical presence, so even though space is continuing to expand at this time, the physical objects (atoms) within it are being drawn together by gravity. This leads us directly into the next phase of our Universe's construction.

We'll begin by making some galaxies.

Remember the picture of the universe after 380,000 years? There were both hotter spots and cooler spots and because the cooler spots contained less energy, the atoms of hydrogen began to be influenced by gravitational forces and began collecting together in enormous clouds of gas. As these gas clouds grew larger and larger, they began exerting an increasingly stronger gravitational force on the surrounding environment which drew in more and more hydrogen atoms eventually developing into enormous swirling pockets of concentrated hydrogen millions of light years across.

These giant gas formations we call galaxies and they began forming aound 400 million years after the Big Bang. If you have the opportunity to observe the sky on a dark night, well away from city lights, most of the thousands of points of light you'll be looking at are actually galaxies. There are in fact many billions of galaxies in our own universe and each one of them contains billions of individual stars.

But just how are stars formed?

Within these expansive galactic gas clouds themselves there are areas where the hydrogen atoms are thicker and denser. Again, these concentrated regions exert a stronger gravitational force which attracts more and more hydrogen atoms. Eventually these pockets of gas form incredibly dense spheres in space millions of times larger than our present Sun.

As the hydrogen atoms get crushed closer and closer together with the ever increasing force of gravity, the Strong Nuclear Force is eventually overcome and the separate nuclei begin to fuse together. This action, referred to as Nuclear Fusion, converts a small amount of the atom's physical matter into light and heat energy helping to fuse more atomic nuclei together releasing even more energy and forming a perpetual chain reaction. At this point the gas sphere begins emitting tremendous heat and light and has now become a Star.

With the large number of atoms involved in the fusion process, the amount of energy released is also enormous and it is, in fact, sufficient to prevent any further compression of the Star by gravity. A balance is thus created between the gravitational force crushing the Star in and the energy released through Nuclear Fusion pushing back out. Due to the incredibly high energies (temperature and pressure) within the core of the Star - up to 20 million degrees - protons and neutrons become crushed together and Electrons are stripped away from the atom's configuration..

Stars are the true alchemists of the universe. They are the only place in all the universe, that we know of, where all the different types of solids, liquids and gases that you know about, and even those that you don't know about, are naturally created. Without stars, there would only be hydrogen and helium atoms floating around. With the eventual formation of stars it is perhaps eeriest to realize that every atom of every thing you can see, touch, taste or feel, including yourself, was actually created inside of a distant and ancient star. We are all, indeed, made of star stuff.

Let's look at how this happens.

Within the cores of the first generation of newly formed Stars (referred to as Population III Stars some over a million times larger than our present Sun) elemental changes began occurring.

Stars begin their fusion process with Hydrogen nuclei, a Hydrogen atom with the electron stripped away leaving just a single proton. As pressure and temperature increases within the star's core, extra protons and neutrons are crushed together forming new nuclei like Helium, which consists of two protons and two neutrons. Adding another proton/neutron combination produces Lithium and adding another proton/neutron combination produces Beryllium. Adding another makes Boron, another makes Carbon, another makes Nitrogen and so on working up through to a nucleus containing 26 Protons and 26 Neutrons creating the element which we now call Iron.

At this point the Star is unable to generate enough fusion energy to hold back the force of gravity and it collapses into itself. The resulting collapse causes the Star to explode spewing a good portion of its newly formed material into space and leaving behind a super dense sphere of crushed nuclei. Now this whole process didn't happen overnight. Our best estimates are that Population III stars began to ignite around 400-500 million years after the Big Bang occurred and 'burned' for another 500 million years. By 1 billion years after the Big Bang, all population III Stars had died out.

As Population III stars were meeting their final fate, the next generation of Stars was already forming. Roughly a billion years after the Big Bang, Population II Stars continued the process of forming from clouds of Hydrogen gas that now also contained some of the new Elements gained from the explosion of earlier Population III Stars. They also produced high enough energies in their cores to continue the fusion process and manufacture all the rest of the natural Elements we know of today.

Population II Stars eventually met the same fate as their earlier counterparts, collapsing upon themselves and sending their insides scattering throughout space. Today, within our own Galaxy and other relatively new galaxies, we find Population I Stars, formed only a few billion years ago, that are composed of much higher concentrations of high numbered elements (such as Metals) due to the explosions of the earlier Population III and Population II Stars. Our own Sun, for example, is almost 2% Metal, not a seemingly high concentration but considering the early composition of the Universe quite a significant portion of its mass.

So now that we have all the elements available floating around in space, we need somewhere to build a world. What comes next?

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Step 3: The Milky Way and Sol

About 8.8 billion years ago or 5 billion years after the Big Bang, the gases that formed our Galaxy, called the Milky Way, began spiralling around what we now know to be a massive Black Hole.

But what exactly is a Black Hole?

Most of us understand that the larger an object becomes the greater the pull of its gravity becomes. For example, a person who weighed 150 pounds on Earth would weigh approximately 354 pounds on Jupiter because it is a much larger planet than Earth and exerts a larger gravitational force. It is clear, then, to throw a rock up into the air would take a lot more force on Jupiter than on Earth. Rocket scientists must take this factor into account when determining how much force their rockets must produce to get a payload off or on the Earth, the Moon or any other celestial body.

Science refers to the force needed to get away from a celestial object as the Escape Velocity of the object, meaning how fast do we have to be travelling so that we don't fall back onto the body we're trying to leave. On Earth, we must be travelling about 40,000 km/h (25,000 miles per hour) to escape Earth's gravity and achieve a stable orbit. On the other hand, if we started on Jupiter, we would have to be travelling over 214,000 km/h to escape its gravity. To escape the surface of our Sun we are talking about needing to reach over 2 million km/h to escape and from the core of a collapsed Star a speed of over 17 million km/h would be needed.

When Population III Stars were mentioned earlier, it was noted that some were millions of times larger than our current Sun. Even after collapsing and sending large portions of their content into space, their remaining cores are so massive that their Escape Velocity can exceed 300,000 kilometres per second - the speed of light. Since light is not travelling fast enough to leave the environment and head into Space the entire area appears black and hence the term Black Hole. There is one of these at the centre of every known Galaxy, most likely created from the collapse of one of the earlier massive Population III Stars.

As Milky Way gases continued to spiral around, stars began forming, growing, collapsing and seeding the surrounding environment with all the various elements that would eventually make up our own world.

A little over 5 billion years ago, certain pockets of gas within the Milky Way coalesced and our own star, called Sol, fired up for the first time.

To better understand the next phases of universe development, it is necessary to discuss how the basic elements, uniquely defined by the number of protons in their nucleus, combine to create different compounds. Although it can appear to be complex and complicated, it is, in fact, the driving force or the crux of all future development on earth for the next billion and a half years or so.

An atom of any element is made up of a specific number of positively charged protons and neutral neutrons stuck together to make up the centre or nucleus and surrounded by an equal number of negatively charged electrons moving around in what we non-scientists simplistically refer to as orbits. Let's look a little closer at this construction.

A Hydrogen atom, element number 1, has 1 proton and no neutrons in its nucleus and is surrounded by 1 electron. Element number 2, adds another proton and 2 neutrons to the mix creating a nucleus with 2 Protons and 2 Neutrons that captures and holds onto 2 electrons making an atom of the element we call Helium. Adding another proton, neutron and electron makes an atom of element number 3 called Lithium. Four protons, 4 neutrons and 4 electrons makes element number 4 called Beryllium, 5 of each makes Boron and 6 of each makes an element most of us are finally familiar with called Carbon. Seven of each makes Nitrogen, 8 of each makes Oxygen and, I think, you can see the pattern from here on.

For our purposes, all stable atoms always have the same number of protons and electrons. This keeps the electrical charge of each atom neutral as the positive and negative charges of the proton and electron balance each other. This is an important consideration when different elements combine to make new compounds and the electric charges change.

When elements combine to form compounds they share their electrons in several different ways. Some give a few of their electrons to another element, some will take a few electrons from another element and sometimes two elements will share electrons between themselves.

Let's see how and why this happens.

Unlike the planets which very closely follow the same path around our Sun year after year, electrons are highly varied in their trip around the central nucleus of an atom. They do, however, exhibit patterns, and it has been determined that electrons can occupy only certain positions as they circle a nucleus based on their speed, momentum, electric charge and other factors.

The most important things to know are that these positions, called Electron Shells, fall at discrete distances from the nucleus, that there is a maximum number of electrons that can occupy each specific shell, that atoms prefer to fill each lower level or lower energy shell with its maximum number of electrons before starting to fill the next highest shell and that no electron can exist in between these shells.

Although the actual reasons for and physics behind the electron shell locations, their energy levels and their composition is well beyond the scope of this book, for our purposes all you really need to know to start with is that electron shell 1 holds a maximum of 2 electrons, shell 2 holds a maximum of 8 electrons and shell 3 holds a maximum of 8 electrons. In addition, atoms prefer to have their outer most electron Shells filled with the maximum number of electrons possible. With this in mind, let's look at constructing our first compound or molecule.

Hydrogen, element 1 with only 1 electron in its first and only shell, is looking to add another electron to fill its first shell with 2 electrons. Oxygen, element 8, has 2 electrons in its first shell and only 6 in its second shell. It's looking to add 2 more electrons to fill its outer shell with 8. When Hydrogen and Oxygen first combine, one Hydrogen atom shares 1 electron with an Oxygen atom which shares 1 electron back making the Hydrogen happy because it now has 2 electrons and has filled its outer shell with the maximum of two electrons.

The Oxygen atom, however, remains unfulfilled because, even with the extra electron from the first Hydrogen atom, it only has 7 electrons in its outer shell so it searches out a second Hydrogen atom and they each share an electron. This makes the second Hydrogen atom stable because it now has 2 electrons in its outer shell and the Oxygen is now stable because it has 8 electrons in its outer shell.

This combination of two Hydrogen atoms with one Oxygen atom forms one of the most common compounds on our planet, scientifically called Di-Hydrogen Oxide, written as H_2O because there are 2 Hydrogen atoms and a single Oxygen atom and known popularly as water.

Let's look at one more example.

Sodium is element 11, an extremely volatile, and potentially explosive metal when exposed to air or water. It has 2 electrons in its first shell, 8 electrons in its second shell and 1 electron in its third shell - 11 in total making it element 11. It really wants to give up that single outer electron and settle into a stable 8 electron outer shell configuration.

Chlorine, on the other hand, is a noxious, toxic gas, fatal to humans with prolonged exposure. It has 2 electrons in its first shell, 8 electrons in its second shell, and 7 in its third and outer shell adding up to 17 in total and making it element 17. It is desperately looking to beg, borrow or steal one more electron from somewhere to complete a stable 8 electron outer shell. Can you see what would happen if we put Sodium and Chlorine together?

The Sodium atom gives up its extra single outer electron completely to stabilize with a remaining 8 electron outer shell while the Chlorine atom takes the extra electron totally for itself to create its own stable 8 electron outer shell and both are happy. Since there is a 1-1 ratio between Sodium atoms and Chlorine atoms we write this compound as NaCl. In this case the Na for Sodium comes from the Latin word 'Natrium'. (Many elements have symbols taken from their latin names. Another example is Pb the symbol for lead, taken from its latin name Plumbum.) Scientifically this new compound is called Sodium Chloride and more commonly it is known as common table salt.

This does raise another important point to consider about compounds. In our first example Hydrogen gas combined with Oxygen gas produces water, a liquid at room temperature, a solid below 0 degrees Celsius and a gas or vapour above 100 degrees Celsius.

In our second example, a volatile, explosive metal combined with a toxic, poisonous gas produced common table salt taken internally by billions of people everyday. There is simply no way of knowing in advance what the properties of compounds might be based on the properties of their individual elements.

Due to the almost unimaginably tiny size of individual atoms, we can rarely see just a few gathered together. However, when billions and billions of Hydrogen molecules occupy the same closed space we call the resulting material Hydrogen gas. And when billions and billions of Di-Hydrogen Oxide molecules (H_2O) occupy the same space we call it water and when millions and billions of Sodium Chloride molecules (NaCl) occupy the same space we call it table salt.

All this background is most important to help the reader comprehend that while the basic elements themselves are created within the internal structure of stars, molecules and compounds are all formed outside of the star environment simply because the energy levels inside of stars are so high that they strip off the electrons and prevent compound formation, as we've discussed, from occurring.

Once a star has 'burned out', collapsed into itself and exploded in what science calls a Supernova, the elemental material, spread out into space, is free to come together and form compounds. And compounds are certainly not restricted to only two elements coming together.

However, despite the vast array of compounds that can be formed from the basic elements, we will concentrate primarily on those that contain Carbon. Carbon is element 6 with 2 electrons in its 1st inner shell and 4 electrons in its second or outer shell. It is, then, looking to share or take on 4 additional electrons to complete an outer shell of 8. As a result, it can react or join with a wide variety of elements in many ways to form unique compounds.

As we've seen, there is no way to predict a compound's properties simply by examining the individual elements that it is formed from. But all compounds that have carbon in their structure are referred to as Organic Compounds and these are arguably the most important in the Universe because they are absolutely essential for all life as we know it.

Step 4: A Home World

Now that we have elements and compounds floating around in space, we must create some place for them to settle down. Planets are the answer so we'll now take a look at how to create some places to begin our efforts to bring life to our universe.

Caught up in the enormous gravity of the newly formed stars, clouds of gas, dust, heavier elements and compounds began orbiting these stars. As gravitational forces drew particles closer together they began melding together forming rocky or gaseous spheres in ring-like configurations that we call Solar Systems.

At about this time in our own solar system, around 4.5 to 5 billion years ago, due to the immense gravitational pull of of the sun, heavier material was being drawn in closer to Sol while lighter material remained on the outer edges. As a result, planetary bodies forming out of the circulating debris, fell into two very distinct groups - the inner planets, composed primarily of heavier solid elements like metals (iron and nickel e.g.) and the outer planets, composed primarily of lighter elements and gases (hydrogen and methane e.g.)

Today the dividing line is a path of sun-circulating material we call the Asteroid Belt. All planets closer to our sun than this distance are rocky, metal-rich bodies while all those further out, called gas giants, are composed primarily of Hydrogen, Helium and Methane.

During its early formation, our own Earth was a slowly spinning, rugged sphere of molten rock and metal circling the Sun in a relatively stable orbit. This was 4.5 billion years ago. Since it was mostly liquid rock, the heavier elements and metals sunk towards the centre producing a highly concentrated iron core that still exists today and is possibly the source of the immense magnetic field that surrounds the Earth. Remnants of solid material scattered throughout the Solar System continued to be pulled towards the Sun causing the Earth to be continually pounded by meteorites, asteroids, and all manner of space debris, each strike, in turn, heating up the planet and keeping it molten.

From our later study of these objects, science has determined that meteorites were primarily composed of Iron and Nickel but a variety of other metals such as Magnesium and Aluminum along with various compounds of Oxygen (oxides), Sulphur (sulphates), Silicon (silicates), and water have also been found. In fact, all the raw ores and mineral deposits that we take for granted here on Earth actually originated far out in space.

As the bombardments slowed and became less frequent, planets began to cool forming their first partial crust. In the case of our own planet Earth this occurred over 4 billion years ago. In addition, at some time between its original planetary formation and its crust solidification, between 4 and 4.5 billion years ago, a catastrophic event occurred that would change the future of planet Earth forever.

A massive body, close to 1/4 the size of the Earth, called Thela, perhaps another forming planet that was knocked out of its orbit, struck the Earth. Luck was with our little planet though and the object more glanced the Earth rather than making a head-on strike. This object removed significant material from the forming Earth but became trapped by its gravity, circling quickly and quite closely. As time advanced, it slowly moved further and further away causing the Earth to slow its rotation as the object's orbit increased in circumference. Today this object remains trapped by Earth's gravity and its size and nearness to our planet affects the rise and fall of our oceans and its reflected light is the trigger for stories of both love and horror. It is, of course, our Moon.

At this time, like similar planets, the Earth's original atmosphere of Hydrogen and Helium gas was dissipating into space, the planet being unable to hold on to it due to its relatively light gravity. Instead, clouds of Ammonia (NH_3) and Carbon Dioxide (CO_2) bubbling up from the lava outpourings deep in the oceans replaced the lighter gases. About 3.7 billion years ago another round of rocks and meteorites began pummelling the Earth, a time referred to as "The Heavy Bombardment". When it finally ceased a few 100 million years later, Nitrogen and Methane formed the new atmosphere and remained in place for another billion years.

Step 5: Making a Planet Liveable

So now we have a semi-molten rocky sphere in space orbiting a new star within the Milky Way Galaxy. How do we go about making this an environment that is conducive to the future development of living things?.

From our own experience, one critical component for a successful, living planet is liquid water which about 4 billion years ago made its first appearance on Earth in sufficient quantities to aid in the cooling of the outer crust. There are several theories as to the exact origin of our water but the most recent experiments lead us to believe that its source was primarily from space, perhaps as part of the huge comets and ice chunks that smashed into the earth, surviving as vapour, and raining down over millions of years to cool and eventually fill our ocean basins. Whatever its source, the arrival of water, able to retain its liquid state over large portions of the Earth's surface, due to the serendipitous placement of the Earth's orbit, marked the creation of a habitable environment able to support the further manufacture and distribution of organic compounds.

Up to this point, we have only examined the situation where 2 basic atoms combine to form molecules. The ability of multiple atoms to join together to form more complex molecules is the next step in the development of our planet.

There is nothing magical or mysterious about this. The same rules apply regarding electron shells, sharing of electrons and seeking of stable configurations for 2,3,4 or even more atoms to create new complex molecules. This is a very important concept for the reader to grasp.

Compounds of two or more elements, composed of atomic-level connections that met the requirement of a stable outer electron shell for each atom, stayed together longer and were better able to maintain their structure under higher temperatures and pressures. Compounds that formed but were unable to meet this requirement, broke-up quickly and reassembled with other atoms to form more stable structures. This process ensured a large supply of randomly generated stable compounds out of the never ending supply of atoms, elements and compounds constantly interacting in the hostile environment of the early Earth around them.

The importance of liquid water in helping to promote the mobility of chemical compounds can not be overstated. In water, chemical compounds were free to float around, constantly moving and providing countless opportunities for encounters with other raw elements or other compounds.

On the ocean floors, outpourings of lava created extremely high temperatures releasing energy sufficient to break apart even stable molecules allowing even more chance for recombinations and new molecular formations. With millions of different combinations and splits occurring every second in the vast oceans of the Earth, it is not really surprising that after a billion years or so some pretty remarkable combinations managed to appear.

Add to this the astounding fact that close examination of meteorite fragments found on Earth has shown that they already, themselves, contained many different types of long chain molecules and compounds and we can begin to see the possibilities. But now we need to build a picture of all the different types of molecules and compounds that existed in the early oceans of the Earth and how they may have come to interact and start the process we now call life.

Step 6: Creating the Building Blocks of Life

With a newly formed star providing unlimited heat and light energy and a well placed planet covered with water and holding a wide variety of elements and molecules freely interacting with each other, we stand ready to create the foundation from which life will emerge.

As mentioned earlier, combinations of basic elements create the many compounds we find on the Earth. Although there are over 100 distinct elements that have been found naturally occurring or artificially created so far, there a few basic elements that are needed for the most essential compounds so we should become familiar with them first.

We've already encountered H for Hydrogen, the most abundant element throughout the universe so its no surprise that it is found in many compounds. We know about O for Oxygen, making up around 20% of the modern day atmosphere of earth, essential for human breathing and also able to combine with Hydrogen to form water molecules. Comprising most of the remaining 80% of our atmosphere is N for Nitrogen and of course, the critical main ingredient of all organic compounds, C for Carbon.

There is one more element that, as we will see, plays an absolutely critical role in the maintenance of life on Earth and that is P for Phosphorous. Of course there are many more elements that play an important role in maintaining life but for now we will concentrate on H,C,N,O, and P. Now that we have identified the key elements and have seen how they might combine together to form different compounds, it's time to inventory them and examine in more detail how they first interacted to start the ball rolling.

The property of simple compounds or molecules, to form stable structures that still retain the capability to join with other molecules, is what leads to the creation of long-chain molecules and sets the stage for the emergence of life.

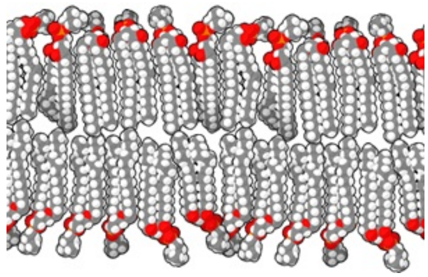
To begin our investigation of how life actually got started and developed on our planet, we will have to initially explore a variety of unique molecules, looking at their basic formation, what they are composed of and how they interact with themselves and other related molecules to form a foundation upon which to build the planet's future.

None of these molecules appears very complicated. They were formed by combining various elements (H,C,N,O,& P) using the same "rules" regarding electron shells we discussed earlier. By themselves, each is unremarkable even simplistic but, as we will see, in combination with other molecules or compounds they become the foundation for the ultimate "compound" - humans.

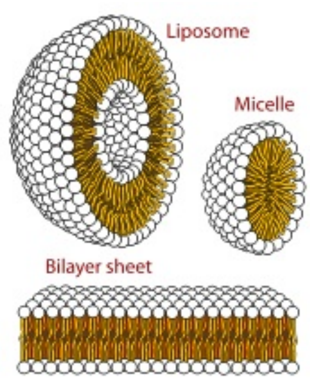
There are several special classes of compounds that form the basis for the construction of all living cells so we'll first have a look at each of them and the types of molecules making up each class. These classes are Lipids, Saccharides, Bases, Phosphates, and Nucleic Acids. Each has a different construction based on a combination of the elements we examined earlier, each has different properties based on its molecular structure as previously discussed and each serves a different purpose in the development of the first living organisms. We will look at each in turn and then see how they may have all come together to create the first living organism.

Lipids

Lipids, also commonly called fats, are long chain molecules that likely formed the first walls of the earliest prototype cells. Lipids are molecules that are formed with a 'head' made of Oxygen and Carbon atoms and a long tail of only Carbon atoms.The significance of these is that the head of the Lipid molecule exhibits a property that makes it hydrophilic - this means it is naturally attracted to water molecules. The tail of the Lipid Molecule, on the other hand, exhibits a property that makes it hydrophobic - naturally repelled by water molecules.



