1: INTRODUCTION TO BOTANY

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CHAPTER OVERVIEW

1: Introduction to Botany

SECTION OVERVIEW

1.1: Introduction

Biology is the scientific study of living organisms and their interactions with one another and their environments. This is a very broad definition because the scope of biology is vast. Biologists may study small organisms, such as the microscopic blue-green algae that give us clues about the evolution of plants, or biomes such as the Mojave desert, shown here with a Joshua Tree in the foreground (Figure 1.1.1). Plant biology is the study of plants and their interactions with their environment.

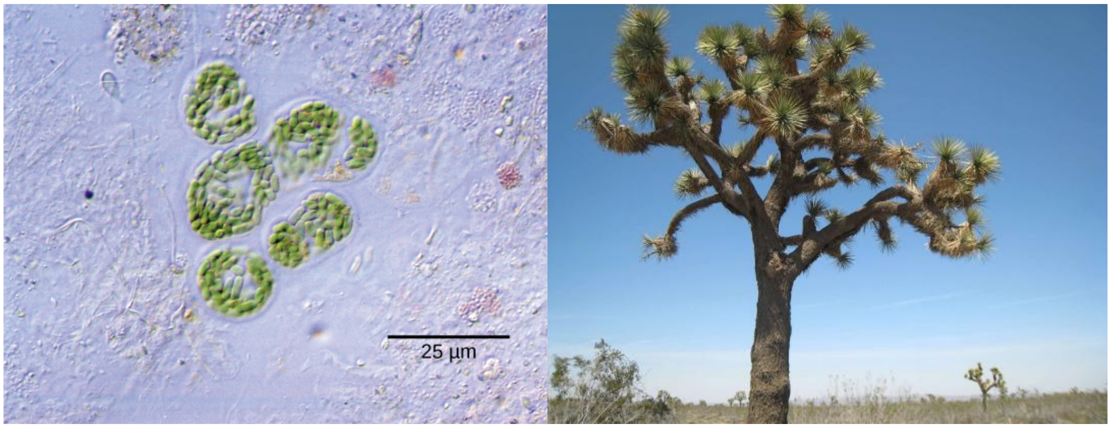

Figure 1.1.1: (a) Cyanobacteria, shown here at 300x magnification under a light microscope, are some of Earth's oldest life forms. (b) A Joshua Tree in the Mojave Desert. Credit a: modification of work by NASA; Credit b: Kammy Algiers (CC-BY).

Science (from the Latin scientia, meaning "knowledge") can be defined as knowledge of the physical or natural world through observation or experimentation. Scientists seek to understand the world and the way it operates. To do this, they use two methods of logical thinking: inductive reasoning and deductive reasoning. Biologists study the living world by posing questions about it and seeking science-based responses. The scientific method is a method of research with defined steps that include experiments and careful observation.

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1.1.1: The Scientific Method

Learning Objectives

- Identify the shared characteristics of the natural sciences.
- Summarize the steps of the scientific method.
- Compare inductive reasoning with deductive reasoning.
- Describe the goals of basic science and applied science.

The Process of Science

Science includes such diverse fields as astronomy, biology, computer sciences, geology, logic, physics, chemistry, and mathematics (Figure 1.1.1.1). However, those fields of science related to the physical world and its phenomena and processes are considered natural sciences. Natural sciences could be categorized as astronomy, biology, chemistry, earth science, and physics. One can divide natural sciences further into life sciences, which study living things and include biology, and physical sciences, which study nonliving matter and include astronomy, geology, physics, and chemistry. Some disciplines such as biophysics and biochemistry build on both life and physical sciences and are interdisciplinary. Natural sciences are sometimes referred to as “hard science” because they rely on the use of quantitative data; social sciences that study society and human behavior are more likely to use qualitative assessments to drive investigations and findings.

Not surprisingly, the natural science of biology has many branches or subdisciplines. Cell biologists study cell structure and function, while biologists who study anatomy investigate the structure of an entire organism. Those biologists studying physiology, however, focus on the internal functioning of an organism. Some areas of biology focus on only particular types of living things. For example, botanists explore plants, while zoologists specialize in animals.

