PROLOGUE

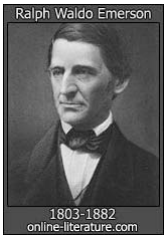
Close to 13.7 billion years ago, the universe began an expansion process commonly called the Big Bang that continues today. Responsible for space, time and all the stuff we are familiar with as well as concepts such as dark matter and energy that we are only beginning to understand, the words big bang totally fail to adequately provide a vision of the formation and evolution of the universe. Despite awesome and amazing complexity beyond our most far reaching words and imaginations, scientists can actually mathematically describe the happening is such great detail that the big bang has appropriately been given the scientific label *theory*. Just as our jury system requires evidence beyond a reasonable doubt, the evidence in support of the big bang theory is so consistent with the evolution of the universe that the word theory is justifiably applicable far beyond a reasonable doubt.

Science operates according to very high standards of testing and reproducibility that are often described as the scientific method. Basically, hindsight analysis of most scientific concepts and advances reveals that science starts with observation. When an observation is made that does not seem consistent with expectations, questions are asked and explanations or hypotheses are suggested to help us understand the observation. Following the explanations, scientists develop tests and experiments that when carried out either provide evidence in support of an explanation or cause rejection of the explanation and a search for a better or alternative explanation. If an explanation survives the testing and is useful for prediction, the explanation is elevated to the level of a theory. Please note that the "lay" use of the word theory does not meet the scientific standard set for the word. At times, people use the word theory inappropriately to represent a story for which adequate evidence does not exist. Use of the word theory for this purpose should be resisted. However, even scientific theories are continually subject to further testing, modification and improvement.

As mentioned, the first and key step in the scientific method is observation. The asking of questions on anything not understood is a major part of the observation process. Because observation is sometimes interpreted in a passive way, an alternative word, notice, might be more appropriate. Read these quotations below about observation.

SCIENCE & OBSERVATION

In the field of observation, chance favors only the mind that is prepared.
Louis Pasteur

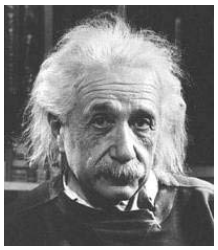


God hides things by putting them near us. Ralph Waldo Emerson

To acquire knowledge, one must study; but to acquire wisdom, one must observe.
Marilyn Vos Savant

You are one of the rare people who can separate your observation from your perception...you see what is, where most people see what they expect.
Tsitsi Dangarembga

Science encompasses the study of the universe and everything in it. The importance of science in our lives cannot be understated. From medicine to weather and earthquake prediction to climate change, society needs to acquire science literacy if we hope to maintain and improve our quality of life. The lack of scientific literacy leads to drug abuse, dangerous and sometimes life threatening pollution and perhaps the biggest challenge ever to the survival of humans; global climate change.



SCIENCE

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."
Albert Einstein

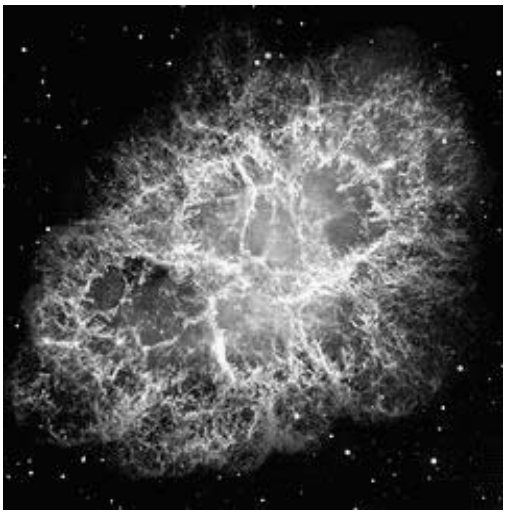
Nothing in life is to be feared. It is only to be understood.
Marie Curie
A scientist in his laboratory is not a mere technician: he is also a child confronting natural phenomena that impress him as though they were fairy tales.