The end result is that as fatty acid molecules collect together due to their attraction to each other, the heads collect together as do the tails. Since they form in water, they begin to form bi-layers as the tails attempt to shelter themselves from the surrounding water molecules while the heads turn towards the water molecules. As bi-layers of these Molecules continue to grow in length, the heads facing water and the tails hiding behind the heads away from water, the growing ends of the bi-layers curl and eventually meet forming an encapsulation called a Micelle or Liposome that creates a barrier to the outside environment while trapping fluid in an inner core.



At this point it is important to recognize that even as they are forming into vesicles, the individual fatty acid molecules themselves are not fixed and unmoving in their positions. In fact, molecular forces remain active and the lipid molecules flip from outside to inside positions every few seconds although they do retain their hydrophilic and hydrophobic orientation. Other lipid molecules break away entirely from the vesicle and are replaced by lipids floating nearby. This constant motion, at the molecular level, permits occasional, temporary gaps to appear in the otherwise impenetrable wall, gaps that can be used by other molecules to sneak into the protected inner sanctum of the primitive vesicle.

Saccharides

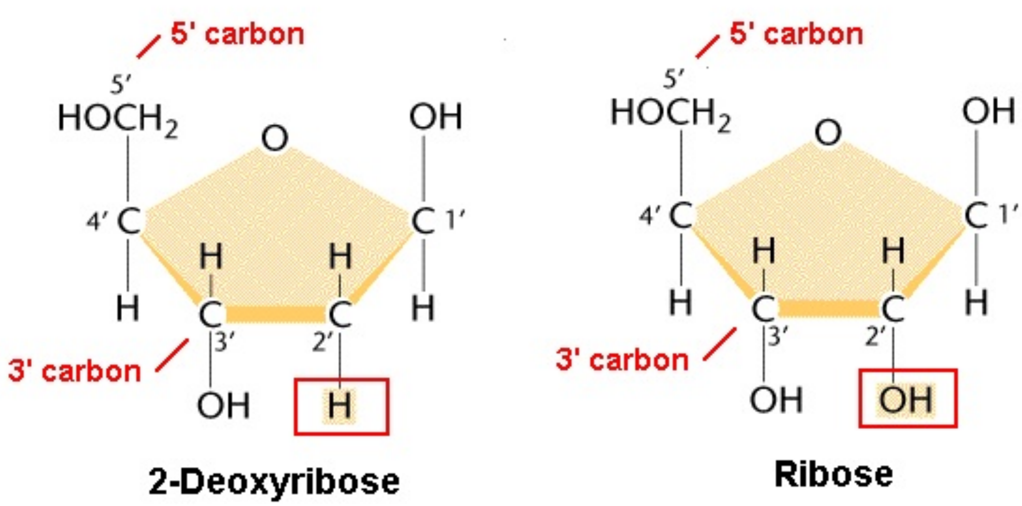
Saccharides, commonly called sugars, are perhaps the best known of the foundation molecules. Saccharides provide the raw material for the production of many intermediate molecules and are critical in the production of energy storage units for all living things.

For one, Glucose ($C_6H_{12}O_6$ - composed of 6 carbon atoms, 12 hydrogen atoms and 6 Oxygen atoms) is produced by plants during photosynthesis through a process that combines Carbon Dioxide with water producing Glucose and releasing Oxygen which many animals, including humans, require to survive. The Glucose is then used in additional processes to create energy molecules that support even further activity.

Combining Glucose with Fructose, a Saccharide found in many fruits, forms the familiar molecule Sucrose or common white sugar

But perhaps the most important Saccharide is one called Ribose. It's structure is shown below along with a close relative that is missing 1 Oxygen atom and is, therefore, called Deoxyribose.

Both Ribose and Deoxyribose connect with two other building blocks, coming up next, to create chains that will eventually become the cornerstone of information transfer between generations of future living cells.



(Klug & Cummings 1997)

Nitrogenous Bases

These molecules are all referred to as Nitrogenous Bases (pronounced Nigh-trog-en-us) because they are all based on and all contain Nitrogen atoms.

There are five different bases that we need to consider at this time. They are called Adenine (Add-in-nine), Cytosine (Site-o-zine), Thymine (Thigh-mean), Guanine (Gwah-neen) and Uracil (Er-a-sill).

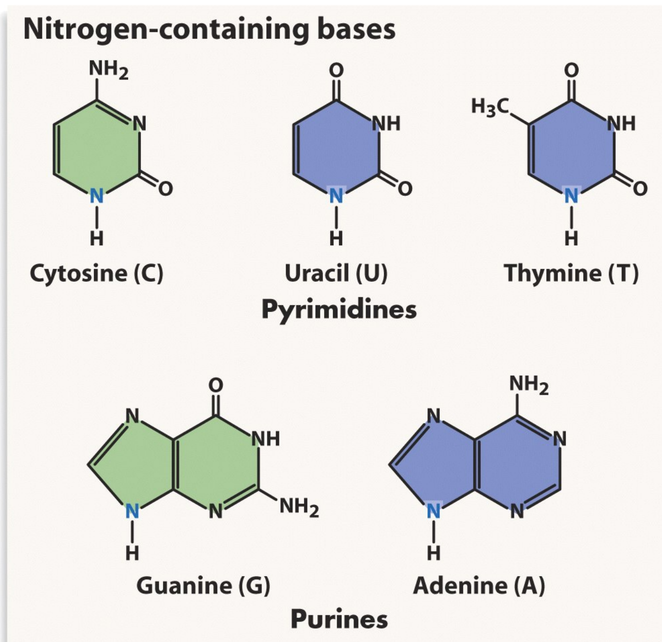


Figure 4-1c Biological Science, 2/e © 2005 Pearson Prentice Hall, Inc.

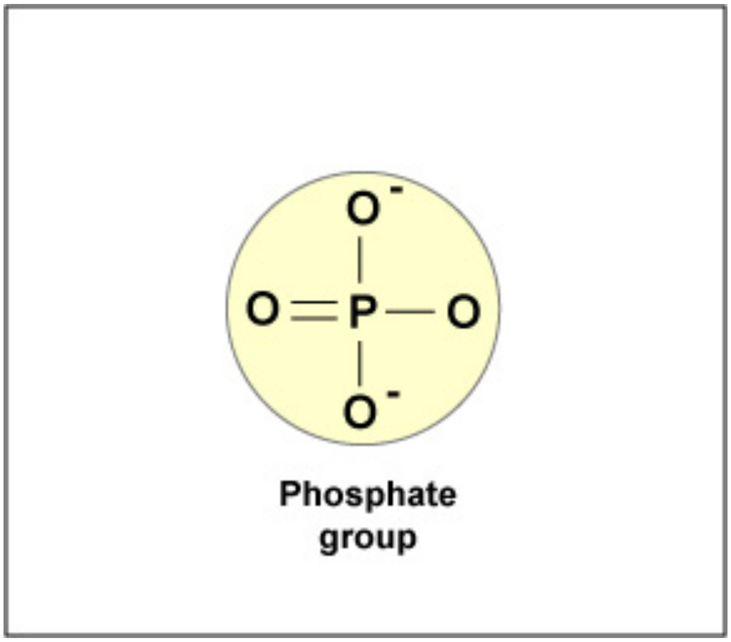
Notice that they all look similar except for different atoms appearing in similar locations. You should also notice they are divided into two groups - Purines and Pyrimidines (Pie-rim-id-eens) Purines are a little larger in size but the real significance here is that these bases will naturally connect with each other when they get near. However they will only connect in two possible ways - Adenine will only connect with Thymine and Guanine will only connect with Cytosine (Green to Green). Uracil is a unique compound that will substitute for Thymine in a special molecule we will see shortly but, like Thymine, it too will only connect to Adenine (Blue to Blue).

You may also have noticed that each base's name in the diagram is followed by a bracketed capital letter, the same letter that starts its name. Again Uracil is a special case that we'll examine further shortly but the remaining base letters, A, G, C & T will soon become familiar.

Just as complex computer applications are programmed at their most basic level by using only 1's and 0's, life itself is programmed or coded for by using only four Bases, represented for simplicity by their four letters. We'll see how that is done later. Now there is just one more class to go before we begin stringing these all together to make something remarkable.

Phosphate Group

These molecules all contain atoms of Phosphorous connected to 4 Oxygen atoms, 3 via a single bond and 1 through a double bond as illustrated below.

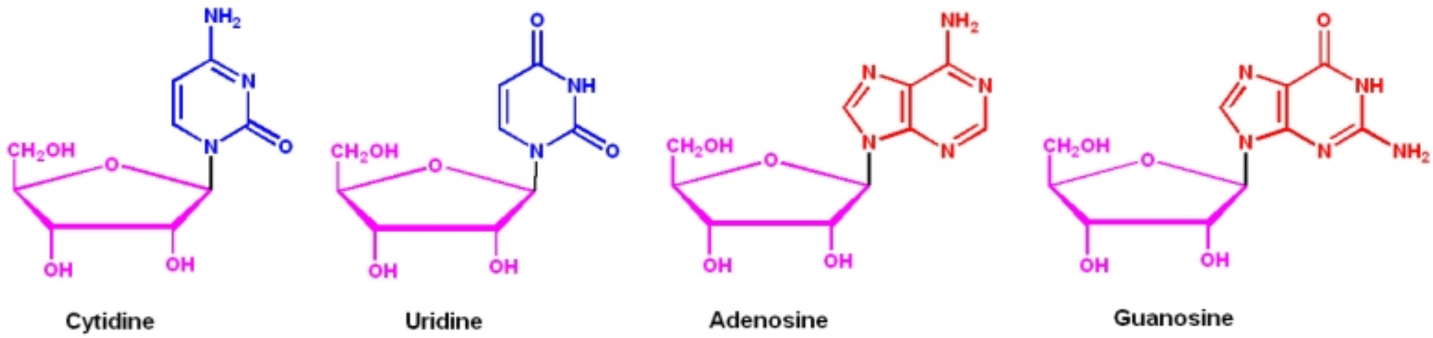


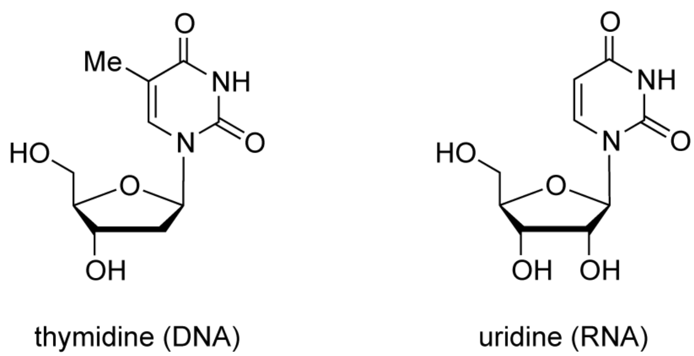
Again this is a fairly simple structure and, more importantly, it is able to connect to molecules identical to itself to form longer chains of two or three Phosphate Molecules. It also has the ability to connect to either the Ribose molecule or Deoxyribose molecule - the earlier Saccharides that were identified.

Now it is finally time to see how all these fit together.

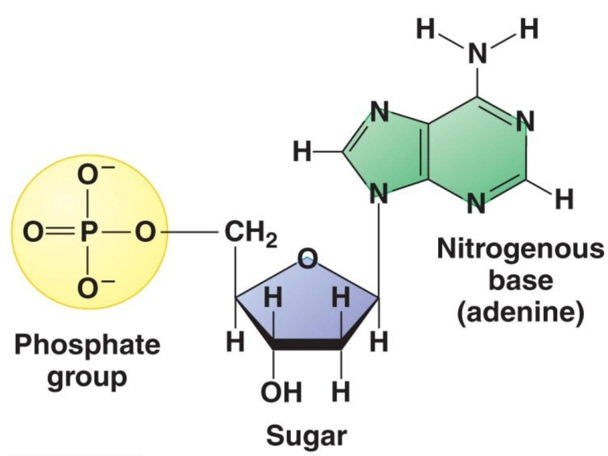
Nucleic Acids (Nucleosides & Nucleotides)

A Nucleoside consists of a Ribose sugar molecule or a Deoxyribose sugar molecule that is attached or connected to one of the previous Nitrogenous Bases - Adenine, Guanine, Cytosine, Uracil or Thymine. In the case of the latter two, Uracil only attaches to Ribose while Thymine only attaches to Deoxyribose. Because in all cases they form a brand new molecule, they all receive new names but I think you'll see the connection to the name of their attached Base.





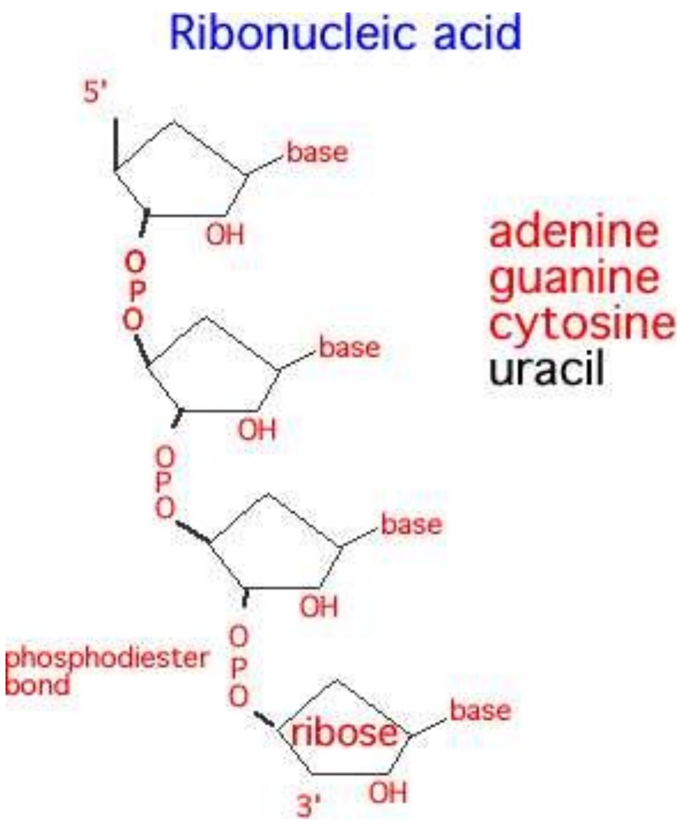
A Nucleotide is simply a Nucleoside that is also connected to the Phosphate molecule we just saw. In the diagram below you can see at the bottom of the sugar that the Oxygen atom on the right is missing so this sugar is Deoxyribose. If the Oxygen atom was there it would be Ribose.



The importance of Nucleotides can not be overstated. Long chains of Nucleotide molecules were the very first molecules that we believe were able to create copies of themselves. How they might have done this we'll discuss shortly. What you need to imagine is a sugar molecule, in this case Ribose, attached to a Phosphate molecule which then connects to one of the 4 Nitrogenous bases.

The Phosphate molecule then connects to another Phosphate molecule which has attached itself to a Ribose molecule which then attracts another Nitrogenous Base molecule. This process continues over and over and the chain grows longer and longer. The backbone of the chain is a sequence of connected Phosphate molecules with attached Ribose molecules which in turn then attract a Nitrogenous Base. This forms a single stranded long-chain molecule we call Ribonucleic Acid or RNA.

A grouping of 3 bases in a row is called a Codon which will appear again shortly.



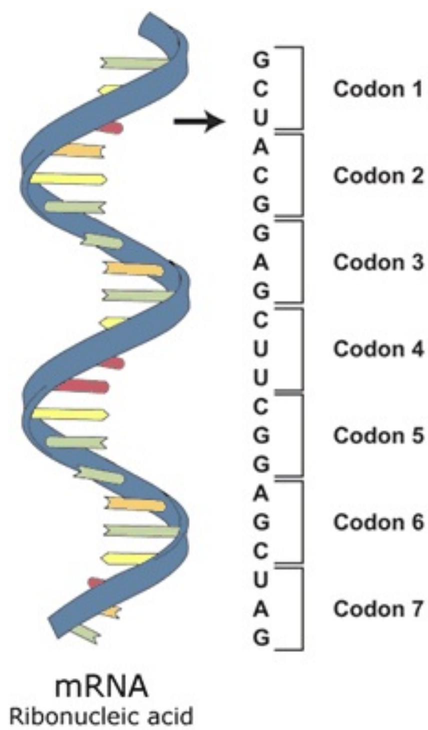


Image adapted from: National Human Genome Research Institute. Talking Glossary of Genetic Terms. Available at: www.genome.gov/Pages/Hyperion/DIR//VIP/Glossary/Illustration/codon.shtml.

RNA is the first molecule we know of that, when created with a particular sequence of bases, endows itself with the ability to replicate itself. A few hundred million years after their first appearance, single RNA strands linked together forming double stranded molecular chains that twisted into a helix shape and formed the molecule we now call DNA.

At this point a brief review might be in order. So, by taking all the following individual steps ....

- First creating simple Atomic Nuclei in the blast of the original Big Bang
- Modifying those Nuclei to form a range of elemental atoms in the furnaces of newly formed Stars
- Spewing those elements out into the void of Space via Supernovae to form compounds
- Collecting the interstellar dust and debris into a developing Galaxy
- Waiting for localized pockets of gas to be drawn in to a central mass that eventually ignites as a Star
- Building and then solidifying a molten rocky sphere in orbit around that star
- Providing liquid water to create a vast interactive environment
- Mixing available elemental atoms together to make new molecules
- Adding simple molecules to other simple molecules to create more complex compounds

.... we have finally arrived at the foundation of all things we consider to be alive - the DNA molecule. But we can't relax just yet. We are still a long way away from life itself.

Step 7: Cells and Life

Let's consider what else we need before we can begin to really call something alive.

The construction of cells and the initiation of self-replication and ultimately the permanent establishment of the self-sustaining actions we collectively refer to as life are perhaps the most complex and least understood of the many activities needed to create a complete universe. It will require significantly more explanation and detail than has been necessary during the first six steps of our universe creation experiment.

The processes involved in the creation and support of permanently living organisms can only be simplified so far before they will begin to appear like magic rather than science while providing all the intricate detail necessary to explain life and make it appear as a completely logical and obvious outcome of natural behaviours can quickly render it incomprehensible to the average reader. This narrative will attempt to strike an acceptable balance between these two obvious extremes.

The real truth is that scientists know more about the first trillionth of a second following the Big Bang than they do about all the processes that turned long-chained chemical molecules into living cells.

This is due, in part, to the giant machines we have built called Colliders, sometimes referred to as atom smashers, that allow us to recreate the enormous energies that existed in the very earliest moments of the Big Bang, permitting us to examine that early environment in great detail.

But it is also due, in part, to the fact that the earliest forms of living cells on Earth have long ago disappeared, leaving no trace of what they may have been like. We are also limited in our knowledge of what the early Earth environment was truly like. We can and do make educated guesses about the early Earth conditions, based mainly on interpretation of existing geologic evidence, but no one can really say for certain.

One widespread methodology used in the search for the earliest life forms (basically a Now-to-Then approach) is to examine our most primitive current life forms (bacteria e.g.) or those that have existed unchanged on Earth for the longest time and work backwards, trying to imagine even simpler life forms and how they may have been constructed. One current process underway removes different pieces of cellular material from living bacteria, bit by bit, to try and determine at what point a living organism ceases to be alive.

An alternate methodology (a Then-to-Now approach) starts with several complex chemical molecules under different primitive-like environments and adds various forms of energy and additional raw materials in an attempt to create something that can grow and reproduce on its own, meeting at least some of the criteria needed to be considered alive. At present, scientists have created primitive cell-like vesicles that do grow and divide on their own but they have still not been able to make a molecule from scratch that can replicate itself - a key component for life as we know it.

At the time of this writing there are over 70 different scientific definitions for life. What this really tells us is that there is still a lot of disagreement and very little agreement on exactly what constitutes life. This makes defining life even more complicated. There are, however, several characteristics that appear in most definitions and which are generally accepted as a minimum for any 'thing' to be considered truly living.

1. Living things are always composed of cells or are single, viable cells themselves;
2. Living things exhibit different levels of organization including cellular, organelle and system;
3. Living things use energy in different ways;
4. Living things grow;
5. Living things reproduce;
6. Living things respond to their external environments; and
7. Living things adapt to changes in their external environment.

For the next step, we'll borrow some parts of the Now-to-Then approach as well as the Then-to-Now approach to see if we can make some sense out of the whole Non-living/Living debate.
To begin we'll look at what we know about today's life forms at the cellular level. Then we can look back in time to see how they may have originated.

All living cells on Earth can be broadly divided into three distinct Domains. The first are called Prokaryotes (Pro-carry-ots) and are identified as single-celled organisms, like Bacteria, that lack a Nucleolus - a separate enclosed portion holding the cells replicating material.

The second are called Archaea (Ar-key-ah). Although they also are single-celled without a Nucleolus, the Archaea are significantly different structurally from Bacteria and are generally found in Earth's most extreme environments, like boiling hot sulphur springs, very high salinity pools, and near lava outpourings at the bottom of the sea, pointing to the possibility that they represent some of the first types of stable living organism that existed on the very early Earth.

The third are called Eukaryotes (U-carry-ots). These are usually multi-cellular organisms, although there are a few single-celled Eukaryotes, and all of their cells do contain a Nucleolus.

The Nucleolus, a segregated space enclosed by is own distinct membrane that holds the replicating molecules, contains all the information needed to duplicate the entire original life form. In the case of Prokaryotes and Archaea, the replicating molecules are spread throughout the entire internal substance of the single cell.

These three Domains, Bacteria, Archaea and Eukarya have been further broken down into five Kingdoms that classify all the living organisms we have discovered on Earth so far. See the following chart.

Classification of Living Things

Domain	Bacteria	Archaea	Eurkarya			
Kingdom	Eubacteria	Archaebacteria	Protista	Fungi	Plantae	Animalia
Cell Type	Prokaryote	Prokaryote	Eukaryote	Eukaryote	Eukaryote	Eukaryote
Cell Structures	Cell walls with peptidoglycan	Cell walls without peptidoglycan	Cell walls of cellulose in some; some have chloroplasts	Cell walls of chitin	Cell walls of cellulose; chloroplasts	No cell walls or chloroplasts
Number Of Cells	Unicellular	Unicellular	Most unicellular; some colonial; some multicellular	Most multicellular; some unicellular	Multicellular	Multicellular
Mode Of Nutrition	Autotroph or heterotroph	Autotroph or heterotroph	Autotroph or heterotroph	Heterotroph	Autotroph	Heterotroph
Examples	Streptococcus, Escherichia coli	Methanogens, halophiles	Amoeba, Paramecium, slime molds, giant kelp	Mushrooms, yeasts	Mosses, ferns, flowering plants	Sponges, worms, insects, fishes, mammals

The Modern Living Cell

Let's begin our investigation into living things by first examining a modern day Eukaryotic cell, after all humans are composed entirely of Eukaryotic cells.