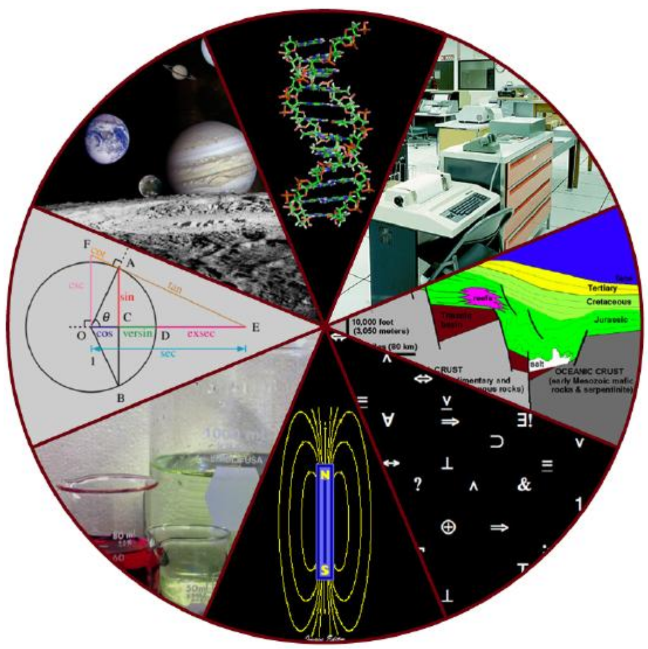

Figure 1.1.1.1: The diversity of scientific fields includes astronomy, biology, computer science, geology, logic, physics, chemistry, mathematics, and many other fields. (credit: “Image Editor”/Flickr)

Scientific Reasoning

One thing is common to all forms of science: an ultimate goal “to know.” Curiosity and inquiry are the driving forces for the development of science. Scientists seek to understand the world and the way it operates. To do this, they use two methods of logical thinking: inductive reasoning and deductive reasoning.

Inductive reasoning is a form of logical thinking that uses related observations to arrive at a general conclusion. This type of reasoning is common in descriptive science. A life scientist such as a biologist makes observations and records them. These data can be qualitative (descriptive) or quantitative (numeric), and the raw data can be supplemented with drawings, pictures, photos, or videos. From many observations, the scientist can infer conclusions (inductions) based on evidence. Inductive reasoning involves formulating generalizations inferred from careful observation and the analysis of a large amount of data.

Deductive reasoning, or deduction, is the type of logic used in hypothesis-based science. In deductive reason, the pattern of thinking moves in the opposite direction as compared to inductive reasoning; that is, specific results are predicted from a general premise. Deductive reasoning is a form of logical thinking that uses a general principle or law to forecast specific results. From those general principles, a scientist can extrapolate and predict the specific results that would be valid as long as the general principles are valid. Studies in climate change can illustrate this type of reasoning. For example, scientists may predict that if the climate becomes warmer in a particular region, then the distribution of plants and animals should change. These predictions have been made and tested, and many such changes have been found, such as the modification of arable areas for agriculture, with change based on temperature averages.

Inductive and deductive reasoning are often used in tandem to advance scientific knowledge (Example 1.1.1.1). Both types of logical thinking are related to the two main pathways of scientific study: descriptive science and hypothesis-based science. **Descriptive (or discovery) science**, which is usually inductive, aims to observe, explore, and discover, while **hypothesis-based science**, which is usually deductive, begins with a specific question or problem and a potential answer or solution that one can test. The boundary between these two forms of study is often blurred, and most scientific endeavors combine both approaches.

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Here is an example of how the two types of reasoning might be used in similar situations.

In inductive reasoning, where a conclusion is drawn from a number of observations, one might **observe** that members of a species are not all the same, individuals compete for resources, and species are generally adapted to their environment. This observation could then lead to the **conclusion** that individuals most adapted to their environment are more likely to survive and pass their traits to the next generation.

In deductive reasoning, which uses a general premise to predict a specific result, one might start with that conclusion as a general premise, then predict the results. For example, from that premise, one might predict that if the average temperature in an ecosystem increases due to climate change, individuals better adapted to warmer temperatures will outcompete those that are not. A scientist could then design a study to test this prediction.

The Scientific Method

Biologists study the living world by posing questions about it and seeking science-based responses. The **scientific method** is a method of research with defined steps that include experiments and careful observation. The scientific method was used even in ancient times, but it was first documented by England's Sir Francis Bacon (1561–1626; Figure 1.1.1.2), who set up inductive methods for scientific inquiry. The scientific method is not exclusively used by biologists but can be applied to almost all fields of study as a logical, rational problem-solving method.

It is important to note that even though there are specific steps to the scientific method, the process of science is often more fluid, with scientists going back and forth between steps until they reach their conclusions.