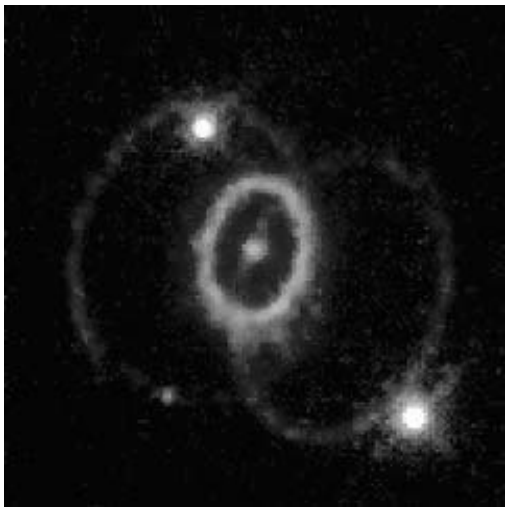
Marie Curie was the first woman to win a Nobel prize and the first person to win two Nobel prizes.

"Science contributes to our culture in many ways, as a creative intellectual activity in its own right, as the light which has served to illuminate man's place in the universe, and as the source of understanding of man's own nature."
John F. Kennedy

Returning to the Big Bang, the table below presents a time-line for the formation and development of the universe from 13.7 billion years ago to the present. Many of the events are very relevant to the focus of this course, chemistry. To facilitate its study, science has been artificially broken down into narrower disciplines. The topic for this course is chemistry or the study of matter, its chemical and physical properties and the energy changes associated with chemical and physical processes. Pay special attention to the time scale and the timing for the formation of matter including quarks, protons, neutrons. The capture of electrons leading to the formation of the first atoms of hydrogen and helium represents another big milestone. The stars and eventually the galaxies that initially formed from the Big Bang then fused the hydrogen and helium into the lighter elements up to and including the element iron. However, there is not enough energy in a star to produce elements beyond iron. Stars do have lives and after cycling through several billion year lifetimes, occasionally explode in what is called a supernova. A very large supernova was observed around the world to the naked eye in 1054 that lasted about 2 years but is still observable today as the crab nebula. In 1987, astronomers were fortunate to be able to observe radiation from a supernova. During a supernova, the intense and concentrated amount of energy is sufficient to produce the elements beyond iron. Thus any elements on earth heavier than iron are the result of a supernova and bring with them a fascinating history.

P-1. Explain the difference between a hypothesis (or explanation) and a theory.

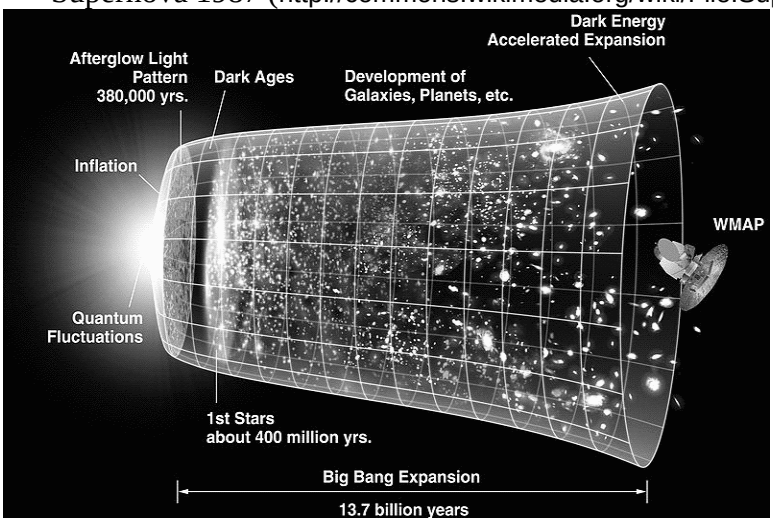




Crab nebula today (http://commons.wikimedia.org/wiki/File:Crab_Nebula.jpg)