Using the human body as an example, one thing we can tell immediately is that Eukaryotic cells are quite varied in their size, shape and function and that when they group together in large quantities they can form material as fluid as the blood in your veins and tears in your eyes, or as solid and flexible as your skin and hair, or as hard and rigid as your bones and teeth. Despite these vast differences there are some common characteristics among all Eukaryotic cells.

They are, on average, about 10 times the size of Prokaryotic or Archaea cells. Each has a plasma membrane composed of Phospholipids (remember those Lipids?) that encloses a body of Cytoplasm. Within the cell's Cytoplasm are small 'bodies' referred to as Organelles that are themselves surrounded by membranes. These Organelles each perform separate functions for the cell.

Every Eukaryotic cell also has a Nucleolus, enclosed by a separate membrane, that holds the replicating molecules carrying its genetic information and instructions for what the cell is to do in order to fulfill its function. Traversing the external membrane are molecular 'gates' that allow certain molecules in and out. These gates are critical for the proper functioning of the cell allowing raw materials in for processing and dispensing finished products needed by the body to survive. Many of our most troubling medical diseases are actually the result of the improper functioning of these gates. Scientists are continually working on methods to fix poorly operating cell gates to restore human health.

One of the internal bodies or organelles found in almost all Eukaryotic cells are themselves very much like a Prokaryotic cell. They are called Mitochondria. (My-toe-con-dree-ah). They have their own plasma membrane, their own internal structures performing specific functions and their own replicating molecules - which bear significant similarity to those of early bacteria.

Among other contributions, Mitochondria provide the energy needed by the cell to carry out its duties. They do this by transforming glucose through a number of progressive steps and creating a special molecule called Adenosine Triphosphate (ATP). The average Mitochondria manufactures millions of ATP molecules every second. It is speculated that Mitochondria were, at one time, actually separate single-celled organisms that somehow became absorbed into a primitive Eukaryotic cell and, because the cell provided protection and the Mitochondria provided energy, a symbiotic relationship developed that benefitted both and secured the Mitochondria's place in all future Eukaryotic cells. The number of individual Mitochondria found in each modern human cell varies widely dependant on that cell's function, all the way from zero in human red blood cells to over 2000 in each human liver cell.

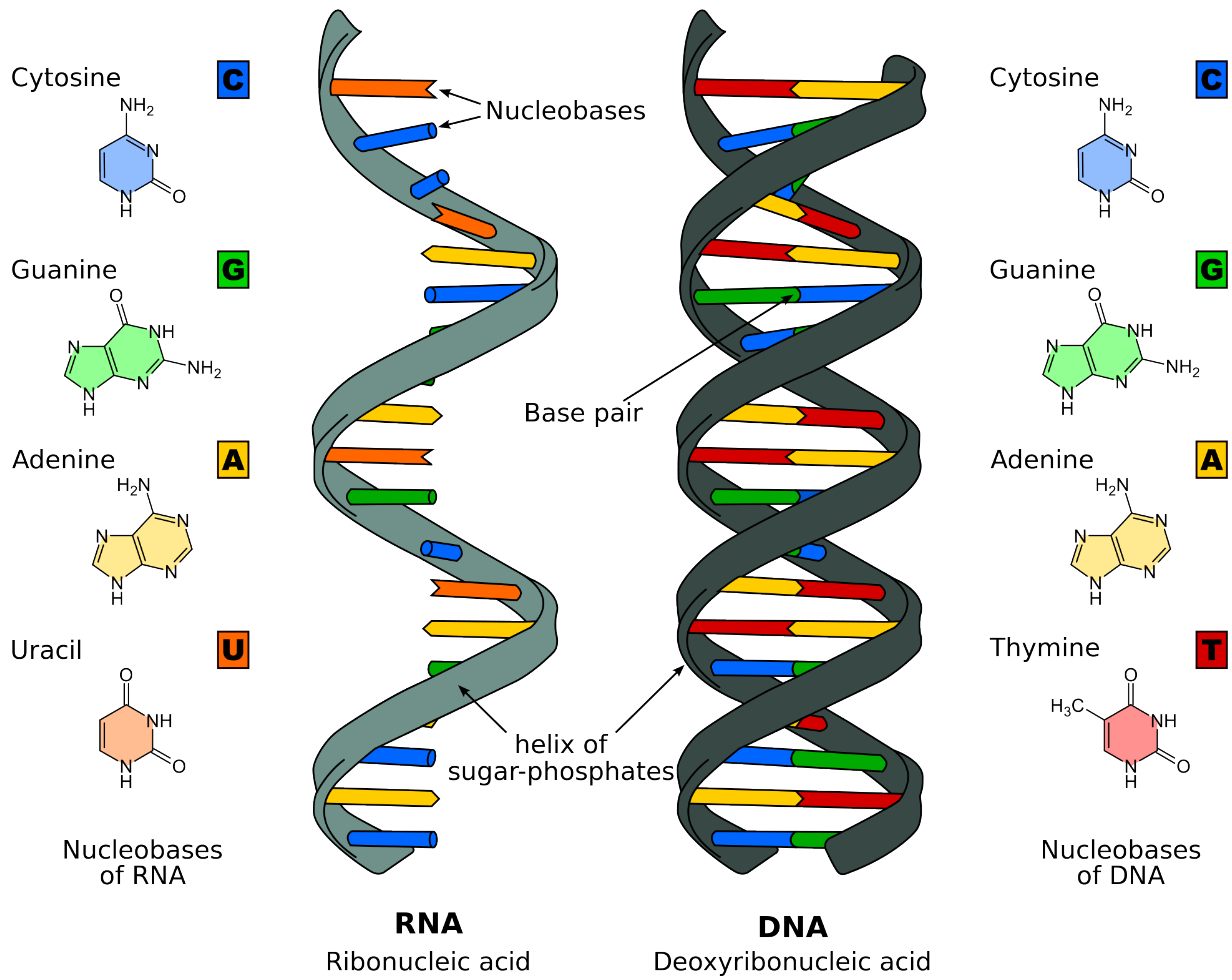
The complete functioning of the modern Eukaryotic cell is a highly complex, complicated series of steps with a variety of unique organelles, gates and processes that enable it to play its part in the maintenance and continuation of the overall organism whether it be a simple moss, a beautiful flower or a human being.

But the primary function of most modern human cells is to produce Proteins, specialized long-chain molecules used throughout our bodies for a variety of different purposes.

We are now going to look at how a modern-day cell actually makes proteins in greater detail before looking way back in time to see how the very first living cells may have first come into being.

DNA, RNA, Amino Acids and Proteins

We can't discuss modern cells without examining the role that replicating molecules play in the continuation of any species. Of course we are talking about DNA - Deoxyribonucleic Acid and RNA - Ribonucleic Acid. You know now that each is basically a repeating molecular chain consisting of a Phosphate molecule attached to a sugar which in turn connects to one of four different Nitrogenous Bases, Adenine, Cytosine, Guanine and either Uracil or Thymine. While RNA is a single-stranded molecule, the DNA molecular chain consists of two separate strands joined together by the bond between complimentary bases - Adenine to Thymine (or Uracil) and Cytosine with Guanine. Here is what they look like.



If we look closer at the DNA double strand, it can be seen that each individual strand is actually a duplicate but opposite copy of the other.

With DNA, Phosphate-Ribose backbones are exactly the same for each strand but the connected Bases are the exact opposite of each other. That is Adenine on the first strand connects to Thymine on the second, Cytosine on the first strand connects to Guanine on the second, Thymine on the first strand connects to Adenine on the second and finally Guanine on the first strand connects to Cytosine on the second.

These Base Pairs A-T, T-A, C-G and G-C are the key to DNA's unique ability. If we were to unwrap or separate the strands of any specific DNA chain then we could, using each of the single strands, construct two complete, identical double DNA chains. Starting with either single strand we could connect a Deoxyribose molecule and a Phosphate molecule with an attached Nitrogenous Base to the appropriate complimentary Base. You may recall that the name we gave to the combination of a Nitrogenous Base, a Deoxyribose sugar and a Phosphate was a Nucleotide. Therefore by adding the appropriate Nucleotide to each single strand along its entire length we would create two DNA chains each identical to the other and both identical to the original double-stranded chain we started with.

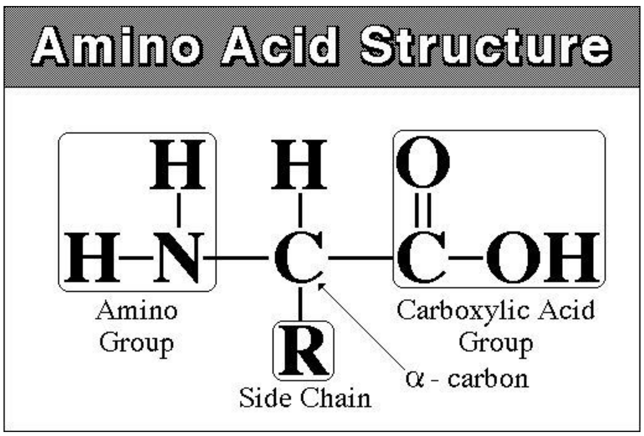
If we started instead with a single stranded RNA chain, added the appropriate Nucleotides, then separated the resulting double strands, we would end up with two chains of RNA each the exact opposite of the other. Since Uracil is substituted for Thymine in RNA, the connected Base Pairs would actually be A-U, U-A, C-G and G-C.

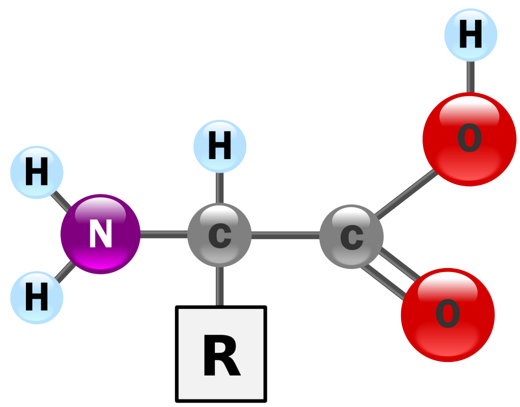
We will see this process in greater detail as we further investigate cell operations in modern day cells and examine cell reproduction. All we have left to do now is to look at two more pieces of the cellular puzzle then we'll summarize the workings of a modern day cell.

Amino Acids

Amino Acids have been called the building blocks of life because they link together to form those complex long-chain molecules, called Proteins, which are used by living organisms to build new cells, to grow, to regulate its internal environment and to fend off enemies and disease.

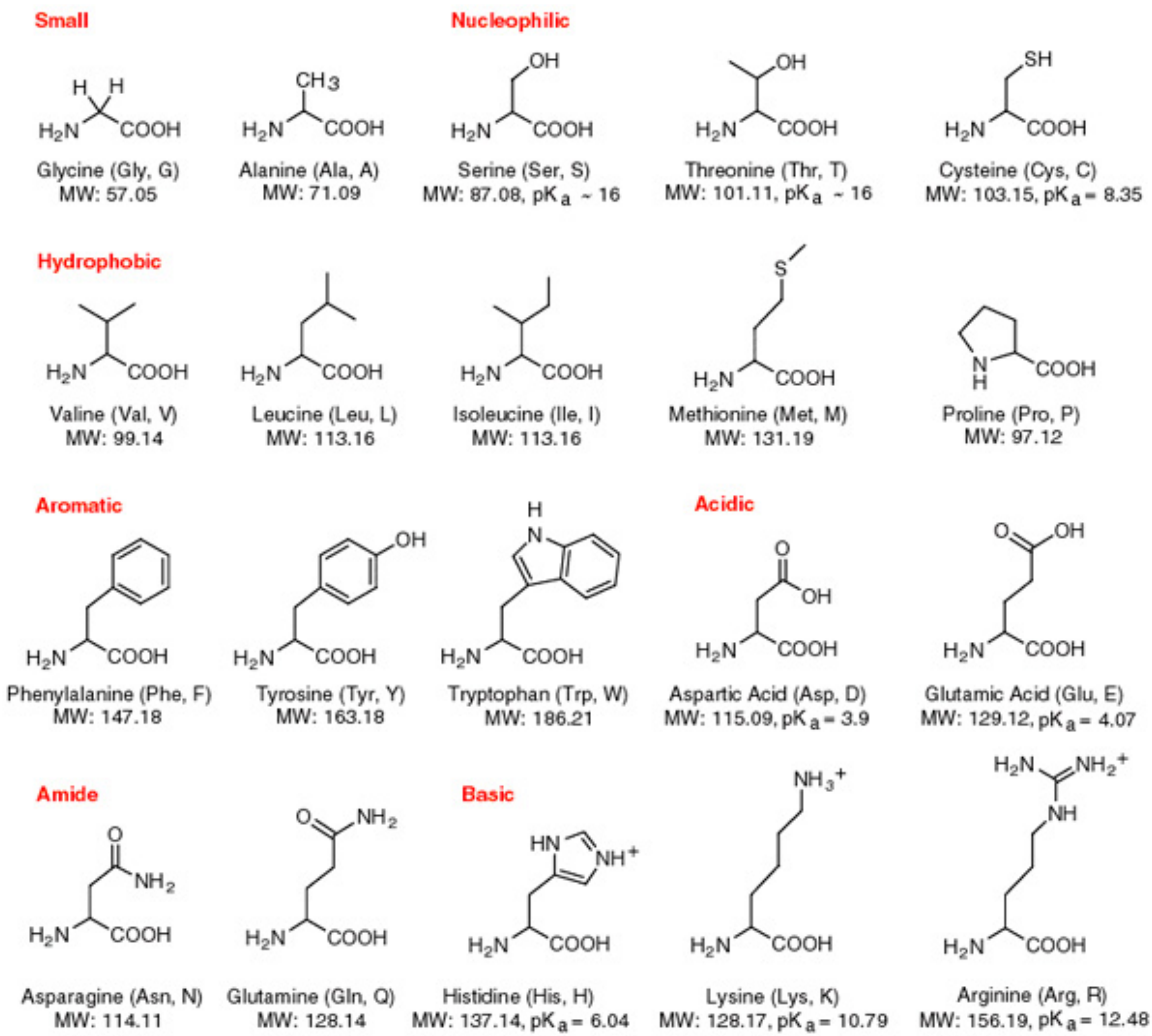
The following diagrams illustrate two different views of the same basic, underlying molecular foundation upon which Amino Acids are built. In each case the letter 'R' represents a completely different and unique molecule that connects to the primary structure to changes its shape, size and function.





There are many possibilities for arranging molecules to create over 250 different Amino Acids but, in fact, there are only 20 primary Amino Acids that are essential for life on Earth and those are shown below.

The name, short form, molecular weight (MW) and sub-group that each amino acid molecule belongs to are given. Try and locate the common foundation shown above and the extra 'R' side molecule that makes each unique.



When connected together in very specific sequences, Amino Acids form Proteins, needed by all living things to survive. Let's look at them now.

Proteins

Proteins are the primary material used in humans (and all lifeforms) to build muscle, skin, bone, hair and most other tissues that are found in our bodies. They are also crucial in regulating the bodies various systems and form many of the structures used to build cells themselves. The 'gates' in cell walls that control the passage of materials in and out, mentioned earlier, are often Proteins.

Proteins are comprised of long chains of the 20 Amino Acids used by living cells. Depending on the sequence of Amino Acids, these chains will curl and twist due to the molecular forces between adjacent molecules. Since different Proteins have different sequences they twist and curl in different ways. Identical molecular chains (the same Proteins) twist and curl in identical ways.

Here are a few simple facts about Amino Acids and Proteins.

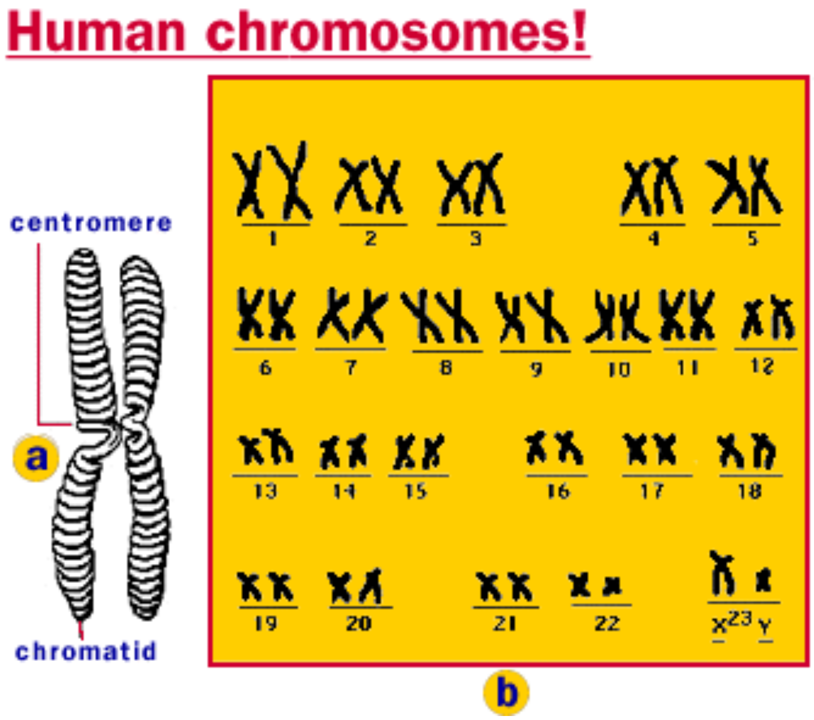
- A very short chain of Amino Acids is called a Peptide.
- The shortest Peptide is only 2 Amino Acids long
- The term Peptide is usually applied to chains less than 50 Amino Acids in length.
- A chain that grows beyond 50 or so Amino Acids is referred to as a Polypeptide
- Proteins themselves are usually many Polypeptides linked together.
- The longest Protein found in humans is a chain of 26,926 Amino Acids called Titin found in muscle tissue.
- The human body contains somewhere between 100,000 and 2 million completely different kinds of Proteins.
- The total number of different Proteins found in all living organisms on Earth is probably over 10 million although no one really knows for sure.
- The total number of individually produced proteins in the human body is many, many trillions, probably even more.

In order to make a Protein it is necessary to join together the correct Amino Acids in the correct sequence. It has been noted several times that the four Bases (A,C,G & T) are the key to life as we know it. Both RNA and DNA are really just long strings of these Bases - in humans a string of about 3 billion Base Pairs contains all the details of our individual blueprint. During the reproductive stage of a cell, this long string is broken up into smaller pieces we call Chromosomes (Chrome-o-zomes).

The Chromosomes in turn are sub-divided into special groups we call Genes. A specific Gene sequence is a portion of any Chromosome identified by a specific string of bases that precedes it, called the Promoter sequence, the Gene sequence itself and another specific string of bases that follows it called the Stop sequence. In addition to these particular Gene sequences there are many chromosome sections containing strings of bases that appear to have nothing to do with life at all along with a few whose purpose we haven't figured out yet. Human Chromosomes contain somewhere around 20,000 specific, different, active Genes among the 3 billion base pairs.

There are two distinct types of chromosomes in every human being. There are certain traits that are passed from generation to generation, depending only on whether you are a male or female, through a pair of Sex Chromosomes, either an XY or YY. In addition there are 22 other chromosomes, called Autosomes, that carry all other inherited information.

The chromosome pairs are numbered 1 through 22 plus the XX or XY combination. This makes 23 pairs or 46 individual chromosomes in each human cell. For each pair, one came from your mother and one came from your father. Chromosomes, individually, are all different lengths (a measure of the number of Base Pairs that make up that particular DNA sequence) and also contain a different number of genes as genes are all of different lengths as well.



Here are a couple of examples to illustrate although all numbers are only approximations or estimates based on scientific work done to date:

- Chromosome #21, the smallest, contains about 200 genes and a total of roughly 46,500,000 base pairs in its entire length;
- Chromosome #14 contains about 800 genes and a total of 106,000,000 base pairs;
- Chromosome #1, the largest, contains over 2000 genes and runs over 247,000,000 base pairs in length.

To start the process of making proteins, as with many other cell processes, a special 'helper' molecule called an Enzyme is required. An enzyme has the ability to assist processes to complete much faster than they normally could without being changed itself in any way.

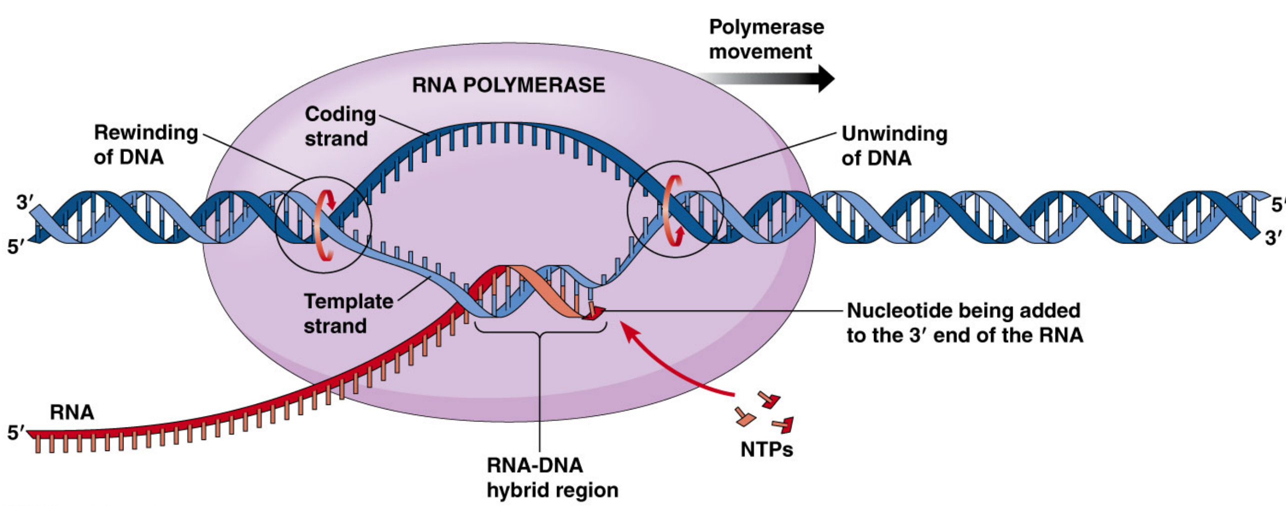
Enzymes are incredibly important and without them life itself would be impossible. They act on the various forces in play at the atomic level and permit combinations of elements and molecules to take place that would normally only rarely happen. As one example, there is an enzyme that reduces the time for a specific chemical reaction to occur from 1 million years to only a few seconds. As you can imagine, this kind of dramatic assistance has undoubtably had a profound influence on the creation of the very first living organisms.