Figure 1.1.1.2: Sir Francis Bacon (1561–1626) is credited with being the first to define the scientific method. (credit: Paul van Somer)

Observation and Question

Scientists are good observers. In the field of biology, naturalists will often will make an observation that leads to a question. A **naturalist** is a person who studies nature. Naturalists often describe structures, processes, and behavior, either with their eyes or with the use of a tool such as a microscope. A naturalist may not conduct experiments, but they may ask many good questions that can lead to experimentation. Scientists are also very curious. They will research for known answers to their questions or run experiments to learn the answer to their questions.

Let's think about a simple problem that starts with an observation and apply the scientific method to solve the problem. One Monday morning, a student arrives at class and quickly discovers that the classroom is too warm. That is an observation that also describes a problem: the classroom is too warm. The student then asks a question: "Why is the classroom so warm?"

Proposing a Hypothesis

A **hypothesis** is an educated guess or a suggested explanation for an event, which can be tested. Sometimes, more than one hypothesis may be proposed. Once a hypothesis has been selected, the student can make a prediction. A prediction is similar to a hypothesis but it typically has the format "If . . . then . . . .".

For example, one hypothesis might be, "The classroom is warm because no one turned on the air conditioning." However, there could be other responses to the question, and therefore one may propose other hypotheses. A second hypothesis might be, "The classroom is warm because there is a power failure, and so the air conditioning doesn't work." In this case, you would have to test both hypotheses to see if either one could be supported with data.

A hypothesis may become a verified **theory**. This can happen if it has been repeatedly tested and confirmed, is general, and has inspired many other hypotheses, facts, and experimentations. Not all hypotheses will become theories.

Testing a Hypothesis

A valid hypothesis must be testable. It should also be **falsifiable**, meaning that it can be disproven by experimental results. Importantly, science does not claim to "prove" anything because scientific understandings are always subject to modification with further information. This step—openness to disproving ideas—is what distinguishes sciences from non-sciences. The presence of the supernatural, for instance, is neither testable nor falsifiable. To test a hypothesis, a researcher will conduct one or more experiments designed to eliminate one or more of the hypotheses. Each experiment will have one or more variables and one or more controls. A **variable** is any part of the experiment that can vary or change during the experiment. The **control group** contains every feature of the experimental group except that it was not manipulated. Therefore, if the results of the experimental group differ from the control group, the difference must be due to the hypothesized manipulation, rather than some outside factor. Look for the variables and controls in the examples that follow. To test the first hypothesis, the student would find out if the air conditioning is on. If the air conditioning is turned on but does not work, there should be another reason, and this hypothesis should be rejected. To test the second hypothesis, the student could check if the lights in the classroom are functional. If so, there is no power failure, and this hypothesis should be rejected. Each hypothesis should be tested by carrying out appropriate experiments. Be aware that rejecting one hypothesis does not determine whether or not the other hypotheses can be accepted; it simply eliminates one hypothesis that is not valid (Figure 1.1.1.3). Using the scientific method, the hypotheses that are inconsistent with experimental data are rejected.

While this "warm classroom" example is based on observational results, other hypotheses and experiments might have clearer controls. For instance, a student might attend class on Monday and realize she had difficulty concentrating on the lecture. One observation to explain this occurrence might be, "When I eat breakfast before class, I am better able to pay attention." The student could then design an experiment with a control to test this hypothesis.

