**The disciplines: Physics, Biology, Chemistry, and Math**

To become a biologist or health-care professional, you have to study a variety of scientific disciplines -- biology, chemistry, physics, and math. You might have noted that the world doesn't actually divide itself in this way. Rather, the disciplines historically have been a way of choosing a sub-class of the phenomena that occur in the world and looking at a particular aspect of them with a particular purpose in mind. Different disciplines have different sets of tools and ways of knowing. Connecting the different ways of knowing and tools is a key part of the "convergence of the physical and life sciences". Looking at something from different disciplinary perspectives adds a richness and depth to our understanding -- like taking two 2-D pictures and merging them into a 3-D image.

Your introductory science and math classes often provide you with some basics -- tools, concepts, and vocabulary -- but may not give you a perspective on what each discipline adds to what you are learning and how they all fit together. Each discipline has its own orientation and perspective towards the development of a professional scientist. Here's a brief (and oversimplified) overview of the different disciplines that you encounter in studying biology.

## Biology

Biology, as you well know, is the study of living organisms. The approach taken by biology is guided by and constrained by the fact that the subject is about living organisms.

* **A lot of biology is complex**  -- Because of the complexity, the first steps in biology (and in other sciences of the complex) are often about identification, classification, and description of phenomena. Whenever a science considers a complex phenomenon it does this -- whether it's biology, organic chemistry, or plasma physics. In biology, it is important to describe the traits, structure, and behavior of a biological phenomenon before looking toward explanations of how it works. So it was important to do Linnaean classification and morphology before the ideas of evolution could be worked out; and an understanding of the nature of organic chemistry and biological molecules was necessary before the molecular functioning of biological systems could be disentangled. This results in biology having a huge vocabulary and many concepts to learn.
* **Biology depends on history**-- By this, we don't mean the history of how the science of biology developed, but the history of how organisms developed. All biological organisms are connected through a common, unbroken, history - a chain or web of lifeforms - that affects how things are today. What has happened over time matters in biology and affects how things are today. This is like geology, and unlike chemistry, physics, or math. (Though when biology gets down to the mechanism of how things actually happen, it is very much like chemistry and physics, and uses math.) The properties of organisms that are currently alive and their relationships to their environments and to each other depend a lot on what happened to their ancestors in the distant past. The history of an organism is written in its genome. Knowledge of evolutionary processes is often an important tool to "explain" why a particular organism solves a biological problem in a given way.
* **Biology looks for mechanism** -- Biology is not just about "What is life?" It's also about "How does it work?" At one level, you might look at the organs and parts of either an animal or a cell and figure out what their function is for the organism. Today, using the tools of chemistry and physics (and using math), biology has gone down to the atomic and molecular level, figuring out the biochemistry of genes and proteins.  Today, such quantitative measurements can be carried out simultaneously on thousands of genes or proteins in an organism.  This has opened a new frontier of science, "Systems Biology", which aims to find mechanisms in these huge datasets and describe how thousands or millions of components work together in a biological system such as a cell, an organism, or a population.
* **Biology is multi-scaled** -- an organism can be considered at many scales, for example, the atomic and molecular scale (biochemistry), in terms of the internal structure and functioning of its organs and parts (physiology), and as a part of a much larger system both in space (ecology) and time (evolution). The relation between these scales can be treated by [reductionism or emergence](https://www.compadre.org/nexusph/course/Reductionism_and_emergence) -- going to smaller scales to explain something (reductionism), or seeing new phenomena arise as one goes to a larger scale (emergence).
* **Biology is integrative**-- Biological phenomena emerge from and must be consistent with the principles of chemistry, physics, and math. In other words, chemistry and physics constrain how an organism can behave or evolve. Therefore biologists must understand how physics and chemistry manifest themselves in biological organisms and higher-order systems. Increasingly, biologists searching for mechanisms of complex biological behavior are finding it valuable to use mathematical, physical, and chemical models in their research.