In the case of modern day protein production, the first enzyme needed is called RNA Polymerase (Pole-im-eraze). In Eukaryotic cells there are actually three different types of RNA Polymerase on active duty - Type I, Type II and Type III. Type II is the enzyme that we'll look at first.

The first part of the protein production process is called Transcription because information (base sequences) are transcribed from a DNA strand to an intermediate form we'll see shortly. It begins when the enzyme RNA Polymerase attaches itself to a portion of one of the DNA segments that make up one of the chromosomes.

The Polymerase structure is such that it can slide along the DNA strand. It continues along the DNA strand until the front-most part of the enzyme reaches the Promoter sequence of bases usually T-A-T-A which has been given the rather obvious name of the TATA sequence. The double-stranded DNA then is temporarily unzipped forming two separated strands and, shortly afterwards, as the enzyme continues to move along the strand, is stitched back together into the familiar double-stranded helix shape. This is similar to the action of a double zipper on a luggage bag where the first zipper clasp undoes the zipper while the trailing zipper clasp reunites the two halves together. In between the two zipper clasps the zipper itself is temporarily wide open.

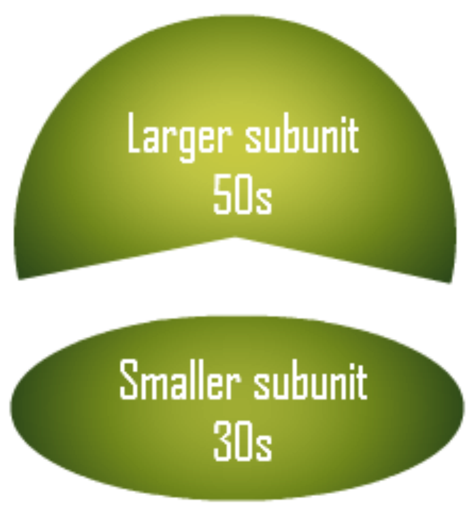
While the DNA strands are temporarily separated, the RNA Polymerase enzyme attracts a multitude of nucleotide pieces (NTPs) that are floating around the cytoplasm and matches them up with one of the temporarily single strands creating a completely new chain. Remember that a nucleotide is a phosphate and a sugar with a base attached and that the bases will line up only with their complimentary counterpart A-T, C-G, T-A and G-C.



The chain continues to grow and is forced away out into the cytoplasm of the nucleolus until the Stop sequence is reached, usually a long string of Adenine bases A-A-A-A-A-A-A called, not surprisingly, the Poly A Tail.

At this point the newly created chain, called Messenger RNA (mRNA) is released and the RNA Polymerase enzyme disconnects from the DNA strand. The Polymerase will continue floating around until it encounters another DNA strand or, possibly, a different segment of the same DNA strand, attaches itself, finds a new promotor sequence and starts the entire process all over. It is important to note that since this process is active at the atomic and molecular level it actually completes very quickly. The entire process from attachment and production of mRNA through to final release for a gene that is 50,000 Base Pairs long could take less than a minute. Given the large number of Polymerase enzymes that exist in each cell, one can see that over the entire lifetime of a single cell (from a few hours to a few days) it would be possible to generate many millions of these mRNA strands.

Once the mRNA strand has been released, it eventually arrives at the membrane surrounding the nucleolus where it passes through the wall via one of the specialized protein gates and ends up in the cytoplasm forming the interior of the cell. Here it encounters first one half of the Ribosome Unit (itself a specialized RNA strand) called the Larger Subunit (50s) which attaches to one end of the mRNA strand. Shortly the second half of the Ribosome called the Smaller Subunit (30s) is drawn to



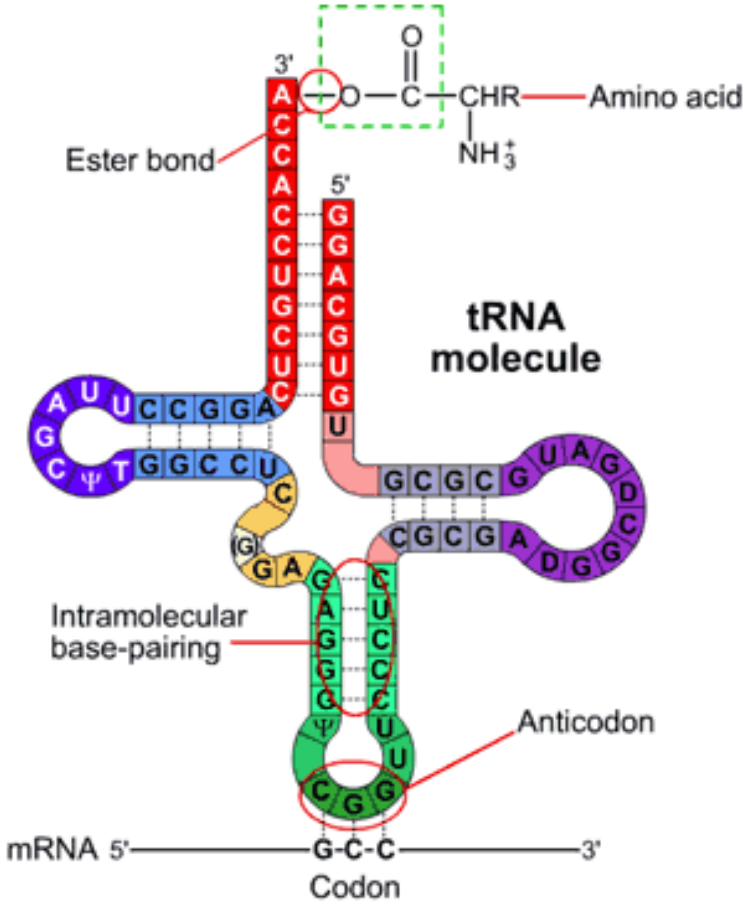
Structure of ribosomal subunit

the first half and together they clamp the mRNA in place.

For clarity, each human cell contains up to10 million Ribosomes so it is not long before this clamping occurs.

In a similar fashion, the Type III Polymerase creates a large number of transfer RNA chains (tRNA) - coming up next. These chains take on a very particular shape due to the bonding of complimentary bases (A-U, C-G) that occur at specific points along their length.

The following diagram shows the tRNA strands divided into different sections by colour and clearly shows the complimentary Base Pairing previously mentioned that causes it to twist into its particular shape.



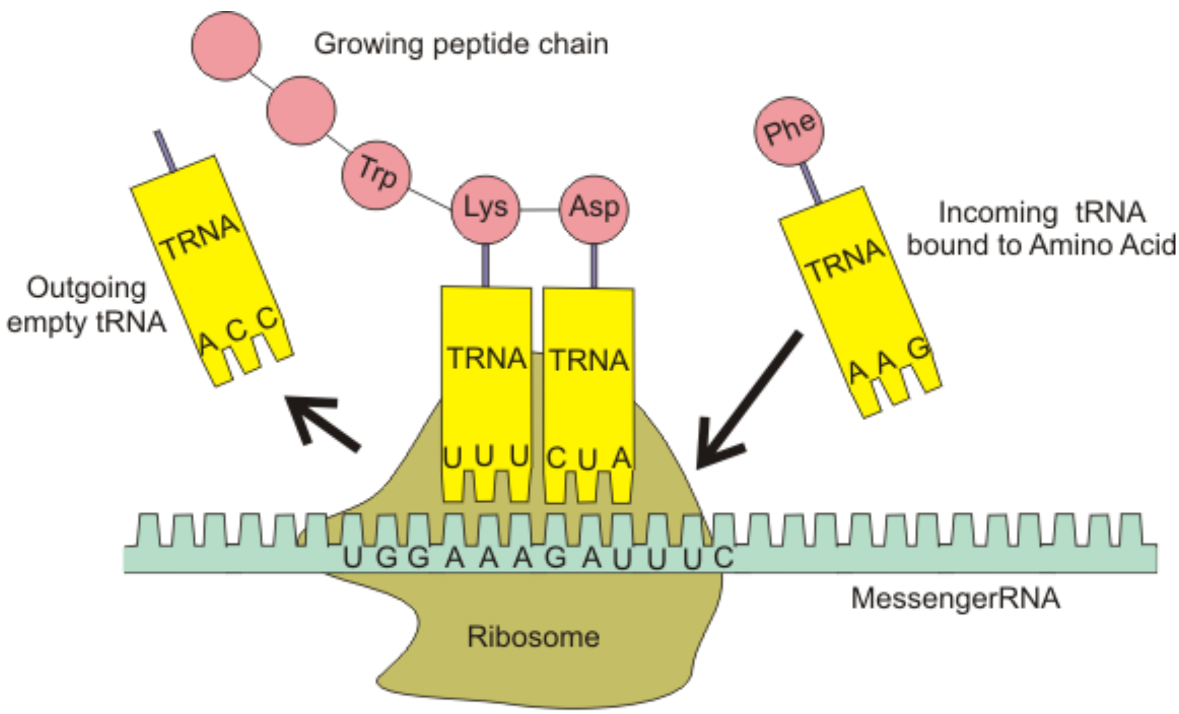
Next look at the bottom of the green loop at the three letters referred to as the Anticodon. For this specific tRNA, the Anticodon is GGC (for this molecule we move from the 5' - called 5-prime - end towards the 3' - called 3 prime - end) which means that the three bases in a row here are Guanine-Guanine-Cytosine. The significance here is that for each different three Base grouping in the anticodon region there is a specific 3' ending on a tRNA chain that attracts and attaches a different and unique Amino Acid.

If the anticodons are associated with the tRNA then where are the codons? The term codon refers to a three Base sequence found on the mRNA chain which, you should recall, was generated in the nucleolus, passed out into the cell's cytoplasm and clamped by the two halves of the ribosome.

Now that we have created the mRNA, created a ribosome that has captured that chain and produced a huge number of tRNAs all carrying assorted Amino Acids, we can finally move onto the actual process that builds our proteins.

This part of the process which actually creates the polypeptide chain or protein is called Translation because the base sequences on the mRNA strand, which have been transcribed from the gene sequence on the DNA strand, are 'translated' into Amino Acid sequences which make up the final Protein.

Here is how it actually happens.



Peptide Synthesis

Once the two halves of the ribosome have clamped onto the start of the mRNA strand, together they begin to attract tRNAs with different anticodon sequences and attached Amino Acids. When a tRNA with an anticodon that is complimentary to the first 3 base sequence of the mRNA is captured, the anticodon and codon become temporarily connected. The ribosome then moves down the mRNA chain the length of one codon - exactly 3 bases.

When the next tRNA, whose anticodon matches the new 3 base codon of the mRNA, is captured, it also temporarily connects codon to anticodon. This action brings the two Amino Acids attached to the two tRNAs close enough together that they bond. The ribosome then moves ahead another 3 bases or 1 codon. This allows the first tRNA to disconnect from its Amino Acid because the bond between acids is stronger than the bond from the acid to the tRNA.

The next tRNA with a matching anticodon is captured and its Amino Acid joins the growing peptide chain. As the ribosome moves ahead again, the first tRNA is finally released from the mRNA strand and floats off into the cytoplasm to eventually capture another Amino Acid and become available to any ribosome within the cell. This process continues with the capturing of tRNAs, the connecting of codon and anticodon, the attachment of Amino Acids to a growing peptide chain and the release of the tRNA back into the cell minus its original Amino Acid until the end of the mRNA strand is reached - the special Stop sequence. At that time, the polypeptide (Protein) is released, the two halves of the ribosome separate, the mRNA is released and the whole process begins again with either different ribosomes and mRNA strands or even with the same ones.

Again, it is important to appreciate, that this entire process advances at a rapid rate taking only a few seconds to build proteins that are thousands of Amino Acids in length. With millions of mRNA strands available, and millions of tRNA carriers available and millions of ribosomes throughout the cell's cytoplasm, all able to work simultaneously, the reader should be able to recognize each cell's capacity to create many millions of proteins in a very short time, thus providing the raw materials for an organism's growth.

So far we've followed the physical universe's development from its earliest beginnings up to the establishment of a habitable planet orbiting a star as a member of a newly formed solar system. We've also examined how basic elemental atoms combine in different ways to create a wide range of molecules with different properties and varying abilities to attach, connect or bond with other molecules. We've learned how these molecules interact with themselves and others to form long chain strands creating a number of key structures essential to the operation of living cells. And we've followed the processes present in modern living cells to transcribe the genetic code found in DNA and build strings of Amino Acids, polypeptides, that eventually become the myriad of proteins all life needs to exist.

What does it all mean - really.

The most critical concept for the reader to grasp is that of the DNA code. Each and every cell in any living organism has a complete set of all DNA strands needed to construct every component necessary to rebuild the entire organism. The only exception is sex cells which contain only 1/2 the necessary DNA so that combining two, one from the female and one from the male, will result in a complete set.

As you've seen, the DNA strands are each made from a sugar, a phosphate and a base. The sugar and phosphate together form only the framework of the chain that allow the bases to pair together in complimentary fashion. The gene functions are defined solely by the order of the bases that make up their length. A microscopic look at a tiny portion of a human gene, substituting it's capital letter for the actual base molecule in place, might look something like this:

...TATAGACGTACAGTCGAGATCACAGCTCGAGCTCTCTTTTTCACCCGAGAGAGTTCA...

This exact sequence would then be replicated during transcription by RNA Polymerase matching nucleotides to the opposite side of the separated strand which would create mRNA that would look like this: (the TATA sequence is not transcribed)

........GACGTACAGTCGAGATCACAGCTCGAGCTCTCTTTTTCACCCGAGAGAGTTCA

If we now break up the actual mRNA sequence into 3-letter groupings, starting at the beginning, we'll get 3-base codons that look like this:

GAC GTA CAG TCG AGA TCA CAG CTC GAG CTC TCT TTT TCA CCC .... etc.

These 3-Base codons will then compliment and connect with the opposite anticodon on the tRNA strand which itself will carry a specific and unique Amino Acid. The strings of Amino Acids assembled in the ribosome then become proteins to be used by the organism to build whatever components are required.

This is how four simple letters A C G T, representing four chemical bases, Adenine, Cytosine, Guanine and Thymine are used to build something as complex as a human. In humans our DNA code consists of roughly 3 billion base pairs representing 20,000 genes. In comparison, E Coli bacteria DNA is only 4 million base pairs in length representing about 3,000 genes.

It was mentioned earlier that one method of examining life was to remove bits and pieces of cellular material (actually portions of DNA) to determine when 'life' might begin. So far, the smallest number of genes that has been found to be required to keep a basic organism living is about 200. The implication here is that sufficiently long and complex replicating molecules (either RNA or DNA) must have existed long before the first living cells appeared on Earth. One other alternative theory proposed is that complex chemical building blocks were actually created elsewhere in space then, after surviving the perils of outer space, were delivered to Earth via meteorites, asteroids or comets and became the seeds for all future life on Earth.

Back To The Past

Its time now to revisit planet Earth, about 4 billion years ago, just after water has made its first appearance, congested with immeasurable numbers of molecules and elements some of terrestrial origin, some of cosmic origin all combining, breaking apart and recombining into a variety of forms that might or might not survive the extremely harsh environments.

Although we have already looked at the basic definition of life, there is value in enumerating the basic functions that all living cells possess. These are a little bit different from the criteria for an entire organism to be considered alive because they identify only the physical construction and functions that all living cells have in common.

The characteristics that all current living cells have in common are:

1. A lipid membrane that encloses the contents of the individual cell;

2. At some point, they undergo cell division producing two identical copies;

3. They all use Adenosine Triphosphate (ATP - via Mitochondria) to derive energy;

4. They all use RNA (incl. mRNA, tRNA and Ribosomes) to make Proteins; and

5. They all use DNA to replicate and pass on genetic information.

If you think about this for a few minutes the implications are enormous. ALL living cells meet these criteria - Bacteria, Archaea, Amoeba, Fungi, Plants and Animals, including humans. All of these contain cells that each follow these same rules. It is undeniable that there is a common origin that binds these all together.

As mentioned earlier there are dozens of theories relating to how life actually got started on Earth even proponents of the idea that life had already developed deep in space and was later delivered onto the Earth, in a sense making us all immigrants. However, until such time as we can duplicate the actual creation of living cells and demonstrate it for the world to see, it will be left to our own imaginations to accept or reject the latest ideas and theories.

We have, in various experiments, been able to observe some molecular behaviour that foretells the ability of organic molecules to create the original 'first living cell'. Our experience also tells us that it is highly likely that millions and millions of attempts were made to form a living cell with virtually every one failing. Even those that were initially successful probably eventually 'died'. It has, however, been directly observed that a common material, montmorillonite clay, exhibits a unique ability to speed up Vesicle formation and RNA strand duplication more than 100 fold. It is likely that this clay played a strategic role in bringing together the original molecules to form the original structures required for life.

At the same time, modern science believes that all these disparate cellular functions could not and did not suddenly appear in one single instant to create the first living cell. Rather, science takes the approach that, through a series of steps, following the established laws of physics, assorted molecules came together, over time, to begin the journey that would eventually result in human lifeforms who would ultimately develop the capacity to actually contemplate and discover the root of their very own existence.

If we step back for a moment and look at what we have so far, there is no question that certain things must have happened before others. If we consider these steps in an orderly, progressive manner we might envision the following activity occurring on our planet over many hundreds of millions of years:

1. Lipids, Sugars, Phosphates, Bases and Amino Acids form as independent molecules due to the atomic forces at work on available elemental atoms;

2. Sugars and Phosphates begin connecting together because of their unique affinity;

3. Bases and Sugars also attach due to their mutual affinity;

4. Free-floating Nucleotides (a Sugar, a Phosphate & a Base) form short single-stranded chains;

5. Nucleotide chains (RNA) continue to grow in length as more and more nucleotides connect in randomly selected Base sequences;

6. A unique long RNA chain assembles and folds back upon itself in a specific shape that provides an ability for it to behave as an Enzyme;

7. Other RNA chains encounter the new Enzyme which then creates duplicates of those chains still attached to each original. You should recall that each duplicate would be an exact opposite of the original chain it was created from;

8. Another Enzyme chain encounters the first Enzyme and is itself duplicated;

9. This produces a unique double-stranded RNA chain, one strand being an Enzyme and the other strand being a template for future Enzyme production.

10. These duplicated double-stranded chains are eventually forced apart by the heat or physical agitation of the hostile environment;

11. A second completed Enzyme then encounters the template and generates yet another template and another new Enzyme soon building up a stockpile of Enzymes and templates which begins to grow exponentially - these Enzymes are the earliest RNA Polymerase - the templates eventually become mRNA;

12. Lipids eventually form into simple Vesicles that withstand attempts at disassembly

13. Some of the replicated RNA strands form small loops that, due to their specific design, attract and capture free Amino Acid molecules in unique ways - the original tRNA;

14. Some replicated RNA Enzymes become able to capture these smaller RNA loops and permit Amino Acids to link together into longer and longer chains - these are the first Ribosomes;

15. Those long Amino Acid chains fold and curl into shapes that become building blocks for advantageous additions to a cell's basic construction such as a wiggling tail that permits greater mobility or a specialized gate that allows greater influx of needed raw materials - the first Proteins;

16. We now have the first self-replicating molecules and simplified Protein production but need a true cell to contain and make use of these new specialized Molecules.

We hinted earlier on how the first prototype cells might have developed. Lipid molecules do collect together to form simple Vesicles but these are still far from a living cell. Modern day experiments and observations have shed some light on the possibilities for early prototype cell construction techniques.

During many experiments we have observed that vesicles that form in environments with high Lipid counts attract more and more Lipids into their circumference. At the same time, the molecular action of Lipids moving in and out and expanding the circumference of the vesicle is sufficient to allow our RNA enzymes and templates to creep into the inner sanctum where they remain trapped. Some existing RNA strands remain trapped in the vesicle's interior where the enzyme continues to replicate them in increasing numbers.The application of heat energy, say from a lava outpouring on the ocean floor causes the separation of RNA strands that have become joined so that enzymes and templates can be found separated and in equal numbers throughout the vesicle.

As the vesicle continues to grow in size, the limits of attraction between adjacent Lipids causes the vesicle to take on the converging shape of a figure 8. As the opposite sides get closer and closer, the pressure of the bending circumference overcomes the molecular attraction between Lipids and the cell wall breaks apart in the middle with the loose ends connecting to their opposite number forming two smaller circular vesicles each complete with internal replicating molecules.

While we have observed most of these actions as they occur under laboratory conditions, this obvious oversimplification is meant simply to present a logical process that is not too far-fetched and could very well have led to the development of the first true living cells.

Increasing complexity and improvement in cell construction would include longer and more complex RNA templates leading to configurations that improved replication speed or long term stability. More complex protein chains could produce new cell components like Fillia, tiny hair-like projections on the outside circumference of the cell, that aid in mobility providing greater opportunity to locate and absorb raw materials needed for cell processing. Advantages like these resulted in more cells of this kind taking over the local environment essentially pushing out the competition.

The long term vulnerability of single RNA strands (more susceptible to breaking or copying errors) eventually led to the dominance of double stranded RNA chains (DNA) while the RNA Enzyme itself has remained as part of the replicating process to this day taking on a variety of forms - Polymerase, mRNA, tRNA and Ribosomes.

This is, understandably, a complex process to comprehend and to accept, but until realistic proof is available, the reader is encouraged to consider that millions upon millions of trial and error attempts every few seconds over a billion years led eventually to the dominance of a cell capable of growing and reproducing itself in a controlled and stable manner.

It should also be obvious to everyone that there isn't just one single type of cell configuration that would have been considered alive. As discussed previously, of millions of tries to construct a living cell, most certainly failed, some after only a few seconds, some living for a few minutes but eventually 'blueprints' were created that allowed for the replication of large numbers of living cells in sufficient quantities and varying designs such that new offspring were created fast enough that the population continued to grow.

At this time on the early Earth, mutations were still commonplace and many new cells failed to survive but those best suited to their environment replaced less adaptable relatives and sustainable life on Earth was finally here.

Eventually, swarms of very simple cells populated the most life-conducive regions of the oceans, i.e.. those containing an abundance of raw materials needed for cell growth as well as a continuous source of energy such as heat, physical agitation or suitable chemical combinations to enable these early processes to continue unabated. Only those cells that could survive long enough to replicate duplicate daughter cells could pass on their strengths to the next generation, which they did, continuously improving the overall population.

By some 3.5 billion years ago, or about one billion years after the Earth first formed, simple single cells had evolved to a state of relative stability. Remember that evolution really means that cells unable to keep up with the advantageous mutations of others either died off too quickly to replicate sufficient progeny or were simply overrun by the much larger numbers of successful cells that consumed the local resources and continued to grow.

