The first person to ever observe and characterize cells was Robert Hooke in 1665, who observed the tiny holes that made up a slice of cork he was observing under one of the earliest microscopes. Those cell remnants were dead and hollow, so he had no idea what the internal structure of a living cell was like. It was not until 1674 that Anton van Leeuwenhoek first identified living cells (unicellular protists) under a microscope. Because they moved under their own power, he called them animalcules (“little animals”) not realizing that they were no more than single cells.

Further observations and work by Theodor Schwann, Matthias Jakob Schleiden, and Rudolf Virchow led to the development of cell theory, which has evolved over the decades as new discoveries about cells have been made.

I. Cell Theory
The original cell theory stated that

- All living organisms are composed of one or more cells.
- The cell is the basic structural and functional unit of life.
- Cells arise from pre-existing cells by a process of cell division.

Modern discoveries have added that

- Energy flow occurs within cells via metabolism and biochemical reactions.
- Genetic/heritable information is passed from cell to cell upon division.
- All cells have the same basic chemical composition.

Recall that there are two basic cell types, prokaryotic and eukaryotic. Bacteria and archaeans are prokaryotic (from the Greek pro, meaning “before” and karyon, meaning “nut”, which refers to the dark-staining nucleus prokaryotes don’t have). All other organisms, including protists, animals, fungi, and plants, are eukaryotes.

Be sure to refer to your lecture notes and text readings to review the basic components and anatomy of prokaryotic and eukaryotic cells. Note that prokaryotic cells, though they do divide in two to reproduce, do not undergo a cell cycle like that described here, which is unique to eukaryotes.

II. The Cell Cycle
One cannot truly understand biology without understanding the basic structure and function of a living cell. One of the most basic functions of cells is reproduction, whether asexual (mitosis) or sexual (meiosis). Scientists have characterized the life cycle of a cell, and we now know that the cell passes through defined stages as it lives. If you observe a population of living cells, whether part of an organism’s body or in a culture dish, you are likely to see cells in various phases of the cell cycle (Figure 1). The stages of active mitosis have been named for easy discussion and referral to the events occurring in each phase.

A. Interphase
Interphase is the cell cycle stage in which cells spend the majority of their time. An interphase cell is busy undergoing the chemical reactions that facilitate energy transfer, growing, and preparing to divide. Interphase is not part of mitosis, which is defined as active cell division. Rather, it is the living stage of the cell. The chromosomes cannot be clearly seen, as they are in the diffuse form known as chromatin. The genes on the chromosomes are actively being transcribed and translated, though which genes are active depends on the identity and function of the individual cell. The stages known as G1, S, and G2 occur during interphase, and are
involved in normal cell growth (G1), DNA synthesis (S), and protein and microtubule synthesis preceding mitosis (G2).

B. Prophase
Prophase is the first stage of mitosis. The chromosomes condense and become visible. Although they have already duplicated, the chromosomes are not yet visible as separate sister chromatids. The nuclear membrane breaks down, and the spindle fibers begin to form at opposite poles of the cell.

C. Metaphase
In this second phase of mitosis, the duplicated chromosomes unwind from each other, becoming visible as two identical sister chromatids attached only at a slightly constricted region, the centromere. It is only now that

the chromosomes take on the “X” shape so often seen in illustrations. But this “X” actually represents not one, but two chromosomes: the identical sister chromatids produced during DNA replication.

Spindle fibers attach to the kinetochore, a protein structure located at the centromere, and the chromosomes are arranged along the equator of the cell.

D. Anaphase
Spindle fibers shorten, the kinetochores separate, and the chromatids (daughter chromosomes) are pulled apart and begin moving to opposite poles.

E. Telophase
The daughter chromosomes arrive at the poles and the spindle fibers disappear.

III. Literature Search and Review
By now you have enough experience to be able to do a thorough literature search to give you some ideas on an interesting, relevant project. Remember that it is vital to discover what is already known about your area of interest (not to mention why it is important and relevant), so that you don’t simply repeat work that has already been done. Previous research should give you ideas about what questions still need to be addressed in this area.

Before your team begins to design a project examining some aspect of mitosis or cellular function, you should perform a literature search and review. (http://www.tcnj.edu/~library/research/guides/HowtoConductaLiteratureReview.htm).

A literature search is an organized search for published material on a selected topic. You will use databases that retrieve academic sources of high quality and reliability. Literature databases allow you to search a wide array of journals and other sources, and enable you to collect scholarly references. Some of these may be in the form of an abstract, whereas others might be the full text of a journal article. You can usually save these to your own computer for future reference.

An effective literature search takes an organized approach:
1. **Decide on a search topic**
With your team, formulate a question to narrow and define the topic. For some ideas, you might wish to read the next lab chapter, which provides an example of a possible research project. It is there to give you ideas, but you should not simply duplicate the example project.