Visual Connection

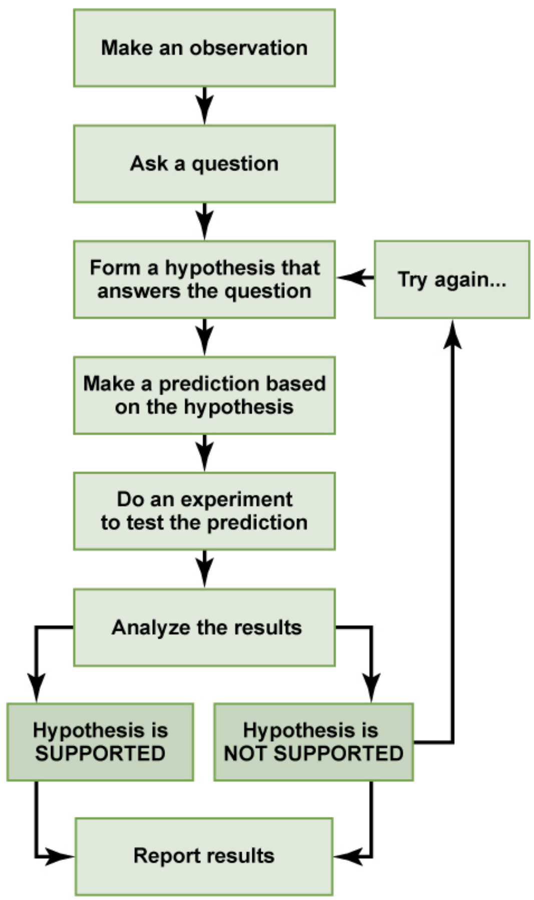

Figure 1.1.1.3: The scientific method consists of a series of well-defined steps. In step 1, an observation is made. In step 2, a question is asked about the observation. In step 3, an answer to the question, called a hypothesis, is proposed. In step 4, a prediction is made based on the hypothesis. In step 5, an experiment is done to test the prediction. In step 6, the results are analyzed to determine whether or not the hypothesis is correct. If a hypothesis is not supported by experimental data, one can propose a new hypothesis. In either case, the results are reported.

The scientific method may seem too rigid and structured. It is important to keep in mind that, although scientists often follow this sequence, there is flexibility. Sometimes an experiment leads to conclusions that favor a change in approach; often, an experiment brings entirely new scientific questions to the puzzle. Many times, science does not operate in a linear fashion; instead, scientists continually draw inferences and make generalizations, finding patterns as their research proceeds. Scientific reasoning is more complex than the scientific method alone suggests. Notice, too, that the scientific method can be applied to solving problems that aren't necessarily scientific in nature (Example 1.1.1.2).

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In the example below, the scientific method is used to solve an everyday problem. Match the scientific method steps (numbered items) with the process of solving the everyday problem (lettered items). Based on the results of the experiment, is the hypothesis correct? If it is incorrect, propose some alternative hypotheses.

Steps of the Scientific Method

1. Observation
2. Question
3. Hypothesis (answer)
4. Prediction
5. Experiment
6. Result

Process of Solving an Everyday Problem

A. There is something wrong with the electrical outlet.
B. If something is wrong with the outlet, my coffee maker also won't work when plugged into it.
C. My toaster doesn't toast my bread.
D. I plug my coffee maker into the outlet.
E. My coffee maker works.
F. Why doesn't my toaster work?

Two Types of Science: Basic Science and Applied Science

The scientific community has been debating for the last few decades about the value of different types of science. Is it valuable to pursue science for the sake of simply gaining knowledge, or does scientific knowledge only have worth if we can apply it to solving a specific problem or to bettering our lives? This question focuses on the differences between two types of science: basic science and applied science.

Basic science or "pure" science seeks to expand knowledge regardless of the short-term application of that knowledge. It is not focused on developing a product or a service of immediate public or commercial value. The immediate goal of basic science is knowledge for knowledge's sake, though this does not mean that, in the end, it may not result in a practical application.

In contrast, **applied science** or "technology," aims to use science to solve real-world problems, making it possible, for example, to improve a crop yield or find a cure for a particular disease. In applied science, the problem is usually defined for the researcher.

Some individuals may perceive applied science as "useful" and basic science as "useless." A question these people might pose to a scientist advocating knowledge acquisition would be, "What for?" A careful look at the history of science, however, reveals that basic knowledge has resulted in many remarkable applications of great value. Many scientists think that a basic understanding of science is necessary before an application is developed; therefore, applied science relies on the results generated through basic science. Other scientists think that it is time to move on from basic science and instead to find solutions to actual problems. Both approaches are valid. It is true that there are problems that demand immediate attention; however, few solutions would be found without the help of the wide knowledge foundation generated through basic science.

One example of how basic and applied science can work together to solve practical problems occurred after the discovery of DNA structure led to an understanding of the molecular mechanisms governing DNA replication. Strands of DNA, unique in every human, are found in our cells, where they provide the instructions necessary for life. During DNA replication, DNA makes new copies of itself, shortly before a cell divides. Understanding the mechanisms of DNA replication enabled scientists to develop laboratory techniques that are now used to identify genetic diseases, pinpoint individuals who were at a crime scene, and determine paternity. Without basic science, it is unlikely that applied science would exist.

Another example of the link between basic and applied research is the Human Genome Project, a study in which each human chromosome was analyzed and mapped to determine the precise sequence of DNA subunits and the exact location of each gene. (The gene is the basic unit of heredity; an individual's complete collection of genes is their genome.) Other less complex organisms have also been studied as part of this project in order to gain a better understanding of human chromosomes. The Human Genome Project (Figure 1.1.1.4) relied on basic research carried out with simple organisms and, later, with the human genome. An important end goal eventually became using the data for applied research, seeking cures and early diagnoses for genetically related diseases.