In these earliest of living cells, fuel to power the necessary processes came from free floating sugars and amino acids that were absorbed through the membrane and broken down into by-products. These organisms were known by the superficially scary name of Heterotrophic Anaerobes (Het-err-o-trof-ick Ann-a-robes). Anaerobes refers to a group of organisms that don't require oxygen and heterotrophic, 'other feeders', means they cannot make their own food so Heterotrophic Anaerobes are organisms that ate some naturally occurring food (sugars and Amino

Acids) and did not consume Oxygen. There is evidence of these single-celled creatures in the ancient rock beds of Australia dating back almost 3.5 billion years.

Over the next 500 million years or so, cells more closely resembling todays prokaryotes began to appear. These first true organisms were chemoautotrophs (Keemo-auto-trofs): they used carbon dioxide as a carbon source and oxidized inorganic materials to extract energy. Later, the most successful prokaryotes were using a process known as glycolysis, a set of chemical reactions that free the energy of organic molecules such as glucose and store it in the chemical bonds of ATP. Glycolysis and ATP continue to be used in almost all organisms, unchanged, to this day.

Sometime during this period, an organism referred to as L.U.C.A. made its final appearance. The **L**ast **U**niversal **C**ommon **A**ncestor refers to the organism from which all future life on Earth arose. This was the time that primitive Bacteria and Archaea split into their separate lines from the L.U.C.A. forever changing the history of life on Earth.

Evolutionary changes continued and some bacteria developed primitive forms of photosynthesis which, at first, did not produce oxygen. These organisms generated their own Adenosine Triphosphate (ATP) by exploiting a proton gradient across the cell's membrane, a mechanism still used in virtually all organisms today.

Between 3 billion and 2.5 billion years ago, photosynthesizing cyanobacteria evolved. They used water in their processes that stripped off and used the hydrogen atoms leaving oxygen as a waste product. The oxygen initially oxidized the dissolved iron atoms in the oceans, creating iron rust which still lines the floors of our oceans. Over time the oxygen concentration in the atmosphere slowly rose, acting as a poison for existing bacteria and eventually triggering the Great Oxygenation Event (GOE), the first major extinction of specific life forms on Earth.

The GOE refers to a period of time roughly 2.3 billion years ago or several hundred million years after cyanobacteria began producing oxygen as a waste product. As noted, originally this new gas was absorbed by the ocean's iron content but eventually as available iron stores became depleted, the gas began to escape into the atmosphere where it accumulated. Oxygen gas was poisonous to the anaerobic cells mentioned earlier and eventually huge numbers were wiped off the Earth in our first Mass Extinction event. In their place aerobic cells, able to utilize oxygen, began to accumulate eventually leading to a relatively stable balance between oxygen production and consumption.

The moon, still very close to Earth at this time, caused tides up to 1,000 feet (305 m) high and the planet was continually wracked by hurricane-force winds. The extreme mixing influences of high tides and gale-force winds are thought to have further stimulated evolutionary processes leading to the establishment of the first life on land at this time.

This first life on land would likely have been algae-like cells, clinging to rocks at the water's edge, able to survive by the constant wash of water they received. Over time, more robust cells would develop that were able to survive longer and longer periods without direct contact with water until the first true land plant cells took hold along side the ocean shores. These cells having retained the capability of photosynthesis would now evolve, relying on Sun energy and nutrients from the moist ground to support their existence.

Two billion years ago all living organisms on Earth were still single-celled Prokaryotes although they were varied and numerous. At some time over the next 200 million years, certain larger Prokaryotic cells engulfed some smaller ones and symbiotic relationships were established.

These smaller Prokaryotic cells eventually settled into a comfortable existence within the confines of the larger cell's membrane and continued to evolve into today's Organelles. They survived because they were protected from outside attack and may have reciprocated by providing vast numbers of ATP molecules (like Mitochondria do today) which directly benefitted the internal processing of the larger cell or they may have flourished by consuming the waste products (bits and pieces of extraneous cellular material) produced by the larger Prokaryote's activity. In either case, replication of these smaller bodies via their own separate mechanism ensured that when the larger cell split into two daughter cells, there would be ample quantities of these new components carried forward to the next generation.

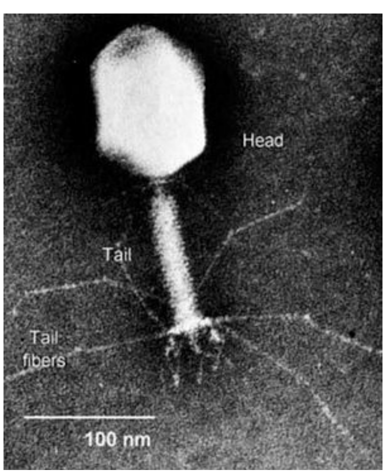
During this same period, one must also realize that not everything was a living, fully replicating cell. There were still millions of attempts that just fell short of being 'alive'. One type of these organized molecules had the correct RNA template to reproduce all its separate components but lacked the RNA enzymes needed to make and assemble all the appropriate proteins.

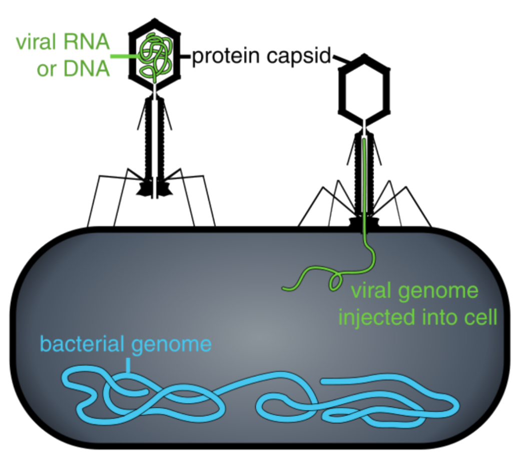
After many failed attempts, one of these molecular assemblies gained a unique advantage. Although it could not replicate itself, it's design was such that, as it contacted a living bacteria, it was able to attach itself and inject its RNA/DNA into the host cell. Since all RNA and DNA chains are essentially the same (same molecular construction just a different order of base sequence) the bacteria's very own protein construction process began replicating all the foreign proteins necessary to construct exact copies of the 'invader'. These protein components then assembled themselves exactly as the original molecule should have and waited.

Eventually, the bacteria cell would recreate so many copies of the foreign molecule that it's cell wall would burst freeing millions of copies of the rogue molecular design. These, in turn, would encounter other bacteria cells and the process would repeat. These particular types of non-living designs are called Bacteriophages and are more commonly referred to today as Viruses.

Two billion years later they are still thriving on Earth, their approach of letting other cells do their reproductive work clearly a very successful adaptation. The fact that they are not truly alive is one reason that they are so difficult to eradicate. Another is their ability to mutate and adapt at an accelerated rate rendering many effective countermeasures useless in a very short time.

Below are two representations of Bacteriophages. On the left is an actual Electron Microscope image and on the right a simplified drawing of how they attack.





But back to the developing life forms on Earth around two billion years ago.

While bacteria and viruses continued their battle for survival, another dramatic change was about to take place. A Prokaryotic cell, with sufficient available material, produced a membrane that successfully enclosed its internal replicating molecules. Although the old way still worked and would continue to work well, this new way provided several advantages. Enclosing replicating molecules within the confines of a separate area, called a nucleolus, protected those molecules more efficiently and made replication easier and faster. The very first Eukaryote cell was 'born'.

While time, along with trial and error, allowed bacteriophages to perfect their design and approach of injecting replicating molecules into living organisms, the new Eukaryotic cells were also undergoing trials with new methods of DNA transfer.

When two cells of similar construction and internal process bonded, there occurred the occasional transfer of replicating templates and enzymes. Again, after millions and millions of failures, two distinct cells managed to exchange copies of their replicating molecules and then successfully divide. The combination of similar but different replication molecules eventually led to more successful progeny and improved adaptation to constantly changing environments.

Sexual reproduction had arrived, which would lead to vast improvements in creating advantageous offspring and set the stage for the population of the remainder of planet Earth.

Before we go further, let's take a look at modern cell biology to understand the difference between simple reproduction and sexual reproduction. There are many resources available to provide the reader with as much detail as desired to achieve a complete and thorough understanding of this particular cellular activity but, in keeping with this book's theme of simplified layman's explanations, I will stick with a brief, condensed overview that will hopefully suffice to provide sufficient insight for our general purpose.

There are two distinct processes that the cells within any sexual organism use to divide and replicate. One, called Meiosis (Me-o-sis), is reserved for the sex cells (or gametes as they are called) and the other, called Mitosis (My-toe-sis), is used by every other type of cell. Each process consists of a number of progressive steps all with suitably complicated names. Instead of these, I will use plain language explanations to try and illustrate the main phases and differences between them.

It's best to start with Mitosis.

Mitosis can be divided into 5 basic phases in a single stage. In humans, at Phase 1, as each individual cell reaches its own age of maturity (this could be anywhere from a few hours to several days depending on the type of cell) the previously loose DNA strands throughout the Nucleolus begin to form into the more familiar chromosome shapes. At Phase 2, the 46 chromosomes in the Nucleolus duplicate to create 92 chromatids. At Phase 3, the Nucleolus membrane dissolves and the 92 chromatids align down the centre of the cell with similar chromatids opposite each other. At Phase 4, exactly one half of the chromatids are pulled to one side of the cell and one half to the other side. At Phase 5, the single cell then divides into two new daughter cells with each new cell containing exact copies of the parent's original DNA strands. A new nucleolus membrane forms around the loose DNA strands and each cell continues its normal function and operation until maturity is reached and replication starts again.

In Meiosis, reproduction of the sexual gamete cells, there are 10 Phases, in two stages, although it is not as complicated as that may sound.

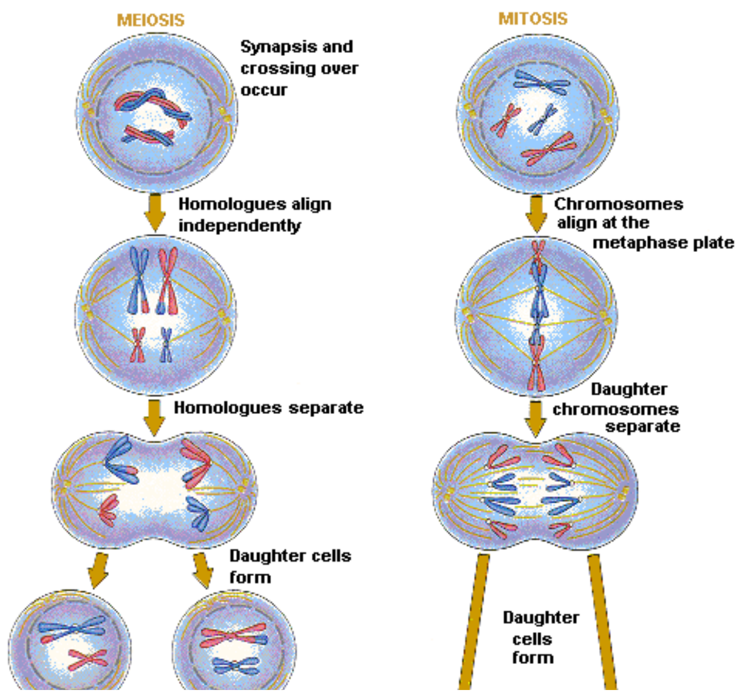
At Phase 1a, loose DNA again forms into chromosomes but at Phase 2a, similar chromosomes pass so close to each other that sections of the DNA strand forming one chromosome separate and swap places with similar sections of the other DNA strand in a completely random fashion..

For example, let's take chromosome 1, consisting of a pair of similar DNA strands, one from the male and one from the female. As the two individual DNA strands, each forming half of the chromosome pair, approach each other, pieces or sections of the two strands swap places at random so that neither strand is any longer an exact copy of the chromosome inherited from the male or female but rather is a randomized mixture of bits and pieces of DNA from each. This genetic modification is repeated for each of the 23 pairs of human chromosomes so that just prior to duplicating all 46 chromosomes, they have each randomized their structure and created new chromosomes unlike any before. Phase 2a then completes as in Mitosis with each chromosome duplicated and forming 96 new chromatids. Phase 3a continues with the chromatids aligning in the centre of the cell, Phase 4a draws half the chromatids to each side and Phase 5a completes the first stage by dividing the cell into two daughter cells each with 46 mixed chromosomes.

But this is where things proceed differently. The two daughter cells each begin Stage Two, which is similar to the 5 Phases of Stage One but with a few important differences. There is no Phase 1b, where loose DNA strands are formed into chromosomes, since the chromosomes are already still formed from Phase 5a. At Phase 2b, the chromosomes separate into individual chromatids but they do not duplicate. This leaves only 46 chromatids per cell instead of the usual 96. Remember that each of these chromatids is totally different from any other having been formed through the random genetic modification of DNA segments. In Phase 3b, the 46 chromatids align at the centre of the cell and at Phase 4b half are pulled to one side and half to the other. In the final Phase 5b, the two daughter cells themselves divide creating four distinct cells each with a completely different set of 23 chromosomes or half the total number of a typical human cell.

During sexual reproduction, one male gamete (Sperm) and one female gamete (Egg) will combine to create a single cell, containing a full set of 46 chromosomes, which will then use the newly formed DNA instruction set to build a complete human being from the randomized DNA code taken from each parent. This is why offspring sometimes resemble the male parent, sometimes the female parent, sometimes look like earlier ancestors and sometimes bear little resemblance to any family member. It is the complete randomness of the exchange of portions of DNA code that ultimately dictate which characteristics or traits the offspring might inherit.

Following is a simplified diagram of Meiosis and Mitosis that may help your understanding.
And here is another view giving the precise terminology for each phase and a diagrammatic representation of the activity at each point.



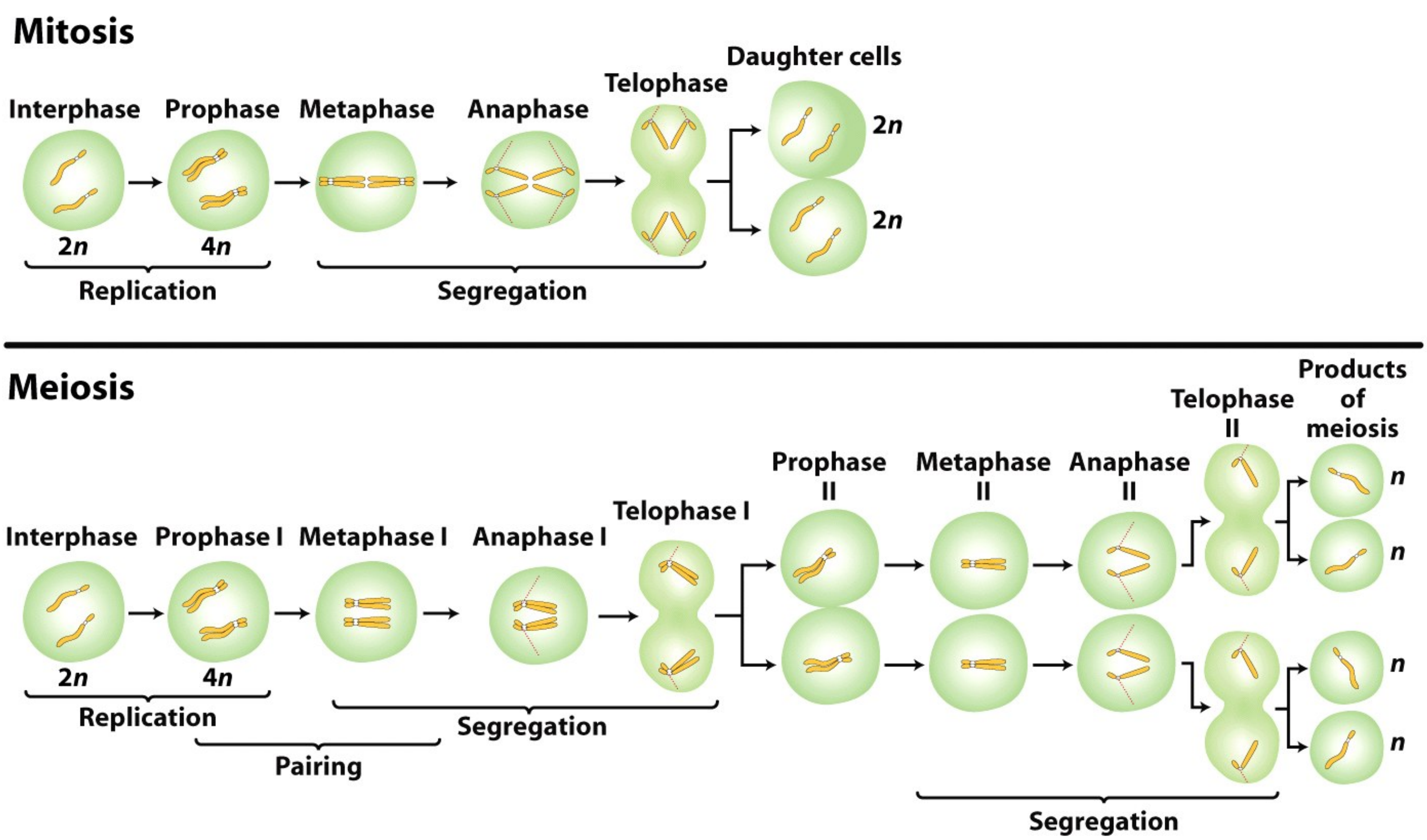


Figure 2-8
Introduction to Genetic Analysis, Tenth Edition

Step 8: Multi-cellular Life

Although continuing mistakes during genetic material transfer, errors in transcription, mutations from cosmic bombardment and losses to other predatory organisms continued to plague early cell development, the occasional cells, able to combine the best traits of their parents, thrived passing on exceptional abilities and configurations through their own line of succession.

It was these superiorly endowed cells that, just over one billion years ago, began to join together providing an even better survival chance than any single cell could expect. In the beginning, multi-celled organisms were all essentially identical forming large masses of similarly constructed cells. Cells hidden deep in the interior of the large mass were protected from outside attack but suffered from a lack of resources available to those closer to the outside edges. As time progressed, those multi-celled organisms that were successfully able to pass not only genetic material from cell to cell but also to distribute scarce resources among the individual cell members began to dominate the seascape.

Within a few hundred million years, multi-celled organisms had begun to develop specializations among the various cells, that formed their structure, with some cells becoming better suited to collecting resources, some better at passing resources to others and some best at transmitting genetic strings that allowed their descendants to replicate all the proteins necessary to duplicate the entire organism.

It is, of course, impossible to pinpoint when this transition actually occurred but, sometime between about 800 million and one billion years ago, differentiation within multi-cellular organisms began. Meanwhile, single-celled life continued to flourish with Protozoa (Pro-toe-zo-a) and Amoeba (A-me-bah) making their first appearance. These lifeforms were so successful that they both survive, virtually unchanged, to this very day.

During this same time, the oxygenated atmosphere under constant bombardment of ultraviolet radiation from the Sun, developed a protective layer of Ozone. This was accomplished as high energy ultraviolet rays struck the normal oxygen molecules, $O2$, splitting them into single, simple oxygen atoms, O. The single atoms then recombined with some of the remaining $O2$ molecules to form ozone, $O3$. The consequences of this layer developing were dramatic.

Ozone is excellent at absorbing ultraviolet radiation so as the quantity of ozone in the upper atmosphere increased, and the amount of ultraviolet radiation striking the Earth was reduced, the rate of survival of land-based cellular life was greatly increased. It would take another 200 million years but under the protective dome of the new ozone layer, land-based cellular life, formerly restricted to the shores of the oceans, would now be free to spread far inland eventually covering the available solid surface in green. The ozone layer was probably fully in place roughly 600 million years ago with the first true land plants appearing about 400 million years ago.

About 550 million years ago, the seas were populated with colonies of single-celled Prokaryotes, Protozoa and Amoeba, single-celled Eukaryotes, multi-celled Eukaryotic organisms with specialized cell structures and the shores were awash with photosynthesizing cells, ready to take over the land as the ozone layer reduced harmful ultraviolet radiation.

In fact, the next few million decades seem to be the time of the largest and fastest introduction of new species in our planet's history - a time referred to as the Cambrian Explosion. Virtually all ancestors of modern creatures are considered to have been conceived during this period. One specific problem associated with this period is, itself, the sudden appearance of so many diverse animals with little to no history of their evolutionary progress existing in the fossil record. Darwin, himself, was forever perplexed by this phenomena and considered it a serious thorn in the side of his evolutionary theory.

It is possible that the immediate ancestors of this sudden outpouring of divergent species were too small, too flimsy or too translucent to leave behind a definable fossil record of their existence and that it was only as a result of the eventual development of shell-like exoskeletons that the number of fossil finds suddenly increased dramatically.

While very limited fossil records exist for the immediate ancestors of the extraordinary number of new species found after this explosion period, there are traces and indications in the geologic strata that point to a large number of earlier life forms. One such indicator are stromatolites (stro-mat-o-lights) which represent colonization by micro organisms beginning nearly 3.5 billion years ago, peaking in quantity and variety about 1.5 billion years ago, dropping off suddenly just prior to the Cambrian Explosion and disappearing altogether by modern times.

Stromatolites were rocky columns found in shallow waters that were inadvertently assembled as early single-celled organisms formed together in large masses excreting waste materials as their inner processes worked. These excretions captured individual grains of sand cementing them together and, over extended periods of time, grew layer upon layer, rising out of the water, like stone monuments, to the tiny cells that laboured unseen on their uppermost edges.

The most widely supported explanation for their decline is that the stromatolite builders fell victim to new predatory creatures - the forerunners to the multitude of new life forms that would appear during the Cambrian Explosion. This theory implies that sufficiently complex organisms were already common on earth almost 1 billion years ago.

Below are real images of stromatolite formations showing their abundance, their general structure and their interior construction.

Another strong indicator of pre-Cambrian advanced life forms are burrows.

Burrows are the traces of organisms moving on and directly underneath the microbial mats that covered the sea floor which are preserved from the period about 565 million years ago. They were probably made by organisms resembling earthworms in shape, size, and how they moved. The burrow-makers have never been found preserved, but, because they would need a head and a tail, the burrowers probably had bilateral symmetry – a significant advancement in organism design. They most likely fed above the sediment surface, but were forced to burrow to avoid predators.

These burrows provide the firmest evidence of the existence of complex life just prior to the Cambrian Explosion. While there is still no definitive, accepted explanation for the apparent sudden appearance of new life forms it is clear that from this point on evolutionary change proceeded at a blistering pace.