Supernova 1987 (http://commons.wikimedia.org/wiki/File:Supernova1987A.jpg)

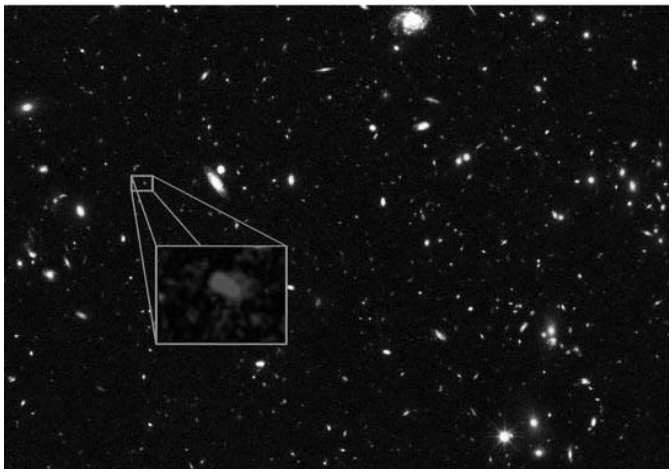
A graphic description of the evolution of the universe.



http://commons.wikimedia.org/wiki/File:CMB_Timeline75.jpg

z8_GND_5296

Light from this source left the source 13.1 billion years ago making it the oldest and most distant source of energy so far observed on earth.



http://www.csmonitor.com/Science/2013/1023/Most-distant-galaxy-ever-found-a-glimpse-into-universe-s-mysterious-dark-ages-video

Time-line for Formation and Development of the Universe

Time (sec. after BB)	Time (yr. after BB)	Time (yr. before present)	Temp. (K)	Description
10^{-43}				Event that eventually leads to formation of energy, space, time, dark energy and matter. Planck Era. At this moment, the universe is thought to be incredibly hot, dense and turbulent when all the fundamental forces currently at work in the universe - gravity, electromagnetism and the so-called strong and weak nuclear forces - are thought to have been unified during this stage into a single "superforce".
10^{-35} to 10^{-33}				Grand Unification Era, at the end of which the superforce begins to break apart into the constituent forces we see today. Around this time so-called inflationary energy triggers a dramatic burst of expansion.
10^{-32}				Formation of matter from energy
10^{-11}			10^{15}	Continued expansion, lowered density, cooling, first gravity, then the strong force, which holds nuclei of atoms together, followed by the weak and electromagnetic forces electromagnetism and weak nuclear force separate out
$5x10^{-5}$			$2x10^{12}$	Quarks, electrons, photons, neutrino form. These particles smash together to form protons and neutrons.
1 - 200			10^{9}	Protons and neutrons come together to make the nucleii of small elements
$9.5x10^{12}$	$3x10^{5}$		3000	Electrons captured by nucleons to form atoms - 75% hydrogen, 25% helium
$6x10^{15}$	$2x10^{8}$	$13.5x10^{9}$	30	Gravity brings together hydrogen and helium and rising temperature triggers the fusion of stars. Fusion combines light elements to produce elements up to and including iron.
$1.9x10^{16}$	$6x10^{8}$	$13.1x10^{9}$		Observation of most distant source and oldest source of light thus far in universe (see below z8_gnd_5296)
$3x10^{16}$	10^{9}	$12.7x10^{9}$		Gravity brings stars together to form galaxies
$2.9x10^{17}$	$9.2x10^{9}$	$4.5x10^{9}$		Prior to this time, a supernova results in production of elements beyond iron. A region of gas and dust from exploding stars in the Milky Way galaxy starts to collapse under its own gravity, forming a small star surrounded by a disk of rocky material and gas. Swarms of giant chunks of debris form within the disc, collide and merge - forming the Earth, moon and other planets.
$3.1x10^{17}$	$9.9x10^{9}$	$3.8x10^{9}$		Earliest life forms on earth.
$4.1x10^{17}$	$13.0x10^{9}$	$7x10^{8}$		Primitive animals appear on earth.
$4.26x10^{17}$	$13.5x10^{9}$	$2x10^{8}$		First mammals appear on earth.
$4.30x10^{17}$	$13.64x10^{9}$	$6.6x10^{7}$		Extinction of dinosaurs on earth.
$4.30x10^{17}$	$13.70x10^{9}$	$6x10^{5}$		Homo-sapiens evolve on earth.
$4.3x10^{17}$	$13.7x10^{9}$	0	2.7	Present.