## Chemistry

Chemistry starts with the idea that all matter is made up of certain fundamental pieces - atoms of about 100 different kinds (elements) - and is about the ways those elements combine to form more complex structures - molecules.  But chemistry is not just about building molecules. It's about what you can do with that knowledge in our macroscopic world.

* **Chemistry is about how atoms interact to form molecules** - Understanding the basic principles of how atoms interact and combine is a fundamental starting point for chemistry.
* **Chemistry is about developing higher-level principles and heuristics** - Because there are so many different kinds of molecules possible, chemistry develops higher-level ideas that help you think about how complex reactions take place.
* **Chemistry frequently crosses scales**, connecting the microscopic with the macroscopic, trying to learn about molecular reactions from macroscopic observations and figuring out what is possible macroscopically from the way atoms behave. The connections are indirect, can be subtle, and may involve emergence.
* **Chemistry often assumes a macroscopic environment** - Much of what chemistry is about is not just idealized atoms interacting in a vacuum, but is about lots of atoms interacting in an environment, such as a liquid, gas, or crystal. In a water-based environment, the availability of H+ and OH- ions from the dissociation of water molecules in the environment plays an important role, while in a gas-based environment, the balance of partial pressures is critical.
* **Chemistry often simplifies**-- In chemistry, you often select the dominant reactions to consider, idealize situations and processes in order to allow an understanding of the most important features.

For a chemist, most of what happens in biology is "macroscopic" - there are lots and lots of atoms involved - even though you might need a microscope to study it. In introductory chemistry you often assume that reactions are taking place at standard temperature and pressure (300 K and 1 atm).

## Physics

The goal of physics is to find the fundamental laws and principles that govern all matter -- including biological organisms. Those laws and principles can lead to many types of complex and apparently different phenomena. Physics as traditionally taught at the introductory level tends to explicitly introduce four scientific skills that may seem different to what you see in introductory biology and chemistry classes, but these four skills will prove valuable for your career.

* **Physicists often spend a lot of time working out the simplest possible example** ("toy model") that illustrates a principle, even if that example appears not particularly interesting, relevant, or realistic. This lets you understand clearly and completely how the principle works.  This understanding then can be woven into more complex situations to produce a better sense of what's going on (although the embedding of the simplicity in a realistic, relevant, and complex situation is often omitted in traditional introductory physics classes).
* **Physicists quantify their view of the real world.** Although there is a lot of conceptual and qualitative reasoning in physics, physicists tend not to be satisfied until they can quantify what they are talking about. This is because purely qualitative reasoning can sometimes be misleading. While you can come up with an argument that says A happens, if you think carefully, you might also come up with an argument that says something different happens -- B. It's not until you can figure out that effect B is 1000 times bigger than effect A that you really know how to describe what's going on. This is just as true in biology and chemistry as physics, but physicists tend to introduce quantification sooner in the curriculum and more extensively than chemistry, which does it more in introductory classes than biology does.
* **Physicists think with equations.** This is more than just calculating numbers: physicists use equations to both organize their qualitative knowledge about what affects what and how, and to reason with in order to determine how things happen, what matters, and how much. Physicists go back and forth repeatedly between thinking conceptually about a problem and thinking mathematically about a problem, so that each of these ways of thinking sheds light on the other.
* **Physicists deal with realistic situations by modeling and approximating.** This means identifying what matters most in a complex situation and building up a fairly simple model that lets you get a good picture of what's happening. This is where the art lies in physics: in figuring out what can be ignored without losing what you want to look at. Einstein got it right when he said: "Physics should be as simple as possible, but not simpler."  All sciences do this, but because physics is about "anything and everything", physicists often assume that they can get away in introductory classes with choosing systems that may seem to be simplified to the point of irrelevance. This way of doing science is a bit different from the way biology is often done -- but elements of this approach and the constraints imposed on biology by the laws of physics are becoming increasingly important both for research biologists and health-care professionals.