It is very important to pause briefly and consider the evolution of life throughout our universe. Rational scientists have yet to identify verifiable proof of the existence of even the most rudimentary forms of life, that we are familiar with on Earth, anywhere within our solar system or even beyond, yet the mathematical probability given the vastness in size and content and length of time in existence of our universe tends to support the reasonable hypothesis that life could have and might have arisen elsewhere. Much of the world waits with great anticipation for the first truly verifiable proof of extraterrestrial life forms to be discovered and announced.

In the meantime, we do have absolute proof that life has originated and evolved in at least one specific place in the universe - our own planet. While scientists continue to investigate the possible processes that led to the origin of the very first cell, they already have done extensive work and uncovered substantial fossil evidence of the evolution of life on Earth, once it became extensively established.

The final 2 steps in creating our universe will follow the growth of life on the Earth in our own universe as this is the only evidence that we have first hand knowledge of but it should be remembered that we have no proof that this is also the way life would progress elsewhere in our own universe or even in another universe, entirely.

Step 9: The Evolution of Plants and Animals

On our planet, at the time that Charles Darwin set sail aboard his ship, the Beagle, on his soon-to-be world changing voyage, 24 December 1831, a mere 185 years ago, the most educated and leading Naturalists of the time, all believed that the entire diversity and variety of living organisms found everywhere on the Earth were placed there at the same moment in time, some 6,000 years earlier.

There was, of course, ongoing investigation into the obvious similarities between many living species and, as early as 1801, Augustin Augier, a french Botanist, published the very first simplified 'Tree of Life' showing the relationship between members of the Plant Kingdom. In 1809, the first tree for animals was published by Jean-Baptiste Lamarck and, in 1840, Edwin Hitchcock published two separate trees, one for plants and one for animals but there was no proposed connection between them.

However, none of these initial attempts to represent the relationship between all species was a true Evolutionary Tree of Life as each of their authors believed strictly in the divine and instantaneous creation of organisms by a single deity. This is where Darwin separated from the others.

Darwin proposed that new species could and did generate on their own, over long periods of time, in response to changes to their local environments including climactic changes, changes in levels of available resources and the demands of predators.

While this writing will not try to detail the many facets of Darwin's observations and conclusions, it is based on the principals of modern evolutionary theory and will attempt to portray, in the simplest manner, the development of life from the earliest multi-celled organisms to the most complex life forms on the planet.

I do believe that some of the loose terminology used when explaining evolution can be too easily misconstrued and misinterpreted by non-scientific readers and listeners. Aside from simply accepting the Theory of Evolution as a bone fide concept based on years of scientific observation and analysis, fossil discovery, identification and classification and a basic acceptance of the age of our planet, I see an important need for people to understand the underlying principal of evolution in order to really appreciate our own remarkable existence.

Here then are a couple of common statements used in people-friendly explanations of evolutionary advancement and a clearer interpretation of what they actually mean.

Phrase One: ...Bacteria develop resistance to antibiotics...

Bacteria never have had the ability to assess an environmental threat and make modifications to their internal replicating mechanisms to ensure their offspring survive. Here is what this phrase really means.

You may have seen TV commercials for disinfectant products (such as Lysol or Mr Clean) that expound their virtues and announce that they kill 99.9% all germs. This is actually true. What may be missed by the listener is the fact that there are many billions or trillions of germs on those soiled surfaces. Killing off all but 0.1% could still leave 100 million to 100 billion germs!

Because bacteria are extremely simple, they can reproduce at a very fast pace, growing and dividing every 15-20 minutes or so. At this rate, within 7 hours, just 1 single bacteria could become a colony of 1 million. Within 10 hours, that same colony would be over 1 trillion bacteria in size. This is much faster than the more complex Eukaryotic cells which can take hours or even days to replicate once. In addition, similar bacteria, while all very close to the same design, are never exact copies of each other. It is these individual, unique differences that really lead to their resistance.

Any bacteria susceptible to the specific disinfectant in use is destroyed and this may very well be 99% or even higher. But no matter what chemicals we may employ there will always be germs that are less affected, due to their genetic design. It is these bacteria that survive passing on those characteristics to their descendants. As bacteria also have that tremendous capability of reproducing quickly, the most susceptible members of the colony perish while those most resistant to the new attack, reproduce and flourish creating new colonies mostly unaffected by the previously lethal application.

So stated as simply as possible, Those that can, live, Those that can't, die. This is evolution at its most basic core.

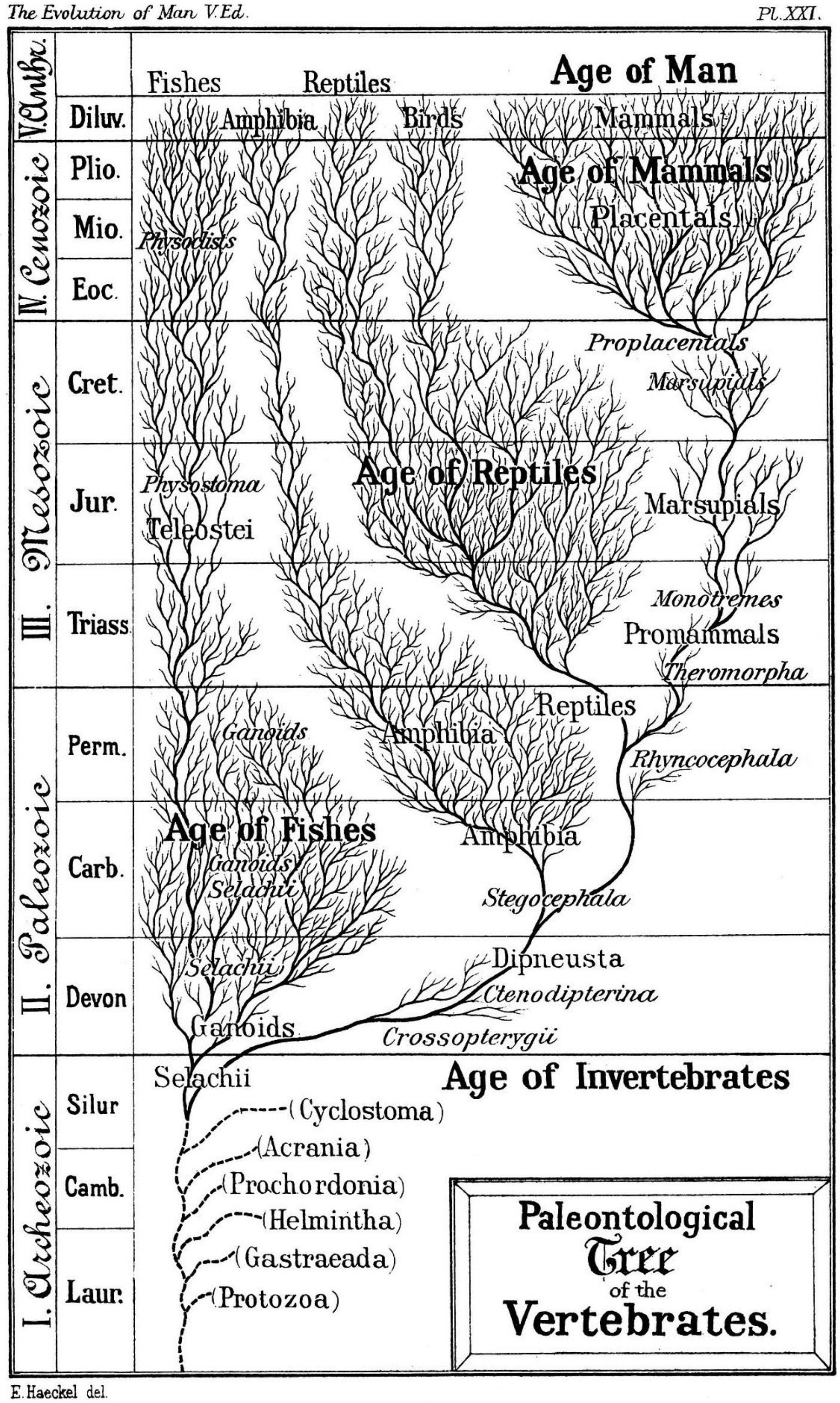
Phrase two: ...these organisms have evolved to cope with their new environment... OR ...in order to survive, these organisms have evolved [a specific mechanism] ...

These types of comments are not patently untrue but I do believe they leave an impression that an organism has control over its destiny or is able to direct its own evolution. This is most certainly not true.

Again what is really meant here is that as environments change over time, those organisms best equipped to survive the changes will live on, passing their strengths onto their progeny while those less suited, or those without any special coping mechanism, will perish quickly unable to reproduce. As time passes, the more capable organism repopulates the environment and becomes the dominant species, sometimes changing so drastically over lengthy intervals, that it bears little resemblance to its originating ancestor. This is as true for Bacteria as it is for Fungi, Plants or Animals and is the crux of Darwin's thesis 'On The Origin of Species', first published in 1859.

Born just a few years after Darwin first set sail, Ernst Haeckel (1834-1919) was one of the first to support Darwin's evolutionary thesis and just 20 years after Darwin published "On the Origin of Species", he presented an early view of the evolutionary Tree of Life that, in a relatively uncluttered display, showed the advancement of vertebrates (animals with backbone structures) over time by including the name of geologic eras and periods along side his branching diagram.

Following is a reproduction of his initial attempt which, while greatly simplified, still bears some value today.



Still, almost 200 years later, opposite sides continue to debate and argue whether life arose all at once a few thousand years ago or in slow stages over billions of years. My best guess is that 200 years from now the arguments will still be ongoing.

I Think Therefore I am

I don't believe, however, there would be much argument from anyone that atoms, molecules and chemical compounds do not think nor do they plan their futures or self-adjust their arrangement in the face of a changing environment. Their attraction to or repulsion from each other and the bonds that determine their composition and function are based solely on the Laws of Physics and nuclear forces far more complex than most of us care to contemplate.

However we are about to embark upon a journey that will take us from the simplest single cell organisms to, perhaps arguably, the most intelligent species on the planet. At some point along that path, thinking becomes a real property of life forms, one that will affect their daily lives and ultimate futures as much as resource availability and external dangers would.

So far we have primarily discussed single cell organisms or, at best, a few unique multi-cellular organisms comprised of collections of similar cells that bind together without yet demonstrating true purpose. Close examination of these creatures reveals a relatively simple structure the most advanced of which contain a nucleolus that surrounds and contains replicating molecules capable of producing protein building blocks that, in turn, provide the raw materials needed for constructing all the various cell components.

Even at this stage it is difficult to assign considered purpose to the activities of cell energy production, replication, protein building and reproduction which are all still driven strictly by interactions at the molecular level and which are continually repeated in cells only because their ancestral progenitors (parents, grandparents etc.) survived to pass on those self-perpetuating actions.

At what point, then, does thinking actually begin? This is yet another of the age old questions that defies a specific answer and which is hotly debated by qualified experts on an ongoing basis.

Say, as an example, that an environmental mutation produced a gene, which coded for an improved protein, that more efficiently captured photons of light, permitting a measurable increase in the total energy produced internally by the cell. That additional energy might be used to increase the rate of motion of the cell's Fillia (tiny hair-like projections along its edges) or its flagella (a tail-like projection) which in turn could allow the cell to move further and faster than its competitors - an improved function that would be passed to its offspring during reproduction.

Future cell generations that moved away from light sources would soon find themselves unable to move as their own energy decreased and Fillia or flagella failed to oscillate, trapping the cell in a resource barren wasteland eventually to die without reproducing.

On the other hand, generations that moved toward light, would find themselves rife with abundant energy, capable of locating and absorbing needed resources and reproducing viable offspring that could carry on exploring further afield into yet to be exploited resource-rich environments.

Now I am not at all trying to suggest that this is 'thinking' in any way. In fact it is really just the opposite. What I am trying to show the reader is how actions, that might appear to be planned and controlled by an organism, can be nothing more than programmed responses to external stimuli. This is precisely the reason it is, for all practical purposes, impossible to pinpoint exactly when living beings began thinking, in much the same way as it is impossible to select which cell was the first to come alive. However at some point during the lengthy evolutionary process, a new and improved physical design was accomplished within an organism such that autonomic reaction to stimuli was not the sole driving force to produce desirable actions.

Just as we saw earlier when increasingly lengthy molecular chains eventually produced patterns that, by their very design, could accomplish their own rudimentary replication, constant mutation and genetic rearrangement eventually created cell structures that were able to respond to stimuli with specific, beneficial actions. [It has been estimated that, on average, the DNA molecule itself undergoes mutations at a rate of 60 base pairs every cell generation]

Taking our earlier example of light stimuli, these new structures may have provided the ability to specifically use increased internal energy supplies in selected areas, to speed up the motion of certain Fillia, perhaps along one side only, or to increase the bend in their flagella to aim their forward motion directly at the light source thus improving their chances of reaching untapped feeding grounds first and improving their odds of survival. Again, these improvements would be passed along to future generations allowing them to multiply more rapidly, eventually squeezing out less capable competitors.

This, then, might be considered the very earliest thinking process with stimuli, sensor and feedback mechanisms working in tandem to increase survival rates. Rudimentary as this might have been, eventual enhancements would include increasing specialization of sensor cells (eyes, nose and ears), more efficient feedback paths between sensors and actual moving parts (nerve networks), better control over self-movement (muscles) and a central switchboard that allowed these parts to cooperate effectively (brain).

These basic improvements were, most likely, all in place sometime just before the Cambrian Explosion, assisting new life forms in their need to discover new and richer resources while avoiding predation from others. Still this 'thinking' was far from future intelligence where eventually careful thought, option processing and problem solving skills would further lead to successful living.

Modern zoologists and animal behaviourists are constantly surprised as they test the boundaries of intelligence in a variety of increasingly primitive life forms. As a measure of primitiveness we generally place all present life forms on a scale based on the relative time of introduction of their 'kind' so we automatically put all Eukaryotic life ahead of Prokaryotes and Archaea since they were introduced last, have more complex structure and eventually led to multi-celled organisms including humans. Green plants are considered less primitive than fungi and the entire Kingdom Animalia is considered less primitive than all plants.

In truth, it actually becomes very complicated trying to pigeon-hole each and every known life form into a specific 'row and column' in the Table of Intelligence with further difficulties introduced when comparing both marine and terrestrial species. However, in general, tetrapods (four-legged creatures) rank above multi-legged creatures putting insects near the bottom superseded by salamanders and newts followed by amphibians, reptiles, birds, mammals, primates and, at the top of the scale, humans.

The Changing Planet

As the timespan of changes in evolutionary progress begins to drop from billions of years to hundreds of millions of years and then to mere millions of years, it is worth looking at how changes to the planet itself impacted the development of all life forms.

Just as was done with the division of life forms into 3 Domains and 5 Kingdoms, (plus other sub-divisions we haven't yet looked at - Phylum, Class, Order, Family, Tribe, Genus and Species), the immense length of time that has passed since the Earth was first formed has been sub-divided into Eons, Eras and Periods. For our immediate purposes, we will restrict our first time division review to the Eon level. There have been four since the Earth was first formed - Hadean (Hay-dee-an), Archean (R-chee-an), Proterozoic (Pro-tear-o-zo-ick) and Phanerozoic (Fan-air-o-zo-ick).

The Hadean covers the period from Earth's initial formation, about 4.5 billion years ago until roughly 3.8 billion years ago. It comes from Hades, the underworld of Greek mythology and refers to the 'hellish' conditions on Earth at this time. During this eon, the planet cooled and solidified, the original hydrogen/helium atmosphere dissipated, the moon was formed, the atmosphere became concentrated with ammonia and carbon dioxide, and water first appeared. Reasonable speculation would suggest that towards the end of this eon, Lipids, Saccharides, Bases, Amino Acids and Nucleic Acids were all forming in the oceans but that living cells were not yet likely present.

The Archean eon started at the end of the Hadean and continued until 2.5 billion years ago. Archean comes from the word ancient and first referred to the oldest known rocks found on Earth at that time. This time saw a change in our atmosphere to a large percentage of nitrogen and a smaller methane component. Replicating molecules were forming and reforming until sustainable patterns emerged and the first stable but very simple reproducing proto-cells appeared. Trial and error led to advancements in cellular design until, just as the Archean eon was ending, photosynthesizing cyanobacteria were multiplying, beginning their influence by releasing oxygen into the oceans and ultimately into the atmosphere eventually replacing the methane, killing off almost all anaerobic bacteria and giving a foothold to the new aerobic cells that flourished.

The Proterozoic eon came next - between 2.5 billion and 550 million years ago. The term Proterozoic comes from the Greek *proteros* meaning 'first' and *zoon* meaning 'life' as, initially, the earliest signs of living organisms were found in rocks from this time frame. It was only later that we discovered signs of the more rudimentary cells of the Archean eon. The Proterozoic eon, however, was the time that single celled Prokaryotes, single celled Eukaryotes and multi celled Eukaryotes appeared in large numbers and great diversity.

During the Proterozoic eon, four major mountain-building episodes occurred, each of which was followed by an interval of continental erosion. Mountain-building was caused by converging geologic plates, just as occurs in present-day plate tectonics. In North America, the Proterozoic episodes of mountain-building greatly expanded the size of the continent. As the continents began to erode, sediments were washed into the oceans, producing shallow water marine environments, rich in resources, where life could flourish.

Widespread continental glaciations evidently occurred at least twice during the Proterozoic eon, once near its beginning and again near its end. Several of these glaciations extended almost to the equator, much farther south than any other cooling events. This unusual situation has led a few geologists to propose that the Earth was almost entirely covered by glaciers for perhaps several million years during the Proterozoic eon. During this “Snowball Earth” phase, life would have been relegated to underwater or underground hydrothermal vents and other such refuges until the build-up of carbon dioxide released from volcanoes warmed the Earth from its deep-freeze. The final major Ice Age marked the transition to the current Phanerozoic eon.

The Phanerozoic eon began 550 million years ago with what we earlier referred to as the Cambrian Explosion, a seemingly sudden eruption of many new life forms, varieties and types. By this time the atmosphere was much the same as it is today, primarily Nitrogen (80%), with a modest percentage of Oxygen (20%) and trace amounts of other gases. Continental plates would continue shifting on the semi-fluid mantle until about 250 million years ago when they congealed to form a single large landmass that has been named Pangea.

Some of the basic 'rules' controlling the destiny of life on Earth throughout this period could be summarized as follows:

1. As the moon moved further away from the Earth, conservation of energy laws caused the Earth to slow its rotation allowing sunlight and heat to accumulate for longer periods on the surface impacting photosynthesis and surface temperatures.

2. Following the impact that formed the moon, the Earth continued (and still continues) to wobble slightly in space causing lengthy cycles of roughly 11,000 years when the planet would heat up or cool down by several degrees thus affecting ice coverage, water temperature and atmospheric conditions all of which would impact life development.

3. When conditions favoured growth and diversification of life, the amount of available resources would become a significant factor in the survival or demise of specific lifeforms with those best able to obtain and process those resources, gaining an upper hand in reproducing surviving offspring.

4. When conditions were against strong growth, those organisms best able to last out the crippling conditions would survive while vast numbers of previously flourishing life forms would perish, never to be seen again. We call these events Mass Extinctions.

5. Factors such as exposure to strong radiation, mistakes in replicating molecules, random swaps of genetic material and internal disruptions to DNA templates would all lead to unexpected, new designs and modifications to previously successful life forms. Some of these would die immediately due to unrecoverable loss of function while others would lead to improved capabilities able to survive worsening conditions.

6. As larger, more powerful organisms appeared, the smaller and weaker ones would become available resources and be consumed in the constant search for food. Those best able to evade capture either through speed, stealth or camouflage would be the ones to survive and pass on those improvements to their progeny.

7. Significant geologic disruptions were still occurring, with massive volcanic explosions spewing huge quantities of ash and rock into the atmosphere, blocking out sunlight and poisoning large areas of land, sea and air, all of which impacted the fragile ecosystem affecting survival rates and extinctions. Powerful earthquakes spilled lava out onto the land and under the sea changing pristine life-supporting landscapes

into desolate wastelands where nothing could live.

All these factors affected evolutionary progress leading to today's wide variety of life that covers virtually every inch of our planet in some shape or form. So lets have a closer look at the advances in life forms from the earliest multicellular organisms to the rise of the human being.

As organisms began to evolve, there were definite, identifiable improvements that led to superior capabilities putting the newest life forms near or at the top of the so-called food chain. At the same time, however, there were literally thousands of side chains where improvements led to the establishment of unique colonies, families or groups that, while not improving their stature or position on the food chain, did lead to their fulfilling a special niche where survival rates were sufficient to continue their growth and adaptation.

In line with our simplified approach i will not be straying far from the mainstream improvements and will stick with a simplified overview of life's progress.

Up to this point we have looked at the division of Earth's history in terms of Eons simply due to the enormous periods of time that elapsed between major and notable events. As the pace of development accelerates and the time frames being looked at reduce to hundreds of millions of years it becomes practical to subdivide the current eon into smaller stages we call Eras.

We have, at his point, reached the The Phanerozoic Eon, literally the "period of well-displayed" life", covering Earth history from around 550 million years ago to the present. It is subdivided into three Eras: the Palaeozoic (Pale-ee-o-zo-ick), the Mesozoic (Mez-o-zo-ick) and Cenozoic (Sen-o-zo-ick) Eras which are separated by major Mass Extinctions of the then existing life forms.

During these Eras, organism diversification and variety were the order of the day. In a relatively short period of time, life became increasingly complex, segregated, and better able to survive minor changes to the overall environment in which it found itself.

Prior to the Cambrian Explosion, the most advanced multicellular life forms were those like the sponges and flatworms that populated the ocean floors surviving by the ingestion of the multitude of single-celled Prokaryotes and Eukaryotes that existed in untold quantities throughout the watery environment.

During the Palaeozoic Era, a wide diversity and variety of life forms developed, each improving on the previous generation, until a form was reached that proved flexible and adaptable, to the point where it dominated its particular niche, surviving even catastrophic events that wiped out less well-suited creatures and plants.

There are a number of major developments during this Era that provide some insight into the evolutionary progression followed by living organisms as they moved from single celled life forms to the varied and complex multicellular organisms that populate the Earth today.

Within a few million years, around 535 million years ago, we find evidence of animals with rudimentary spinal structures that probably protected nerve filaments to control tails and fins that in turn improved mobility and increased foraging ranges.

At 530 million years ago, tiny footprints on land have been found preserved indicating that water-bound beings were already experimenting with survival outside of the ocean's environment, well before plants took a firm hold on the land. It was most likely the lack of consumable resources that forced them back into the sea where food was abundant.

