BIOL 1400 -- Scientific Method Notes

"To the intelligent man or woman, life appears infinitely mysterious. But the stupid have an answer for every question." --Edward Abbey

I. How is science actually *done*?

A. Gathering facts is important. . .
   1. . . . but which facts do you gather? How do you know what facts to look for?
   2. You can gather facts to try to work out a general "law of nature" -- this is called **induction**. But how do you know when you have enough facts? How do you know you've got the right ones?
   3. As one of the great scientists of the 1800s once wrote. . . About thirty years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service.

B. While induction, or **inductive methods**, are still useful in many ways, the most commonly used scientific method is the **hypothetico-deductive method**:
   1. A scientist observes something that isn't explained.
   2. She formulates a **hypothesis** -- statement about how some aspect of the world might work.
      a. Often it's best to come up with **multiple working hypotheses**.
      b. In other words, try to come up with several possible explanations for something, so you don't get too attached to any one.
   3. She then puts hypothesis or hypotheses through some sort of test. . .
      a. which might be a formal **experiment** (more on this later. . .)
      b. or less controlled **observations**.
   4. The hypothesis is either rejected, or provisionally accepted. . .
      a. . . . but it must *always* be subject to further testing.
      b. The test results will hopefully lead to more hypotheses

c. As you'll see later, a hypothesis that can't be tested isn't science.

C. Theory: a hypothesis that has been repeatedly tested and confirmed, **and** that is generally applicable in a wide range of situations.

1. *A very common error* is to assume that "theory" means "guess" or "speculation" or "assumption that some dweeb in a white coat pulled out of thin air."
2. The "Law of Gravity", radioactivity, the existence of atoms, bacteria causing disease, etc. are "only theories". . .
3. They have been so thoroughly tested, we can pretty much assume they're close to truth -- at least they seem to work adequately in the real world. . .
4. . . . but every now and then, even a well-tested theory gets shaken up and must be revised! (Example: Albert Einstein revolutionized the way people thought of the "Law of Gravity.")

D. There is **NO** absolute "proof" in science.

1. Any test of a hypothesis is limited in space and time.
2. But any theory that's interesting should go beyond what has been tested so far.
3. A good theory will be the source of **predictions** that themselves can be tested.
4. We can, however, **disprove** hypotheses and theories.
5. A statement that cannot be disproven is not a scientific one.

E. Science may not "get it right" the first time. In fact, it usually doesn't.

1. Scientists are anything but infallible -- the scientific community has its share of fools, idiots, bigots, close-minded arrogant twits, and even the occasional frauds and crooks. (Trust me on this; I've met all of them.)
2. Even good scientists make mistakes -- it happens all the time.
3. But science itself is **dynamic** and **self-correcting**.
4. Hypotheses that don't work eventually get torn down, or at least modified. Mistakes and frauds may last a while, but eventually they get questioned, exposed, and dropped.