Many people do not appreciate or are even aware of the importance of science in their lives. If you think about it, you will realize that our lives are enveloped in science and technology.

P-2. Name five activities that contribute to your life that do not involve advances that can be attributed to science.

P-3. Our lives seem to be focused on entertainment and stuff. To illustrate this point, name as many Oscar winners, celebrities, sports stand-outs and then name some Nobel prize winners or even well known scientists.

P-4. In 50 years, will the celebrities or the scientists be remembered more for their impact on society?

As we begin our study of chemistry and the role of chemistry in our lives, it is useful to place ourselves in a historical context. While the Universe is 13.7 billion years old and the earth was formed 4.5 billion ago, the early ancestors of humans can only be traced back the relatively short time of two million years. Homo sapiens emerged about 40,000 years ago. For the first 30,000 years homo sapiens were hunter-gatherers. Tools developed by homo sapiens for hunting improved during the time and local populations of animals were undoubtedly affected and threatened. Some scientists think that there was enough of an impact to drive some animals to extinction. However, until the last several hundred years, the global impact of humans has not been too significant.

During the last 400 million years, there have been five major extinction events that have resulted in the extinction of huge percentages of life on earth. Climate changes that resulted in glaciation and even an asteroid have been identified as the causes of these extinctions. Since homo sapiens appeared on earth, animal extinctions are increasing at an alarming rate especially in the last few hundred years,. Some scientists think that humans are witnessing the 6^{th} extinction and that humans are responsible. Whether or not this is true, there is considerable evidence that we are at a crucial point in history. How did we arrive at this pivotal point and can we make sure that a 6^{th} extinction does not become reality?

About 10,000 years ago, humans began to domesticate animals and grow plants for food. The plow was invented about 7000 years ago and domesticated animals used to pull the plow. With the ability to grow more food than personally needed, agriculture developed with the trading of products becoming possible. The availability of water became increasingly important and societies began to use irrigation as they abandoned nomadic life styles. It took a long time but eventually cities became more common. The cities were generally located on rivers both for drinking and waste removal. However, cities were generally not very large because of transportation issues and the need to be close to farms.

Around the middle of the 18^{th} century the pace of change increased dramatically. Until then power sources to enable mechanization were limited primarily to domesticated animals, wind and water and wood burning. England was an exception as coal was already in widespread use. As a result, the production of textiles and iron in England increased rapidly. This was the beginning of the first phase of the industrial revolution. The invention of the steam engine in 1769 by James Watt enabled industries to develop without the use of water power. Simultaneously, the production of iron and the ability to machine iron led to better mechanization and improved the ability to mine coal.