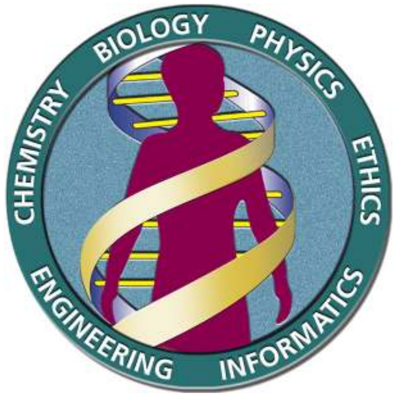

Figure 1.1.1.4: The Human Genome Project was a 13-year collaborative effort among researchers working in several different fields of science. The project, which sequenced the entire human genome, was completed in 2003. (credit: The U.S. Department of Energy Genome Programs)

While research efforts in both basic science and applied science are usually carefully planned, it is important to note that some discoveries are made by **serendipity**, that is, by means of a fortunate accident or a lucky surprise. Penicillin was discovered when biologist Alexander Fleming accidentally left a petri dish of *Staphylococcus* bacteria open. An unwanted mold grew on the dish, killing the bacteria. The mold turned out to be *Penicillium*, and a new antibiotic was discovered. Even in the highly organized world of science, luck—when combined with an observant, curious mind—can lead to unexpected breakthroughs.

Reporting Scientific Work

Whether scientific research is basic science or applied science, scientists must share their findings in order for other researchers to expand and build upon their discoveries. Collaboration with other scientists—when planning, conducting, and analyzing results—are all important for scientific research. For this reason, important aspects of a scientist's work are communicating with peers and disseminating results to peers. Scientists can share results by presenting them at a scientific meeting or conference (Figure 1.1.1.5), but this approach can reach only the select few who are present. Instead, most scientists present their results in **peer-reviewed manuscripts** that are published in scientific journals. Peer-reviewed manuscripts are scientific papers that are reviewed by a scientist's colleagues, or peers. These colleagues are qualified individuals, often experts in the same research area, who judge whether or not the scientist's work is suitable for publication. The process of peer review helps to ensure that the research described in a scientific paper or grant proposal is original, significant, logical, and thorough. Grant proposals, which are requests for research funding, are also subject to peer review. Scientists publish their work so other scientists can reproduce their experiments under similar or different conditions to expand on the findings. The experimental results must be consistent with the findings of other scientists.

Figure 1.1.1.5: Scientific conferences are one means of reporting scientific findings. Often, scientists present findings that they plan to publish or have recently published at conferences. These are the recipients of PLANTS Grant for undergraduates to attend BOTANY 2018, a conference organized by the Botanical Society of America. Image by The Botanical Society of America (CC-BY-NC-SA).

A scientific paper is very different from creative writing. Although creativity is required to design experiments, there are fixed guidelines when it comes to presenting scientific results. First, scientific writing must be brief, concise, and accurate. A scientific paper needs to be succinct but detailed enough to allow peers to reproduce the experiments.

The scientific paper consists of several specific sections—introduction, materials and methods, results, and discussion. This structure is sometimes called the "IMRaD" format, an acronym for Introduction, Method, Results, and Discussion. There are usually acknowledgment and reference sections as well as an **abstract** (a concise summary) at the beginning of the paper. There might be additional sections depending on the type of paper and the journal where it will be published; for example, some review papers require an outline.

The **introduction** starts with brief, but broad, background information about what is known in the field. A good introduction also gives the rationale of the work; it justifies the work carried out and also briefly mentions the end of the paper, where the hypothesis or research question driving the research will be presented. The introduction refers to the published scientific work of others and therefore requires citations following the style of the journal. Using the work or ideas of others without proper citation is considered plagiarism.

The **materials and methods** section includes a complete and accurate description of the substances used, and the method and techniques used by the researchers to gather data. The description should be thorough enough to allow another researcher to repeat the experiment and obtain similar results, but it does not have to be verbose. This section will also include information on how measurements were made and what types of calculations and statistical analyses were used to examine raw data. Although the materials and methods section gives an accurate description of the experiments, it does not discuss them.

Some journals require a results section followed by a discussion section, but it is more common to combine both. If the journal does not allow the combination of both sections, the results section simply narrates the findings without any further interpretation. The **results** are presented by means of tables or graphs, but no duplicate information should be presented. In the **discussion** section, the researcher will interpret the results, describe how variables may be related, and attempt to explain the observations. It is indispensable to conduct an extensive literature search to put the results in the context of previously published scientific research. Therefore, proper citations are included in this section as well.