By 485 million years ago, the first true vertebrates - animals with a distinct skeletal backbone, were swimming the oceans but they still lacked teeth and consumed food by filtering out tiny morsels when swimming, mouths open, through their environment.

As for plants, it would take another 50 million years before those algae-like cells, clinging to the shoreline, were evolved sufficiently to begin to spread inland and populate the landscape with photosynthesizing plants, that would eventually provide food to those water-bound beings living near the shore. During the next 80-100 million years, a number of dramatic changes occur.

Anthropoids, multi-legged creatures, finally achieved the appropriate mechanisms that allowed descendants to move from extracting oxygen from the water to extracting oxygen directly from the atmosphere permitting the first permanent exploration of solid ground by mobile life forms. The lack of predators allowed for a rapid expansion of these new explorers and they soon dominated the landscape.

Around 420 million years ago, the ancestors of modern spiders and scorpions began leaving the water and remained to live on land, feeding on the fungi, lichens and mosses that were spreading everywhere. Within another 10 million years, evolution had equipped fish with teeth and after an additional 15 million years, land based plant life had become much more complex, although it still more closely resembled sea algae in form and structure without true leaves, stems or seeds. At the same time mites, and early multi-legged creatures resembling modern day 'Daddy-Long-Legs' made their first appearance and Tetrapods, four-legged creatures, left their first footprints behind on land.

By 360 million years ago, the planet began to become recognizable: insects roamed the land but had yet to take to the skies, sharks headed the food chain in the world's oceans, vegetation had spread everywhere with ferns appearing for the first time and those four-legged Tetrapods had now gained adaptations that would allow them to occupy a variety of land habitats.

Over the next 60 million years, plants would evolve the ability to use seeds to reproduce, a huge advantage whenever environments changed dramatically. Amphibians would initially dominate the seashores and inland waterways but, by 300 million years ago, reptiles would begin to take over as the eggs they laid no longer required immersion in water, like those of amphibians, reducing predatory attacks and ensuring stronger offspring born ready to be independent of parental care.

By 280 million years ago, beetles had appeared and seed plants including the earliest conifers were spreading everywhere. Over the next 30 million years, the Earth rose to become a truly bountiful world with enormous numbers and varieties of water-based and land-based life including fungi, plants and animals in addition to the already abundant Prokaryote, Archaea and Eukaryote cells that lived along side them.

And then 250 Million years ago it happened.

Where Did They All Go?

Modern techniques for dating geologic strata indicate that 251 million years ago, the Earth underwent its second, and greatest, Mass Extinction event, the first being during the Great Oxygenation Event.

Within the relatively short period of some 100,000 years, up to 96% of all marine species and 70% of terrestrial vertebrates disappeared completely. It is also the only known mass extinction of insects ever to have occurred with 83% of all genera (the classification group just above species) wiped out. The impact to life was so dramatic that some estimates indicate that it took another 30 million years for the Earth to fully recover.

Of course there are multiple theories for what happened to initiate such a catastrophic decline and no absolute agreement on any single cause. There is some evidence the extinctions occurred over two or more phases, the earlier phases taking place more gradually with the latter phases happening much more rapidly over much shorter timeframes.

Proposed causes for the more gradual environmental change phases include, large variances in actual sea level, increases in overall acidity of the ocean or a drop in its oxygen content, or even modifications to ocean current circulation patterns due to climate change. Independent evidence suggests there was an overall average increase in atmospheric temperature of 8 degrees C, an increase in ocean temperature to about 40 C or 105 F, an increase in atmospheric carbon dioxide levels to 2000 parts per million (ppm) while normal levels at that time hovered around 300 ppm and a measurable increase in the amount of ultra-violet radiation reaching the ground impacting the existing plant life and, ultimately, the animal life.

Explanations for the more rapid decline in marine and land creatures during the later phase include the possibility of a substantial impact event (meteor, asteroid etc.), massive volcanic explosions releasing gases and ash that blocked out sunlight, or even a runaway greenhouse effect due to large releases of methane gas from the shifting ocean floor.

Whatever the cause, this largest of Earth's mass extinctions, cleaned the slate so-to-speak setting evolutionary progress back millions of years. At the same time, however, as was mentioned previously, those particular creatures, plants and organisms able to survive the devastation were the best adapted and most able to pass along superior characteristics to their offspring thereby flooding the Earth with new and improved lineages.

Dinosaurs, Flying Insects and Mammals

We are now entering the Mesozoic (or "middle") Era, that covers the time fame from 250 million years ago to 66 million years ago and which itself is subdivided into three separate periods, the Triassic (Try-ass-ick), the Jurassic (Ger-ass-ick) and the Cretaceous (Cre-tay-shush). During the roughly 200 million years covered during this time, again there were some significant events that bear noting.

By 220 million years ago, reptiles in both marine and terrestrial environments began growing to enormous sizes and the wide range and types of creatures we call dinosaurs first appeared and flourished. The earliest turtles began their aquatic lifestyles and those annoying flies first took to the air. Huge forests of Gymnosperms (from the Greek 'gymnos' for naked and 'spermo' for seed) such as pines, cypresses and their relatives, covered the land. These trees held their seeds loosely in cone-like structures rather than individually protected within hard shells like future flowering plants would.

By 200 million years ago we have the first accepted evidence of viruses that could infect Eukaryotic cells appearing, viruses that would eventually plague mankind. Butterflies, moths, hermit crabs and starfish would all make their first appearance over the next 5-10 million years.

By 160 million years ago, Rays swam in the oceans, blood-sucking insects roamed the forests, marsupials (kangaroos) hopped across the landscape and the earliest known ancestors of modern birds flew across the skies.

By 130 million years ago, angiosperms (flowering plants) had taken hold, their newly evolved structures providing the ability to attract and feed insects which in turn spread their pollen. This led to a rapid expansion of both flowering plant and insect species across the entire planet.

By 80 million years ago, bees were well established, snakes and ticks both flourished, ants had begun to colonize the Earth and the very first placental mammals, animals that carried their offspring internally to full term prior to live birth, were just becoming established.

Within 15 million years, around 65 million years ago, just as it seemed that all was proceeding in an orderly fashion, it happened again.

The End For Some, Just the Beginning For Others

At the end of the Cretaceous Period, 65 million years ago, although not every scientist agrees, a majority now do believe that the Earth was impacted by a substantial, non-terrestrial body at least 180 km in diameter, possibly an asteroid or comet, that struck the planet in a region near the present day Yucatan Peninsula.

This hypothesis has been validated by the 1990 discovery of Chicxulub crater in the Gulf of Mexico, roughly 180 km across, along with scientific analysis of the geologic layer within the Earth's crust that corresponds to the 65 million years ago time frame. At multiple locations across the world, this same layer has been shown to contain 1000 times more Iridium than any other geologic strata. Iridium is an element that is normally extremely rare on Earth but has been found in abundance in numerous meteorites.

The effect of such an impact would have been the vaporization and mixing of ocean water, impacting object material and portions of the Earth's crust and the ejection of this mixture high into the atmosphere where, within a matter of weeks, it would cover most of the planet's skies, blocking out sunlight, halting photosynthesis and rapidly cooling the environment. Eventually this dust would settle in a thick layer across the land portions of the planet, leaving its telltale signature. Flora and fauna adapted to the warm and temperate climatic belts would largely fail to survive such an immediate and drastic change in their living conditions.

Perhaps the most well-known victims of this particular catastrophic event were all the non-avian dinosaurs, however, a host of other species disappeared at the same time as well, among them assorted mammals, lizards, birds, insects and certain plants. In the oceans, large numbers of fish, sharks, molluscs and many species of plankton were devastated. It has been estimated that 75% or more of all species existing at the time became extinct but despite the extensive elimination of large numbers of life forms, as with earlier extinctions, there was still an upside.

The sudden and massive reduction in predator populations and drop in overall resource competition allowed for the gradual introduction of entirely new lines of plants and animals including heretofore unknown species such as horses, whales, and bats, along with entirely new species of birds, fish, lizards and, perhaps the most important of all, a new kind of mammal called a primate. This tiny shrew-like animal would be the first in an evolutionary line leading, eventually, to the establishment of the human race.

The Changing Landscape

It is worthwhile at this point to pause in our examination of the evolution of life on Earth to take a closer look at another major factor impacting the diversity of all animal and plant life and both aiding and hindering the spread of new species across the planet throughout the entire history of life on Earth.

Ever since it first solidified, some 4 billion years ago, our planet's crust has been shifting around, breaking up into smaller irregular shapes then reconsolidating into single, massive supercontinents only to be broken up again. Evidence of this process was uncovered and initially introduced by Alfred Wegener, in 1912, when he first proposed his theories (in German) regarding Continental Drift. However it would not be until the early1950's, after numerous supporting discoveries had been made that this theory would become widely accepted.

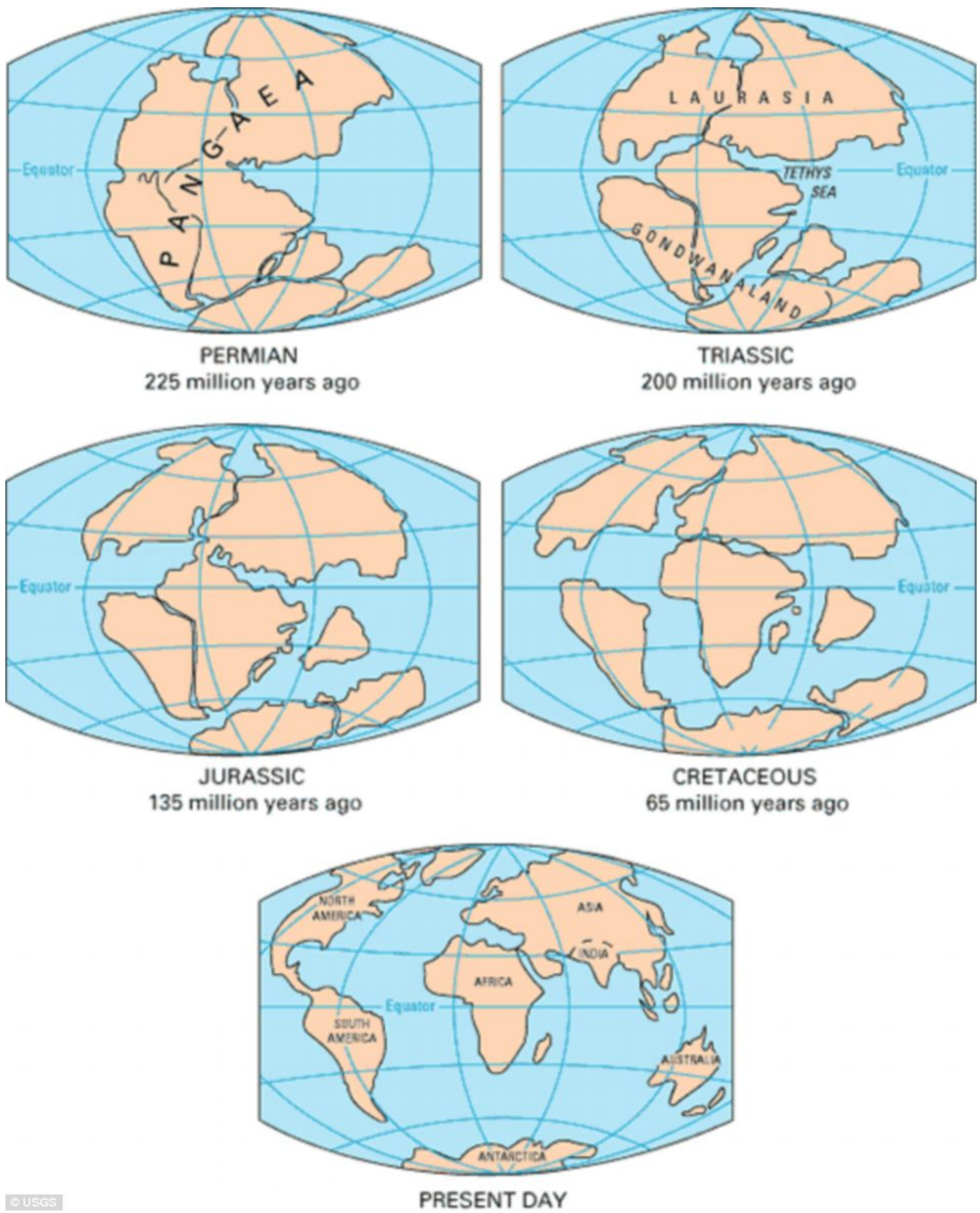
The root cause of this process, that is still ongoing today, and which will continue far into the foreseeable future, most simply put, is that large sections of the Earth's crust called plates 'float' on top of the more flexible and fluid mantle. Fissures in the mantle permit molten material from deep within the Earth to reach the surface where it spreads out pushing the more solid plates around like giant puzzle pieces.

The fourth-last supercontinent, called Columbia or Nuna, appears to have assembled in the period from 2 to 1.8 billion years ago. Columbia then broke up and the next supercontinent, Rodinia, formed from the assembly of its fragments. Rodinia lasted from about 1.1 billion years ago until about 750 million years ago, but its exact configuration and history are not as well understood as those of the later two supercontinents, Pannotia and Pangea.

When Rodinia split apart it did so into 5 separate pieces. Most of these pieces coalesced again to form the relatively short-lived supercontinent of Pannotia. This supercontinent included large amounts of land near the poles with only a relatively small strip connecting those polar masses. Pannotia lasted until 540 Million years ago, near the beginning of the Phanerozoic Eon, and then broke up, giving rise to the lesser continents of Laurentia, Baltica, and the southern supercontinent of Gondwana.

Sometime between 480 and 440 million years ago, Laurentia and Baltica reformed into a single landmass and by 250 million years ago all the separated land masses had consolidated once again into the most recent and perhaps best known supercontinent we now call Pangea. Over the course of the next 250 million years, Pangea would finally separate into the familiar continental shapes we know today.

Below are a number of representations that show the breakup of this latest supercontinent, Pangea, over the course of 250 million years, including the name of the appropriate geologic period, and ending with the modern day arrangement of the continents.



Evidence for this rearrangement of the Pangea land mass is abundant from the similarity of geologic strata in widely disparate present day regions to the striking resemblance of both flora and fauna along the 'edges' of formerly connected pieces.

In addition, numerous regions across the Earth now hold singularly unique wildlife, such as kangaroos and koalas in Australia, tigers in India, lions in Africa and a host of other region-specific plants and animals, those species having evolved after Pangea broke apart isolating their development and stranding them forever in their original homelands.

As well, the lengthy and arduous migration paths of many modern birds have been attributed to the gradual, physical separation of nesting areas as the land moved further apart and climate changes from season to season became more pronounced.

All this is to remind the reader that it was truly a multiplicity of factors that drove the evolution of life from those very first self-replicating molecules through to the early primates roaming the forests of the African continent - factors such as available chemical components and other resources, environmental conditions including varying ocean temperature and atmospheric composition, the strength or limitation of cosmic radiation and regular sunlight, the constantly shifting patterns of both land and sea areas, catastrophic geologic events and disasters of extraterrestrial origin, and even the tiniest genetic mutations or errors in DNA replication all interacted to generate the enormous depth and diversity of life that covers our planet today.

Step 10: The Primates Arrive

Around 63 million years ago, the very early primates began to diverge into two different groups - the 'wet-nosed' primates which led to our modern day lemurs and 'the dry-nosed' primates which led to modern day monkeys and apes. It was about this time that the dry-nosed primates lost the ability to internally manufacture vitamin C forcing all future decedents to consume fruits and vegetables to obtain this critical nutrient.

By 30 million years ago, the dry-nosed primates had diverged and separated into two distinct factions known today as new world monkeys and old world monkeys. The new world monkeys are those that were isolated on the geologic plate that eventually became South America as Pangea continued its breakup. New world monkeys never evolved a lineage of apes which is why today there are no naturally occurring species of gibbons and baboons, (the lesser apes) or chimpanzees, orangutang or gorillas (the greater apes) in either North or South America.

On the other hand, the old world monkeys which remained behind on the African plate did evolve separate lineages and around 25 million years ago had begun to differentiate into monkeys and apes - apes losing their prehensile tails and developing the trichromatic vision we, as humans, still retain.

Proconsul Africanus is one such possible ancestor of both the great and lesser apes, including humans, that inhabited the African forests at this time. This earliest ancestor had a mixture of both Old World monkey and ape characteristics. Proconsul's monkey-like features included thin tooth enamel, a light build with a narrow chest and short forelimbs, and a quadrupedal lifestyle. Its ape-like features were its lack of a tail, ape-like elbows, and a slightly larger brain relative to body size.

Once again it is appropriate to pause briefly along the evolutionary path to introduce the correct terminology used to classify all living things. This classification system subdivides the five kingdoms noted earlier into finer and finer divisions based on creatures similar traits and characteristics.

To quickly review, the highest level of classification are the three Domains named Bacteria, Archaea and Eukaryotes which were further separated into the five Kingdoms; Monera (the prokaryotes): Protista (the single-celled eukaryotes); Fungi (fungus and related organisms); Plantae (the plants); and Animalia (the animals). From this point each Kingdom is further categorized through Phylum, Class, Order, Family, Tribe and Genus. The lowest division is Species and the most unique quality of any single species is its ability to successfully interbreed and produce viable, fertile offspring. In addition, each of these high-order categories can itself be broken down into super and sub groups helping to further define the similarities among classifications.

In order to follow the rather complex path from ape to man there are several key points that must be made.

During the entire evolutionary process, it must be remembered, there are no sudden changes from generation to generation, no instant morphing from one species to another, no 'miracles'. Each change, even the most dramatic ones, are just subtle alterations of the genetic structure over long periods of time that may, or may not, lead to some potential advantage, in the competitive race for limited resources.

From generation to generation changes are virtually imperceptible. Over hundreds of years a small degree of superiority may begin to exert itself and, over thousands of years, cumulative changes may clearly provide a definite edge. By the time several hundred thousand years have passed an entirely new species may have appeared and, after one million years, all trace of the originating species may be long gone and buried.

The important point here is, that while evolution is often portrayed as moving ahead with large, discrete changes, in fact dozens, hundreds, even thousands of slightly modified offspring were continually born, each starting a potential new branch off from the main line. Unfortunately nature intervened and most of these didn't survive for long. The problem is that all these remains leave a very complex trail as anthropologists attempt to lay out a complete fossil record from ape to man.

This process also belies the age-old question of 'Which came first - the chicken or the egg?'. The question itself is, of course, ridiculous. It attempts to reduce the core principals of evolution to a simplistic, black and white, yes or no answer as if some strange creature laid an egg that miraculously hatched a chicken when, in fact, the chicken species (*gallous domesticus*) actually evolved gradually over millions of years beginning with the first feathered dinosaurs some 200 million years ago.

Before embarking on the final evolutionary pathway, here is the complete classification structure for modern Human Beings including the approximate dates at which time the particular characteristics of the noted classification group first appeared. It provides a good summary of what we've covered so far.

Human Beings fall under the following category classifications:

Group Description	Group Name	First Appearance
Domain:	Eukaryota	2.1 Billion Years Ago

This Domain includes all life forms that are based on cells that contain a Nucleolus, whether single or multi-celled organisms.

Kingdom:	Animalia	590 Million Years Ago

This Kingdom includes all Eukaryotic, multicellular life forms that are mobile in either a marine or terrestrial environment.

Phylum	Chordata	530 Million Years Ago
Sub-Phylum	Vertebrata	509 Million Years Ago

This Phylum includes all animals that have even a rudimentary spinal column or collection of nerves along their lateral flank while the Sub-Phylum limits members to those with actual physical backbone structures.

Superclass	Tetrapods	395 Million Years Ago
Class	Mammalia	220 Million Years Ago
Sub-Class	Eutheria	125 Million Years Ago

Tetrapods includes all animals with only 4 limps while Mammalia include only those that birth live young (non-egg laying) and Eutheria further restricts members to placental mammals only which excludes marsupials (kangaroos, wallabies, koala and opossum etc.).

Superorder	Euarchontoglires	100 Million Years Ago
Order	Primates	75 Million Years Ago
Sub-Order	Haplorrhini	40 Million Years Ago

The Superorder here includes all primates, rodents, rabbits and tree shrews while the Order itself includes only the primates. The Sub-Order further restricts the primates to the 'dry-nosed' variety primarily monkeys and apes.

Superfamily	Hominoidea	28 Million Years Ago
Family	Hominidae	15 Million Years Ago
Sub-Family	Homininae	8 Million Years Ago

The Superfamily Hominoidea includes all ape-like creatures, including humans while the Family includes only Humans, Chimpanzees, Gorillas and Orangutang. The Sub-Family includes only Humans, Chimpanzees and Gorillas.

Tribe	Hominini	5.8 Million Years Ago
Sub-Tribe	Hominina	2.5 Million Years Ago

The Tribe Hominini includes Humans, Chimpanzees and the Australopithecines (Os-trol-o-pith-e-scenes) while the Sub-Tribe includes only Humans and all of their closest relatives.

Genus	Homo	2.4 Million Years Ago

This Genus is restricted solely to Humans although there is continuing disagreement as to precisely where and when that distinction occurred.

Species	Homo Sapiens	.5 Million Years Ago
Sub-Species	Homo Sapiens Sapiens	.2 Million Years Ago

The Species Homo Sapiens refers to the earliest modern human beings who walked the Earth beginning about 500,000 years ago while the Sub-Species Homo Sapiens Sapiens refers to the anatomically and behaviourally identical to ourselves modern man who appeared around 200,000 years ago.

From Monkey to Man

So now we can return to the evolutionary path with a clearer understanding of the terminology and timeframes associated with the ascent of humans.

In the narrative that follows, I will utilize the proper scientific designation *italicized* to identify unique species and make their separate identification easy and obvious. In some cases the original lengthy name is shortened by reducing the first descriptor to a single letter - for example *Australopithecus afarensis* is shortened to *A. afarensis.* It should also be noted that many of these assigned names are based on the location of their fossils first discovery making for some odd nomenclature and adding to the difficulty of recognizing strict chronological evolutionary development.

When we last left the evolutionary path it was 25 million years ago and *Proconsul Africanus* , a sort of half-monkey half-ape was roaming the forests of Africa.

By 15 million years ago, Hominidae - the great apes speciate (form a separate and distinct species) from the ancestors of the gibbon and baboon (lesser apes) and by 13 million years ago, Homininae speciate from the ancestors of the orangutang.