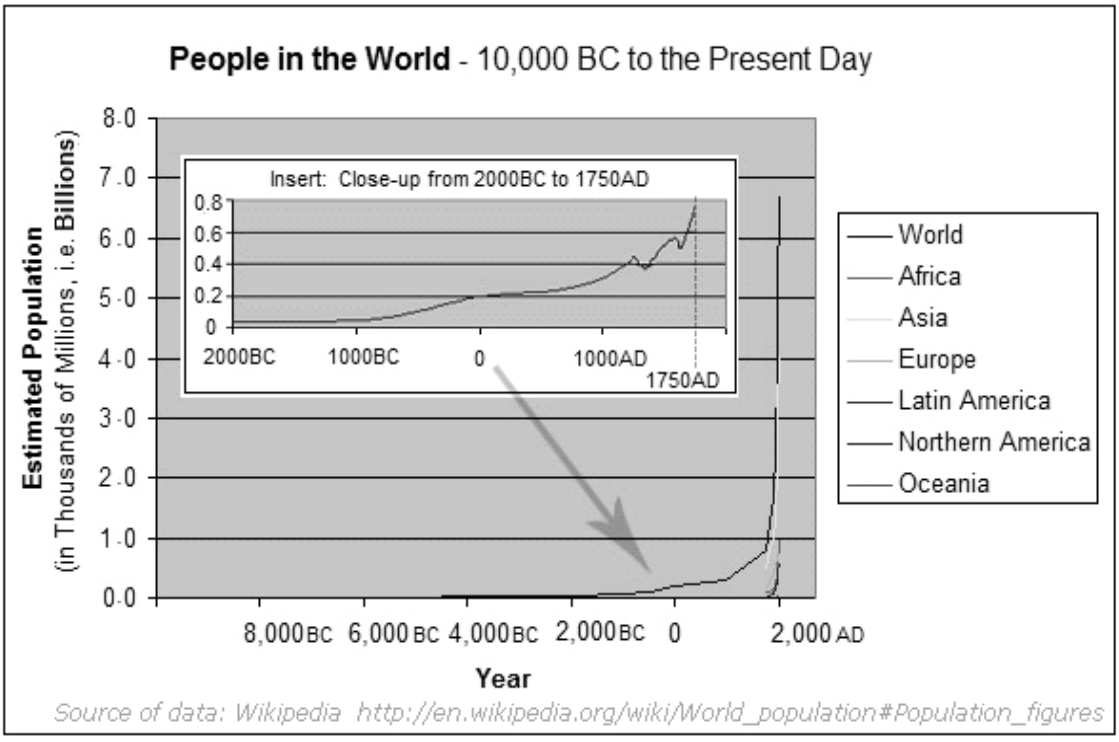
Around the middle of the 19^{th} century, the ability to produce steel and the development of electricity brought about the second phase of the industrial revolution. Chemistry advanced to the stage that useful chemicals such as dyes and medicines could be produced. Agriculture got a major boost in the early 1900's

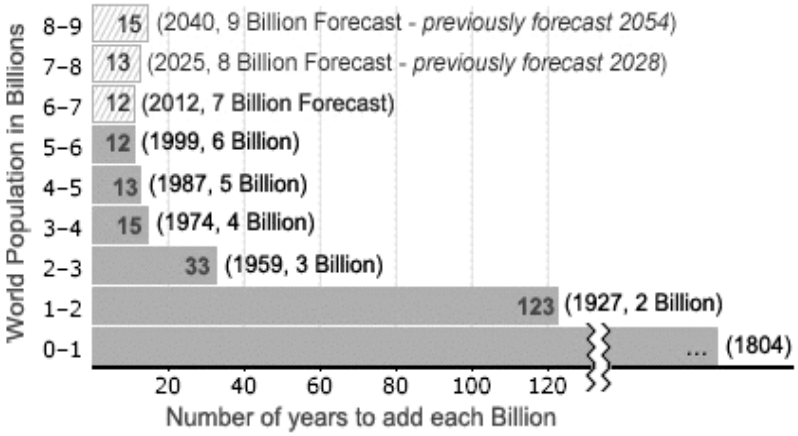
when the German chemists Fritz Haber and Carl Bosch developed a method for producing ammonia and fertilizers from nitrogen. Until that time, agriculture relied predominantly on bird guano from Chile for fertilizer. Unfortunately, the Haber-Bosch process also made the synthesis of explosives easier. Haber also used his chemistry expertise to develop toxic chemicals that were used in World War I.

To mention one more significant advance, until electricity became a readily available source for transmission of energy, aluminum was as expensive as silver. The development of processes to produce aluminum using electricity made it an abundant, useful and inexpensive metal that we find everywhere in or lives. It is interesting to note that titanium has many valuable properties also but to this day, inexpensive methods to refine titanium have not yet been discovered.