Finally, the **conclusion** section summarizes the importance of the experimental findings. While the scientific paper almost certainly answered one or more scientific questions that were stated, any good research should lead to more questions. Therefore, a well-done scientific paper leaves doors open for the researcher and others to continue and expand on the findings.

Review articles do not follow the IMRaD format because they do not present original scientific findings (they are not primary literature); instead, they summarize and comment on findings that were published as primary literature and typically include extensive reference sections.

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1.1.2: Organisms Studied in Botany

Learning Objectives

Describe the importance of plants in the study of botany and list other organisms that typically included in the study of botany.

Botany is the scientific study of plants and organisms that were historically considered plantlike. It helps us understand why plants are so vitally important to the world. Plants start the majority of food and energy chains, they provide us with oxygen, food and medicine. Most plants are what you typically think of: multicellular eukaryotic organisms that are ancestrally terrestrial and photosynthesize. In the process of photosynthesis, these organisms produce their own food, using sunlight, carbon dioxide, and water into organic molecules, or food. However, some organisms ecologically are considered plant-like due ot their role in nature. For example, green slugs, *Elysia chlorotica* (see Figure 1.1.2.1) collect chloroplasts from algae and use them for their entire life as food producers. Therefore, green slugs, while technically classified as animals, have plantlike characteristics.

Figure 1.1.2.1: Green slug *Elysia chlorotica* captures chloroplasts from the alga *Vaucheria litorea*.

Plants are in the domain Eukarya and in the kingdom Plantae. There are about 320,000 species of plants that have been named so far. They fill our terrestrial ecosystem and provide food and shelter for animals. Plants cells contain chloroplasts, which conduct photosynthesis. They are thus **autotrophic**, synthesizing their own organic carbon. In addition, most of the plant cell is filled with a large membrane-bound structure, the central vacuole, which functions in store. Plant cells are surrounded by rigid cell walls containing cellulose. Plants are multicellular, composed of like cells that function as tissue. Their leaves, stems, and roots function as organs. Plants can be small like duckweed or large like the giant sequoia (Figure 1.1.2.2).

Figure 1.1.2.2. On top, two species of duckweeds (*Wolffia globosa* and *Spirodela polyrhiza*). . On the bottom, Giant Sequoias from King Canyon National Park. Copyright Eric Guinther (CC BY-SA 3.0) for top image, Kammy Algiers (CC-BY) bottom image.

While fungi are neither closely related to plants, nor do they share key characteristics (like photosynthesis), they are sometimes included in the study of botany. Perhaps this is because the fruiting bodies that some fungi use for reproduction (such as mushrooms) may seem plantlike in the sense that they a stationary structures emerging from the soil. Fungi are **heterotrophic**, meaning that they feed on other organisms to obtain organic carbon. Unlike animals, which ingest their food, fungi secrete digestive enzymes to breakdown large molecules surrounding them. They then absorb the smaller molecules. Fungal cells are surrounded by rigid cell walls that contain the polysaccharide chitin. Some fungi are unicellular while other are multicellular.

Although fungi and plants are not closely related, their are intertwined ecologically. For example, mycorrhizae are fungi that grow in or on plant roots and assist with nutrient absorption. Additionally, fungi often decompose dead plant material, releasing nutrients back into the soil and promoting further plant growth.

Other organisms studied in botany are "protists", which have complex, eukaryotic cells but are not plants, animals, or fungi. Some "protists", like slime molds, resembling fungi in the sense that they are heterotrophic. Other "protists" superficially resemble plants in that they conduct photosynthesis and are autotrophic. These are collectively called **algae**, but they arise from many different groups, and some are not closely related to plants at all. Multicellular algae are sometimes called **seaweeds**. Most algae have cell walls, which may or may not contain cellulose.

Photosynthetic prokaryotes, which have simple cells, are sometimes studied in botany as well. For example, **cyanobacteria**, are commonly called blue-green algae, but this is a misnomer because true algae are eukaryotes. Instead, cyanobacteria are photosynthetic bacteria, that often form filaments of cells. Bacteria that are pathogens of plants may also be included in the study of botany. Viruses, which are infectious particles that contain protein and nucleic acid, can also infect plant cells. Unlike plants, fungi, "protists", and prokaryotes, viruses are not technically considered organisms because they are not composed of cells.

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1.1.3: Intro to Evolution

Learning Objectives

- Describe the role of evolution in the history of life.
- Describe the role of natural selection in evolution.