## Math

Math is a bit different from the sciences. In its essence math is about abstract relationships. Since math is about abstract relationships and how they behave, it's not "about" anything in the physical world. But it turns out that a lot of relationships in science can be modeled by relations that obey mathematical rules, often very accurately.

Math as taught in math classes often is primarily about the abstract relationships -- learning how to use the tools of math. Making the transition to using math in real-world situations may be quite jarring as there are now additional things to pay attention to other than the math itself -- such as figuring out how the elements of the real-world system get translated into a mathematical model and worrying about whether the mathematical model is good enough or not.

Bringing these all together to permit coherent and productive thinking is a challenge! In this class we expect and encourage you to bring to bear knowledge you have from your other science classes -- to try to see how they fit together, support each other, and to learn to identify when a particular disciplinary approach might be most appropriate and useful.

# Difference Between Science and Engineering

Science and engineering are two streams that are taken by a lot of students these days. There are some who cannot appreciate the differences between science and engineering, ostensibly confused by the fact that engineers study those very science subjects that are studied by scientists.

**Science**

Understanding laws of nature such as those involving physics and chemistry is what science is all about. Science makes us knowledgeable about our world and how it works.

We know that it is the earth that revolves around the Sun, and we also know why we see lightening before we can hear the thunder. Science is basically enhancing our knowledge base by explaining nature to us. It is the science that tells us that how to solve problems in a logical fashion. Science expands our horizons through a knowledge base that is a creation of generations of scientists. The word science itself comes from the Latin word meaning knowledge.

All our knowledge about climate, environment, rivers, glaciers, mountains, biology genetics, diseases, medicines, space, evolution, etc is science. This knowledge is in the shape of testable premises, which is the main characteristic of science. Another notable feature of science is that it is rational and logical and can be explained and proved.

**Engineering**

Engineering is the study of the existing body of scientific knowledge to make its use to create new designs and structures. Thus, it is an application of all the body of knowledge that science has produced thus far. This includes totally new designs, as well as learning from past mistakes and creating faster, lighter, more efficient products.

Engineering is creating new products that are improvements upon existing designs making use of the same scientific principles. For example, in the field of mobile phones, every other month we find new and better mobiles with new features in the market. This is a result of the hard work, research, and dedication of the engineers who are always trying to bring better products for us.

**Science vs Engineering**

• Science is enhancing our knowledge about the universe and our surroundings in a rational and logical manner while engineering is the application of this scientific knowledge to create new and better products and designs

• Science is about how things work and not necessarily about new technologies

• Applied science comes closer to engineering as it thinks of making products that are more useful and better for human beings

• Engineering makes use of science and mathematical principles to come up with better and more efficient structures and designs

• Engineering can exist without science as it takes imagination, trial and error and fantasy to be able to create better products

Science is defined as the branch of [knowledge](http://www.differencebetween.net/language/difference-between-knowledge-and-information/) or the study that deals with a systematically arranged body of truths or facts which [can](http://www.differencebetween.net/language/difference-between-can-and-may/) be logically and rationally explained. It is [knowledge](http://www.differencebetween.net/language/difference-between-knowledge-and-skill/) of the physical and material world that is derived from oneï¿½s observation and experimentation.

It is closely related to philosophy, physics, chemistry, geology, and biology. It is divided into two major groups of empirical sciences wherein knowledge is based on phenomenon that can be observed and validated through research, namely:

ï¿½ Natural sciences, which study natural phenomenon such as biology.  
ï¿½ Social sciences, which study human behavior and society.  
Two other categories [are](http://www.differencebetween.net/language/difference-between-are-and-were/) based on specific fields of discipline like interdisciplinary and applied sciences such as:  
ï¿½ Mathematics, which is similar to empirical sciences because it involves the careful and systematic study of an objective. It is important in the formation of hypotheses, theories, and laws.  
ï¿½ Engineering, which is the discipline of gaining and using scientific, mathematical, economic, social, and practical knowledge to design and build machines, devices, and structures to improve the lives of the people.