Looking around us at the cars, televisions, computers, appliances, airplanes, smart phones, central heating and air conditioning, medicines and the multitude of developments that contribute to our quality of life, it is apparent technology is advancing faster than our ability to deal with it. Along the way there have been unforseen problems that have accompanied the advances. Many of our new tools require an ever increasing amount of energy. Many parts of the world are technologically developing and also adding to the energy and resource burden of the earth. Most energy comes from the burning of fossil fuels. There is significant evidence that human action is warming the earth. Consequences could include microclimatic changes that could adversely affect agriculture, sea level changes that could flood low lying areas, melting of glaciers that supply fresh water, acidification of the oceans that destroys coral reefs, increased wild fires, dangerous pollution and even wars. Climate change will be discussed in detail later in the course. The use of DDT to kill mosquitos saved millions from malaria but also caused egg shells of birds to thin beyond a viable level. Nuclear energy provides a significant portion of the world's energy needs but the world lives under the threat of nuclear weapons. Currently, Iran and North Korea could join the countries with nuclear weapon capability and are threats to peace. Antibiotics have saved millions of lives but overuse is enabling bacteria to develop resistance. It is possible we are entering a new era where bacterial diseases could once more become commonly fatal. Frogs are disappearing world wide. While many people do not appreciate bats, bats eat millions of insects and help to keep insect populations under control. Recently a fungus has been killing bats by the million on the east coast of the U.S. and the fungus is spreading rapidly. Honey bees are needed to pollinate many agricultural products but the bee population has been dropping rapidly in the last few years. The list goes on and we need to think before we act and also take corrective action quickly.

Much of the energy and resource burden can be attributed to an explosion of the population of the earth which has been doubling at the alarming rate of about every 60 years. About 1 million people are added to the earth every 4.5 days and one billion people are added about every 12 years. As a result of population increases, all of the earth's resources are under stress. Animals have been hunted to extinction. Habitat loss has also contributed significantly to extinctions. To provide sufficient food, pesticides are commonly used to increase yield but also cause substantial wildlife damage and possibly cancer for humans. The environmental effects and especially energy use are near or at a tipping point where dire consequences are likely to occur unless corrective action is taken now. Humans have a tendency to act only in crisis situations. Unfortunately, a crisis situation is too late when it comes to climate change. Corrective action will take years to implement and decades before an impact is realized. It is imperative that society understand the current dilemma if we are to minimize the impact of our actions. Almost everyone can contribute to solving the problem by turning off lights, driving and flying less, turning up the thermostat in the summer and down in the winter. We are all guilty of using excess and we tend to look around and write it off because everyone else is doing it. In this sense we are all hypocrites and need to do everything we can to minimize hypocrisy. The time to start is now by learning about the problems and making an effort to take corrective action.


People in the World - 10,000 BC to the Present Day
Estimated Population
(in Thousands of Millions, i.e. Billions)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Insert: Close-up from 2000BC to 1750AD
0.8
0.6
0.4
0.2
0
2000BC
1000BC
0
1000AD
1750AD
8,000 BC
6,000 BC
4,000 BC
2,000 BC
0
2,000 AD
Year
World
Africa
Asia
Europe
Latin America
Northern America
Oceania
Source of data: Wikipedia http://en.wikipedia.org/wiki/World_population#Population_figures


World Population in Billions
8–9
15
(2040, 9 Billion Forecast - previously forecast 2054)
7–8
13
(2025, 8 Billion Forecast - previously forecast 2028)
6–7
12
(2012, 7 Billion Forecast)
5–6
12
(1999, 6 Billion)
4–5
13
(1987, 5 Billion)
3–4
15
(1974, 4 Billion)
2–3
33
(1959, 3 Billion)
1–2
123
(1927, 2 Billion)
0–1
...
(1804)
20
40
60
80
100
120
Number of years to add each Billion