The history of life on Earth goes back more than three and a half billion years. This past serves as a key to understanding the diversity of life. A unifying theme that can be employed throughout this course to boost biology from an overwhelming sea of facts to a coherent study of life is the theory of evolution. Evolution explains both the diversity and unity of life. Through time, some species evolved adaptations that increased their ability to survive and reproduce in their environment. This gave them an evolutionary advantage to other species. **Natural selection**, the most dominant evolutionary force, is a main mechanism that is responsible for the diversity of species on Earth today. Yet, it is through evolution that we also understand the unity of all life. All living organisms today can be followed back to a common ancestor. Scientific evidence from this is extensive and includes data from fossils, genetics, cell biology, and molecular biology, just to name a few. Through descent with modification, our common ancestors gave rise to the species we see on Earth today.

Figure 1.1.3.1: A glimpse at the diversity of wildflowers in Figueroa Mountain, California. Left: chocolate lily (*Fritillaria biflora*). Middle: California poppies (*Eschscholzia californica*) and lupines (*Lupinus sp.*) Right: shooting stars (*Dodecatheon sp.*). Image by Kammy Algiers (CC-BY)

Evolution

Evolution can be defined as the change in the genetic make up of a population over time (or, for short, change over time). It is important to note that the change happens from one generation to the next. Thus, an individual cannot evolve because their genes do not change throughout their lifetime. However, a population, a community, or an ecosystem can change over time, as can a species or a group of species. The time it takes for evolution to occur is better described as generation time. This can be very short (minutes for a bacterium), or very long (a century or more for a sea turtle). It is the time it takes for one generation of individuals to reproduce and pass their genes down to the next generation. Charles Darwin's book "*On the Origin of Species"* published in 1859 described and popularized the theory of evolution and proposed a mechanism for evolution he called natural selection. Independently, Alfred Russell Wallace also introduced the concept of natural selection.

Natural Selection

There are many forces or mechanisms that cause evolution. However, natural selection is a key mechanism as it is the one that produces adaptive traits. For natural selection to occur, several conditions must be met:

1. The population must contain genetic variation in the trait. This means the differences in the traits of the individuals within the population.
2. The trait must be heritable. This means the individual receives the genetic information for the specific trait from their parent(s).

3. There must be variation in fitness as a result of the trait. This means that some traits result in the individuals with higher reproductive success (they have more offspring) than others.

If these three criteria are met, individuals with the most adaptive trait for the current environment will have more offspring, and thus the adaptive traits will accumulate in the environment.

1.1.4: Life Cycles

Learning Objectives

- Describe the role of ploidy in the haplodiplontic (alternation of generations) life cycle of plants.
- Compare and contrast gametophyte and sporophyte generations.

Organisms or cells that contain two copies of each chromosome are considered **diploid, or 2n** (they contain homologous chromosomes in pairs that were acquired from their parents). Organisms or cells that contain one set of chromosomes are considered **haploid, or n**, meaning they only contain one of each chromosome, either material or paternal. Your body cells are diploid and contain pairs of chromosomes. Your gametes (egg and sperm cell) are haploid and contain unpaired chromosomes. For more on ploidy, see Biology 2e 11.1 Meiosis.

Plants have a **haplodiplontic (alternations of generations) life cycle**. In plants, there are two distinct generations that alternate: the gametophyte and the sporophyte generation. The gametophyte begins as a single-celled spore that germinate into a multicellular life stage. This mature gametophyte life stage is haploid and by **mitosis** (division of cells with identical genetic information) produces gametes. These gametes are either egg or sperm cells. Often cross fertilization occurs where the sperm cell of one plant individual fertilizes the egg cell of another plant individual. The results is a fertilized egg, or **zygote**, which is diploid. This begins the sporophyte generation in plants. The sporophyte then divides into a multicellular life stage (division occurs by mitosis). This mature sporophyte will now produce spores by meiosis, a type of cell division that reduces chromosome numbers to half. The sporophyte is diploid, but the spores are haploid. The spores disperse and germinate into new gametophytes, repeating the process (see Figure 1.1.4.1).