Engineering, therefore, is a science that is broad and has four main branches:

ï¿½ Chemical engineering, which is the study of chemicals and their principles for the design and production of materials and fuels essential to man.  
ï¿½ Civil engineering, which involves the planning and construction of infrastructure like roads, bridges, and buildings.  
ï¿½ Electrical engineering, which includes design and production of electrical and electronic systems such as electrical and electronic circuits, devices, [computer](http://www.differencebetween.net/science/difference-between-human-and-computer/) systems, motors, telecommunication, etc.  
ï¿½ Mechanical engineering, which involves the design of physical and mechanical systems like aircraft, weapons, transportation, and other mechanical devices.

There are several more branches including naval engineering, architecture, biomedical, industrial, and nuclear engineering. Engineering applies the sciences of physics and mathematics and works with nature to design things that are [necessary](http://www.differencebetween.net/language/difference-between-necessary-and-sufficient/) to man.

One important tool that engineers use to help check their designs for flaws and mistakes is the computer. Computer-aided design (CAD) [software](http://www.differencebetween.net/category/technology/software-technology/) is used to create 3D models and drawings which allow engineers to analyze their designs without having to build prototypes.

Science is very helpful to man. It makes life easier, and it helps us in our search for knowledge, truth, and the creation of things that are essential to us.

Summary:

1. Science is the study of systematically arranged facts that can be logically explained while engineering is a branch of science that deals with the discipline of gaining and using scientific, mathematical, economic, and practical knowledge to design and produce machines and devices that are useful to man.  
2. Science has several classifications including natural science, social science, empirical and applied sciences while engineering has four main branches that include: chemical, mechanical, electrical, and civil engineering.  
3. Engineering uses different [scientific](http://www.differencebetween.net/science/difference-between-scientific-laws-and-scientific-theories/) fields in its pursuit of suitable designs and methods of producing devices for the benefit of man.  
4. Science is a collection of knowledge and validated systems while engineering is the utilization of these systems and knowledge to create devices and structures.

Both subjects require students to manipulate and test materials, engage in arguments based on evidence and work in teams, but there are crucial differences between the two fields. Before, during and after children engage in an engineering design challenge, it’s important to help them understand what makes each field distinct. These four questions can help you frame your explanation of the differences between engineering and science.

#### What’s the simple definition?

Science is the body of knowledge that explores the physical and natural world. Engineering is the application of knowledge in order to design, build and maintain a product or a process that solves a problem and fulfills a need (i.e. a technology).

#### What’s the procedure?

Scientists use the scientific method. Engineers use the engineering design process. The scientist starts with asking a question. Then they do background research, formulate a hypothesis, test that hypothesis by conducting an experiment, analyze the data and communicate their results. Engineers start by defining the problem, then they identify the criteria and constraints, brainstorm ideas, plan, create a technology and improve upon their design.

#### What’s the goal?

Scientists and engineers have different goals. Scientists seek to describe and understand the natural world. Engineers consider various criteria and constraints in order to design solutions to problems, needs and wants that better the lives of humans, animals and/or the environment.

#### What’s the result and impact?

Scientists use their varied approaches—controlled experiments or longitudinal observational studies—to generate knowledge. The final result might be a research paper or a book, and the knowledge therein can be used to help us understand and make predictions about the natural world. Engineers use scientific knowledge to create a technology. What does this mean in a real-world context? Use this example: a virologist is a scientist who researches how viruses are spread and how they affect the human body. A biomedical engineer can use the virologist's research to create an anti-viral drug that blocks a certain virus from spreading to new cells in the body.

In this way, both engineers and scientists are extremely important, and both fields benefit from the ingenuity and hard work of its counterpart. In some cases, scientists rely on the innovations that engineers design to further their research (e.g. microscopes or monitors), for example. To help students envision the wide range of careers and opportunities available to them, it’s important to reinforce distinctions between the fields and deepen their understanding and appreciation.