2. **Use appropriate keywords to use in your search**
Identify important keywords. In the example above, you might include “mitosis, onion, spindle fiber, chromosome,” or any number of terms you wish to include that might generate interesting findings. Also consider:
- When to use broad terms, and when to use narrower terms to refine your search
- Use synonyms for your keywords to find every possible variant of the vocabulary used in the research on this topic.
- Use dictionaries to check spelling and find keyword synonyms
- Using online encyclopedias (e.g., Wikipedia) to find initial background information that might help you refine your search or choose an area for your research topic.

3. **Choose a Database**

GoogleScholar ([www.googlescholar.com](http://www.googlescholar.com)) is an excellent place to start, but there are other databases available through the UM library system that you may wish to use, as well.

4. **Perform your Search**
- Truncate (shorten) your keywords to make your search broader.
- If you are not sure how to spell a keyword, use wildcards ([http://www.oxfordscholarship.com/page/209/wildcards](http://www.oxfordscholarship.com/page/209/wildcards)).
- To narrow your search, use phrases enclosed on quotation marks. For example, “colchicine effect on spindle fibers”.
- Use the database to search for keywords in different places, such as “title” or “abstract”.
- If you find a useful article by a particular author, search that author’s name to find papers on the same topic.
- If you find a useful article, search its Literature Cited section to find additional, related sources.
- Make sure the literature you are citing is recent and current.
- Make sure the literature you use is from a peer-reviewed, scientific journal.
- Make sure to identify whether your source is a journal article, a book, a thesis, etc.

5. **Determine the availability of the material you wish to reference.**
If the paper you wish to read is not available online, you may be able to get a copy by contacting the people at the Richter Library Help Desk. If our library does not have the paper you need, they may be able to get it via interlibrary loan. Since this requires turnaround time, this is one very good reason to start this assignment immediately, and not find yourself hamstrung by time constraints.

Each student will be assigned the task of finding [at least one relevant paper](http://www.oxfordscholarship.com/page/209/wildcards) from a refereed scientific journal on the topic of mitosis/cellular function, and preferably narrowed to an area discussed in advance by your team during this lab session. Once you find a paper of interest, read it completely and analytically. Your assignment is to turn in (1) the journal paper and (2) a one-page summary and review of the paper to your instructor. At the end of your summary, include at least three observations/questions inspired by that research publication. One or more of these could lead your
team to an interesting and unique research project of your own design. Your laboratory instructor will give you additional details about this assignment.

Your literature search paper and summary are due at your next laboratory session, (whether or not there is a class meeting on that day). Your Laboratory Instructor will give you the information you need to turn this in on time.

**IV. Experimental Design**

Once you familiar with your model system via the literature, your team should view the chemicals in Table 1. These will be available in lab for your use in treating onion root tips, your model organism for this study of mitosis. Your team must look up the Material Safety Data Sheet (MSDS) for the active ingredient in any substance you choose to use. (Simply Google: MSDS [name of compound] and you will find the necessary information.) Remember that you must have a good rationale for choosing a particular compound. Be able to explain why your research idea is relevant and meaningful.

**Table 1.** Available compounds for use in treatment of onion root tips. NPK stands for Nitrogen, Phosphorus, Potassium, three of the most common ingredients in inorganic plant fertilizers. The percentage of each of the three elements is listed in order. For example, NPK fertilizer listed as 20-20-20 is 20% nitrogen, 20%, phosphorus, and 20% potassium.

<table>
<thead>
<tr>
<th>Commercial name</th>
<th>Purpose</th>
<th>Active ingredient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better-Gro fertilizer</td>
<td>NPK 20 – 13 – 13</td>
<td>n/a</td>
</tr>
<tr>
<td>Green Light</td>
<td>Root stimulator and starter solution, fertilizer</td>
<td>indole-3 butyric acid 0.0004%</td>
</tr>
<tr>
<td></td>
<td>NPK – 5 – 20 – 10</td>
<td></td>
</tr>
<tr>
<td>Preen</td>
<td>Weed preventer plus plant food</td>
<td>trifluralin 1.47%</td>
</tr>
<tr>
<td></td>
<td>NPK: 9 – 12 – 9</td>
<td></td>
</tr>
<tr>
<td>Round-Up</td>
<td>Weed and grass killer</td>
<td>glyphosate isopropylamine salt 2.0%, pelargonic acid and related fatty acids 2.0%</td>
</tr>
<tr>
<td>Spectracide</td>
<td>Lawn disease control</td>
<td>myclobutanil 2.0%</td>
</tr>
</tbody>
</table>

In the next exercise, you will gain laboratory experience that will help you determine what type of project you can undertake in the next lab sessions.