At this time, *Pierolapithecus catalaunicus* is believed to be a common ancestor of both humans and the other great apes, or at least a species that brings us closer to a common ancestor than any previous fossil discovery. It had the special adaptations for tree climbing as do present-day humans and other great apes: a wide, flat rib cage, a stiff lower spine, flexible wrists, and shoulder blades that lie along its back.

By 10 million years ago, the lineages representing humans and the Genus Pan (modern day chimpanzee and bonobos) speciate from the ancestors of the gorillas.

Around 7 million years ago, the Hominina, a subtribe of Hominini who are closely related to or ancestors to humans, speciate from the ancestors of the chimpanzees. Both chimpanzees and humans have a larynx that repositions during the first two years of life to a spot between the pharynx and the lungs, indicating that the common ancestors of both have this feature, a precondition for vocalized speech in humans.

The latest common ancestor of humans and chimpanzees lived around the time of *Sahelanthropus tchadensis*, around 7 million years ago. S. tchadensis itself is sometimes claimed to be that last common ancestor of humans and chimpanzees, but the claim has not been established. The earliest known representative from the ancestral human line post-dating the separation with the chimpanzee lines is *Orrorin tugenensis* or Millennium Man, first discovered in Kenya and believed to have lived almost 6 million years ago.

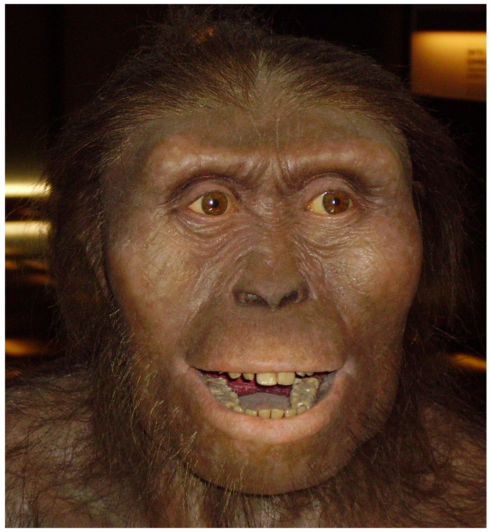
I

Ardipithecus is, or may be, a very early hominin genus (tribe Hominini and subtribe Hominina). Two separate species have been uncovered and further described : *A. kadabba*, dated to approximately 5.6 million years ago and *A. ramidus*, which lived about 4.4 million years ago. *A. ramidus* had a small brain, measuring between 300 and 350 cm3. This is about the same size as the modern bonobo and female common chimpanzee brain and slightly over a fifth the size of the modern Homo sapiens brain.

Ardipithecus was arboreal, meaning it lived largely in the forest where it competed with other forest animals for food, no doubt including the contemporary ancestor of the chimpanzees. *Ardipithecus* was probably bipedal as evidenced by its bowl shaped pelvis, the angle of its foramen magnum and its thinner wrist bones, though its feet were still adapted for grasping rather than walking for long distances.

A member of the species *Australopithecus afarensis* left human-like footprints in volcanic ash in Laetoli, Kenya (Northern Tanzania), providing strong evidence of full-time bipedalism. *A. afarensis* lived between 3.9 and 2.9 million years ago, and is considered one of the earliest hominins---those species that developed and comprised the lineage of ''Homo'' and ''Homo's'' closest relatives after the split from the line of the chimpanzees.

It is thought that *A. afarensis* was ancestral to both the genus Australopithecus and the genus Homo. Compared to the modern and extinct great apes, *A. afarensis* had reduced canines and



molars, although they were still relatively larger than in modern humans. *A. afarensis* also had a relatively small brain size (380–430 cm^3) and a prognathic (i.e. projecting anteriorly) face.

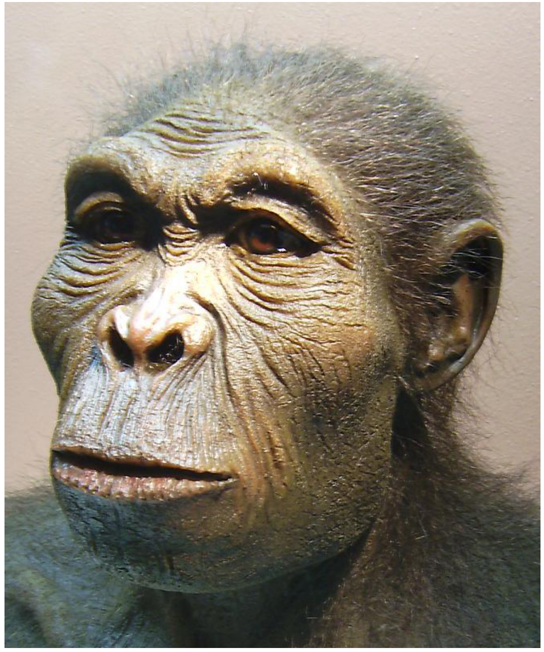
Australopithecines have been found in savannah environments; from scavenging opportunities, they probably developed their diet to include meat. Analyses of *A. africanus* lower vertebrae suggests that these bones changed in females to support bipedalism even during pregnancy.

By 3.3 million years ago, *Kenyanthropus platyops*, a possible ancestor of Homo, emerges from the Australopithecus genus and it appears that stone tools were, at that time, being deliberately constructed.

By 3 million years ago, bipedal australopithecines (a genus of the Hominina subtribe) evolved in the savannas of Africa and were being hunted by Dinofelis - the sabre-toothed tiger. Loss of extensive body hair occurred from 3 to 2 million years ago in parallel with the development of full bipedalism.

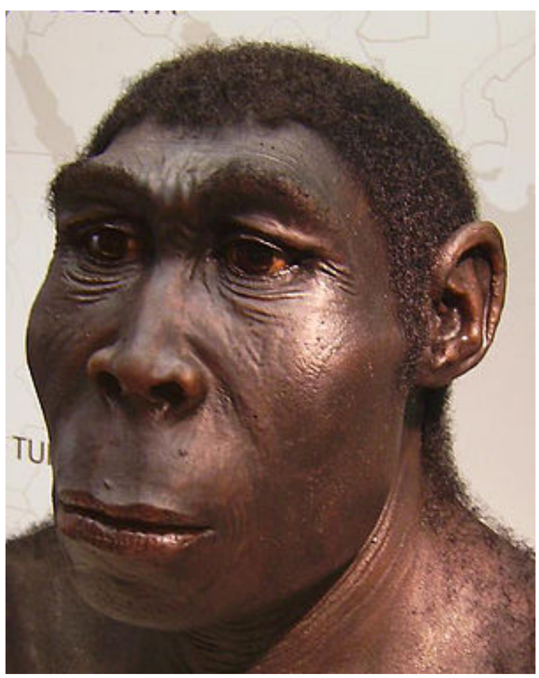
At 2.8 million years ago, Homo first appears in East Africa. Along with most Australopithecines they are considered the first hominins—that is, they are designated (by some) as those earliest humans and human relatives or ancestors to rise after splitting from the lineage of Pan, the chimpanzees. Others consider the genus Pan as hominins also, and perhaps the first hominins.

Homo habilis now appears—the first, or one of the first, hominins to master stone tool technology. Stone tool implements have also been found along with *Australopithecus garhi* dated to a slightly earlier period.



Homo habilis, although significantly different in anatomy and physiology, is thought to be the ancestor of *Homo ergaster* or African *Homo erectus* but it is also known to have co-existed with *Homo erectus* for some one-half million years until about 1.5 million years ago.

By now, 2 million years ago, *Homo erectus* had evolved in Africa. *Homo erectus* would bear a striking resemblance to modern humans, but had a brain about 74 percent of the size of modern man. Its forehead was less sloping than that of *Homo habilis* and the teeth were smaller.



Homo ergaster, known as *African Homo erectus*, and other hominin species such as *Homo georgicus, Homo pekinensis and Homo heidelbergensis* are often put under the umbrella species name of *Homo erectus*. Starting with *Homo georgicus*—found in what is now the Republic of Georgia and dated at 1.8 million years ago —the pelvis and backbone grew more human-like, which would enable *H. georgicus* to cover very long distances and to follow herds of prey animals. This is the oldest fossil of a known hominin found outside of Africa.

Control of fire by early humans is achieved about 1.5 Million years ago by *Homo ergaster who* reached a height of around 1.9 metres (6.2 ft). Evolution of dark skin, which is linked to the loss of body hair in human ancestors, is complete by 1.2 million years ago.

Homo pekinensis first appears in Asia around 700 thousand years ago but, according to the theory of a recent African origin of modern humans, they could not be ancestors to modern humans, but rather, were an offshoot cousin species from *Homo erectus*.

This supports the previous contention that multiple branches of evolutionary offspring develop as separate and unique species only to eventually die out leaving no further descendants.

Homo heidelbergensis was a very large hominin that developed a more advanced complement of cutting tools and may have hunted big game such as horses.

Homo antecessor may be a common ancestor of both humans and Neanderthals. At present estimate, humans have approximately 20,000–25,000 genes and share 99% of their DNA with the now extinct Neanderthal and 95-99% of their DNA with their closest living evolutionary relative, the chimpanzees.The human variant of the FOXP2 gene (linked to the control of speech) has been found to be identical in Neanderthals. It can therefore be deduced that *Homo antecessor* would also have had the human FOXP2 gene.

600 thousand years ago,1.5 m (5 ft) tall *Homo heidelbergensis* left footprints in powdery volcanic ash solidified in Italy. *Homo heidelbergensis* may also be a common ancestor of both humans and Neanderthals because it is morphologically very similar to *Homo erectus* but *Homo heidelbergensis*

had a larger brain-case, about 93% the size of that of *Homo sapiens*. The holotype of the species was tall, 1.8 m (6 ft) and more muscular than modern humans.

Both Omo1 and Omo2 sites, found along the Omo River, Ethiopia, yield the earliest fossil evidence for anatomically modern Homo sapiens. By a 2015 study, the hypothetical man Y-chromosomal Adam is estimated to have lived in East Africa about 250 thousand years ago. He would be the most recent common ancestor from whom all male human Y chromosomes are descended.

Around 160 thousand years ago, *Homo sapiens (Homo sapiens idaltu)* found in Ethiopia near the Awash River, are burying their dead and practicing mortuary rituals. This implies at least a rudimentary belief in an afterlife, by protecting fallen comrades bodies from animal predation.

Additionally, proof exists that they were capable of butchering hippopotami, implying well organized hunting parties with a subsequent sharing of captured resources. Also uncovered at this time, was potentially the earliest evidence of anatomical and behavioural similarity to modern man, including the use of red ochre for painting purposes and evidence of organized fishing.

The hypothetical woman, Mitochondrial Eve, is estimated to have lived in East Africa between 99 and 200 thousand years ago; she would be the most recent female ancestor common to all mitochondrial lineages in humans alive today. Note that there is no evidence of any characteristic or genetic drift that significantly differentiated her from the contemporary social group she lived with at the time. Her ancestors, as well as her contemporaries, were all *Homo sapiens*.

Around 60 thousand years ago, *Homo Sapiens* had begun to migrate out of Africa and most likely interbred with Neanderthals they encountered. By 50 thousand years ago, *Homo Sapiens* had reached Southeast Asia and by 40 thousand years ago had reached Australia. In Europe, Cro-Magnon man was now present and the independent lineage Neanderthal had died out.

By 30 thousand years ago, Europeans had begun developing light skins, and *Homo floresiensis* had died out, leaving *Homo sapiens* as the only living species of the genus Homo.

Sometime around 25 thousand years ago, humans crossed over the present day Bering Straits and began spreading throughout North and South America.

Approximately 10-15 thousand years ago, the first agriculturally based tribes began to settle around the fertile valleys of theTigris and Euphrates and other significant rivers across the planet ending their previous nomadic ways and forever changing the face of future civilizations on Earth. These tribes began cultivating various grains, like wheat, rice and corn that formed a staple food base allowing them to remain in one geographical locale.

As tribe sizes increased, it became necessary to supplement their limited grain based diets with various animals by capturing and domesticating them rather than killing them outright. These first 'farm animals' included more easily controlled animals such as goats, chickens, cows, pigs and sheep. As skills improved, larger animals were captured and trained to become pack animals such as oxen, horse, camel, llama and even elephant.

By 8 thousand years ago (6,000 BCE) substantial civilizations had taken hold along side many of the Earth's major rivers and seas among them, Middle Eastern, North African, Mediterranean, Chinese, East-Asian, South-Asian and North, Central and South American and history began to be permanently recorded for the first time.

In what would seem to be a mere heartbeat over the entire course of the evolution of life and a mere fraction of an instant over the entire course of time, *Homo Sapiens Sapiens* would consolidate populations, build impressive cities, establish laws and would ultimately rise and establish themselves as the dominant species and rulers of this world.

May we truly have the wisdom and foresight to manage our position of privilege and ensure our place within the Universe for millennium to come.

Appendix

The following chart summarizes the events described in the previous text in chronological order. Included are the event name or description, the approximate number of years ago from the present that it occurred, an explanatory or secondary note of interest where appropriate and, at certain points, the name of the Geologic Time Frame (Eon or Period) within which those events fall.

Given that there is no absolute proof or even agreement among experts on time frames or even order of precedence, the reader is encouraged to review this table only as a general overview of significant events that have occurred since the beginning of all time.

UNIVERSE CREATION	**YEARS AGO**	
Energy and the Big Bang	13,800,000,000	
Quarks formed. +1ns.	13,800,000,000	(300 trillion degrees K)
Protons/Neutrons +1ms	13,800,000,000.	(300 billion degrees K)
First hydrogen nuclei - 1 sec-3 min.	13,800,000,000.	(300 million degrees K)
First helium nuclei - 3 min - 20 min	13,800,000,000	
First electrons around 1st atoms	13,799,650,000	385,000 yrs. 3000 degrees K

STARS, GALAXIES and PLANETS	**YEARS AGO**
Quasars 1st stars Type III	12,900,000,000
Second Gen Stars Type II	12,200,000,000
First galaxy formation	12,000,000,000
Milky Way Begins Forming	11,000,000,000
Third Gen Stars Type I	10,000,000,000
Local Galaxy Clusters	7,000,000,000
Our sun is formed	5,500,000,000
Our planets formed	4,600,000,000

PLANETARY LIFE CREATION	**YEARS AGO**	
The Moon is formed	4,400,000,000	HADEAN EON
1st crust is formed	4,350,000,000	
Water vapour in atmosphere	4,300,000,000	
Oceans formed on earth	4,200,000,000	
Replicating molecules	4,000,000,000	
Amino acids	3,900,900,000	
Nucleic acids	3,900,700,000	
Ribonucleic acids	3,900,600,000	
Deoxyribonucleic acid (DNA)	3,900,500,000	
Genes	3,800,400,000	ARCHEAN EON
Chromosomes	3,800,300,000	
Cells	3,800,000,000	
Single cell organisms	3,600,000,000	
Virus and Bacteria	3,500,000,000	

Photosynthesis begins	3,200,000,000	
Blue-green algae (waste oxygen)	3,000,000,000	
Great Oxidation Event GOE	2,600,000,000	(1st Mass Extinction - mostly Anaerobic bacteria)

EVOLUTIONARY DEVELOPMENT	**YEARS AGO**	
First major glaciation of Earth	2,500,000,000	PROTEROZOIC EON
Series of mountain building/erosion	2,000,000,000	
Cell Nucleolus Develops	1,500,000,000	
Sexual reproduction in cells begins	1,000,000,000	
Multi-cell organisms develop	800,000,000	
sponges/jellyfish/corals	700,000,000	
Final Snowball Earth scenario	600,000,000	
		PHANEROZOIC EON
Start of Cambrian Explosion	580,000,000	(Geologic Period)
Flatworms 1st moving cellular beings.	570,000,000	
First ocean plants	560,000,000	
Spiders/scorpions	550,000,000	CAMBRIAN
Millipedes	540,000,000	
Mollusc (worms w/shells)	530,000,000	
Trilobites	520,000,000	
Nautilus/squid (intelligent molluscs)	510,000,000	
Starfish	500,000,000	
Crabs (first foray onto land)	490,000,000	
Sea squirts (earliest fish-like)	480,000,000	ORDOVICIAN
Sharks and Rays	435,000,000	
First land plants -lycophytes	420,000,000	SILURIAN
Bony fish w/swim bladder	410,000,000	
First walking insects - centipedes	400,000,000	
Flying insects	380,000,000	DEVONIAN
Coniferous forests	370,000,000	
First amphibians	370,000,000	
Salamanders/newts	340,000,000	CARBONIFEROUS
Frogs/toads	330,000,000	
1st flowering plants - angiosperms	290,000,000	
First reptiles	280,000,000	PERMIAN
Earliest upright reptiles	270,000,000	
Permian-Triassic Extinction	252,000,000	96% Marine, 76% Land 50% insects species died
Pangea - Single land mass	250,000,000	
Earliest mammals	230,000,000	MESOZOIC
Pangea splits into continents	220,000,000	TRIASSIC
First Dinosaurs	190,000,000	
First feathers	150,000,000	
Middle of dinosaur age	140,000,000	JURASSIC
First birds	130,000,000	
Grasses and grains	100,000,000	

Tree shrew	100,000,000	CRETACEOUS
Great extinction (Dinosaurs)	65,000,000	CENOZOIC
Marsupials/egg-laying mammals	65,000,000	
Earliest primates (lemurs/monkeys)	60,000,000	
Earliest known Hominid	7,000,000	PALEOGENE
1st bi-ped	6,000,000	
Lucy (Australopithecus)	3,200,000	
Australopithecus Africanus	2,500,000	
Homo habilis - tool maker	1,900,000	
Homo erectus (organization-teamwork)	1,800,000	
First glacier period	400,000	
Swanscombe man	250,000	
Homo sapiens sapiens	200,000	
2rd glacier period	190,000	
Mother of all humans (Africa)	150,000	
Earliest Neanderthals leave Africa	120,000	
3rd glacier period	70,000	NEOGENE
4th glacier period	50,000	
Modern man leaves Africa	50,000	
Man crosses Bering Sea to N.A.	25,000	
First agriculture settlements	15,000	
First cities	10,000	

ANCIENT CIVILIZATIONS	**YEARS AGO**
Stone age	20,000 BCE
Egyptian civilization	4,500 BCE
Bronze age begins	4,000 BCE
Hammurabi code of law	1,800 BCE
Phonetic alphabet invented	1,600 BCE
Moses on Mt Sinai (Ten Commandments)	1,250 BCE
Hebrew kingdom divided	926 BCE
Confucius (Shantung Province, China)	551c - 479 BCE
Buddhism founded	540? BCE
Socrates (Athens)	469 - 399 BCE
Plato (Athens)	427? - 347 BCE
Aristotle (Stagirus, Macedonia)	384 - 322 BCE
Alexander the Great (Pella, Macedonia)	356 - 323 BCE
Archimedes (Syracuse, Sicily)	287? - 212 BCE
Great wall of china built	212c BCE
Roman Empire	191c - 476c AD
Gaius Julius Ceasar (Rome)	100? - 44 BCE
Paper used by chinese	100c BCE
Cleopatra (Alexandria, Egypt)	69 - 30 BCE

EXPLORATION/RELIGIOUS EXPANSION	**YEARS AGO**
Jesus (Nazareth) (Christianity 200c AD)	1? - 30 AD
Justinian I begins Byzantine Empire	527 AD
Mohammed (Mecca) (Islam 620c AD)	570 - 632 AD
Charlemagne	742 - 814 AD
Viking exploration	800c - 950 AD0
Leif Erickson lands in north america	1000c AD
William the Conqueror/Battle of Hastings	1066 AD
Magna carta signed by King John I	1215 AD
Great plague of europe (25,000,000d)	1347 - 1351 AD
Printing press (Gutenberg, Germany)	1450 AD
Christopher Columbus (Genoa, Italy)	1451 - 1506 AD
Leonardo da Vinci (Vinci, Tuscany (Italy))	1452 - 1519 AD
Rifle invented	1460 AD
Nikolas Copernicus (Thorn, Poland)	1473 - 1543 AD
Martin Luther (Eisleben, Germany)	1483 - 1546 AD

ERA OF ENLIGHTENMENT	**YEARS AGO**
Mona Lisa painted	1503 AD
Watch invented	1510 AD
Martin Luther's 95 thesis	1515 AD
William Shakespeare (Stratford-on-Avon, Eng)	1564 - 1616 AD
Galileo Galilei (Pisa, Italy)	1564 - 1642 AD
Johannes Kepler (Weil, Germany)	1571 - 1630 AD
Cannon invented	1603 AD
Rembrandt Harmensz van Rijn (Leyden, Neth)	1605 - 1669 AD
French settle Canada	1605 AD
Pilgrims land at plymouth rock	1620 AD
Sir Issac Newton (Grantham, England)	1642 - 1727 AD
Great plague of London (75,000d)	1665 AD
Great fire of London	1666 AD
Steam engine (Thomas Savery)	1698 AD
Napoleon Bonaparte (Ajaccio, Corsica)	1769 - 1821 AD
American revolution	1775 - 1787 AD
French revolution	1789 - 1799 AD
George Washington elected	1789 AD

THE INDUSTRIAL REVOLUTION	**YEARS AGO**
Telegraph invented	1837 AD
Communist manifesto (Karl Marx)	1848 AD
Sigmund Freud (Moravia, Czechoslovakia)	1856 - 1939 AD
U.S. Civil War	1861 - 1865 AD
Canada United	1867 AD
Telephone invented	1876 AD
Automobile invented	1885 AD
Ford motor company established	1903 AD

Wright Brothers at Kitty Hawk	1903 AD
Russian revolution	1905 AD
Mexican revolution	1911 AD
World War I	1914 - 1918 AD
Russian civil war	1918 AD
Stock market crash (Oct)	1929 AD
Spanish revolution	1931 AD
Spanish civil war	1936 AD
World War II	1939 - 1945 AD
Japan attacks Pearl Harbour (Dec 7)	1941 AD
Germany surrenders (May 7)	1945 AD
A-bomb lands on Hiroshima (Aug 6)	1945 AD
Japan surrenders (Sep 2)	1945 AD

THE MODERN AGE	**YEARS AGO**
Israel declared (May 14)	1948 AD
People's Republic of China declared (Oct 1)	1949 AD
Korean War	1950 - 1953 AD
Vietnam War	1950 - 1975 AD
Berlin wall erected (Aug 13)	1961 AD
John F. Kennedy assassinated (Nov 22)	1963 AD
Man lands on the moon (July 20)	1969 AD
Nixon Resigns (Aug 8)	1974 AD
52 U.S. hostages freed (Jan 18)	1981 AD
Mikail Gorbachev becomes soviet leader (Mar 11)	1985 AD
Berlin Wall falls	1989 AD