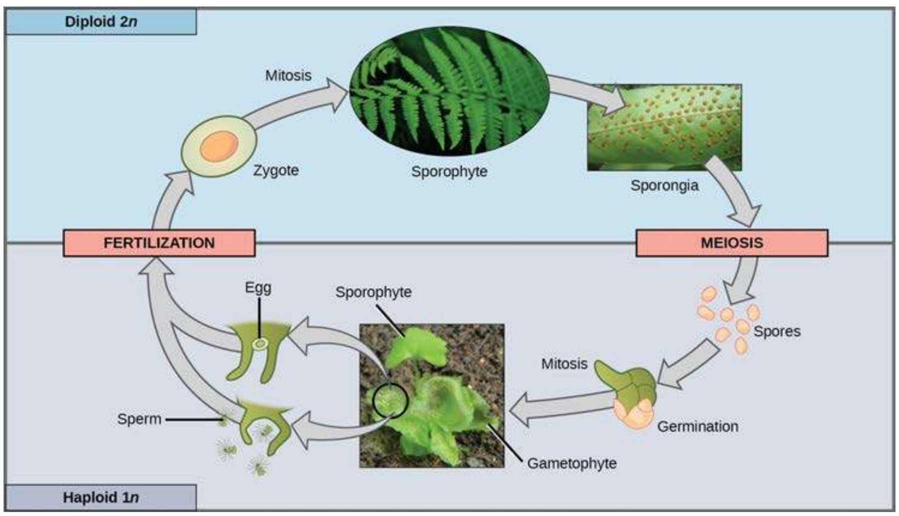

Figure 1.1.4.1: The plant life cycle is haplodiplontic (alternations of generations). Fern is shown as an example. The haploid (n) multicellular life stage is called the gametophyte as it produces gametes (egg and sperm cells) that fuse during fertilization to form a diploid (2n) zygote. This zygote develops into a mature diploid sporophyte by mitosis, carrying both genetic information from the fused gametes. The mature sporophyte produces spores by meiosis, which are haploid. The spores germinate by mitosis to develop into a mature multicellular gametophytes, which is still haploid. The life cycle continues as gametes are produced (OpenStax licensed CC-BY).

Note that both the gametophyte and sporophyte are mature plants. However, they reproduce in different ways and have different chromosome counts. The gametophyte generation produces gametes by mitosis that are fertilized, undergoing sexual reproduction. The sporophyte generation produces spores by meiosis that are dispersed. Both gametophyte and sporophytes grow by mitosis.

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1.1.5: Subfields and Applications in Plant Biology

Learning Objective

Describe the various subdisciplines of plant biology.

Branches of Plant Biology

The scope of biology is broad and therefore contains many branches and subdisciplines. The branch of plant biology can further be divided into many subdisciplines as well. Botanists may pursue one of those subdisciplines and work in a more focused field. Botany's origins come from ancient studies of herbal medicine. Even today, **ethnobotany** focuses on the traditional knowledge and practical uses of plants in medicine, religion, food, etc.

An **agronomist** or **agricultural scientist**, is a scientist who studies crops. Their focus may include crop quality, growth, nutrition, or disease. George Washington Carver (1860-1943) was an American agricultural scientists who revolutionized crop rotation (Figure 1.1.5.1). He found that by planting different crops in the same location, the nutrients such as nitrogen in the soil are replenished. He promoted planting peanuts as part of the rotation.

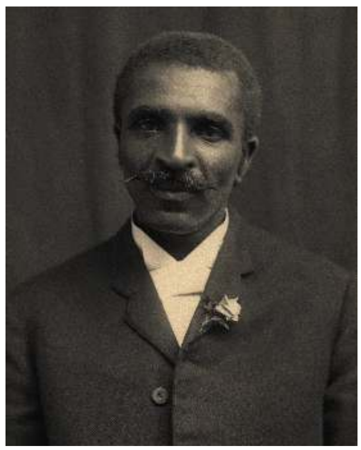

Figure 1.1.5.1: George Washington Carver was an American agricultural scientist and inventor who promoted crop rotation to prevent soil depletion. He was the most prominent Black scientist of the early 20th century. (Wikipedia; Public Domain)

Phytochemists are plant biochemists who study chemical substances of plants. This is a field that incorporates chemistry as well as biology. These compounds can be studied for medicine, culinary purposes, or as dyes and building material. Some botanists study plant hormones so they can understand the mechanisms of plant growth and regulation. A **plant geneticist** would study plant genes, often working to create new varieties of plants or crops. **Molecular biology** biological processes at the molecular, including interactions among molecules such as DNA, RNA, and proteins, as well as the way they are regulated. A plant molecular biologist would be interested in these aspects of plants. A **plant physiologist** would study the internal chemical and physical activities of plants and plant metabolism. **Plant anatomy** would focus on the structures of plants.

A **systematic botanist** studies the diversity of plants and their evolutionary relationships. **Paleobotanists** study plant fossils and are interested in understanding past environments and ancient plant types. This can also aid in our understanding of the evolution of modern plants.

Plant ecologists are scientists that study the interaction of plants with their environments. Plant ecologists can focus on populations, communities, or ecosystem interactions. **Restoration ecologists** and **conservation biologists** focus on the the negative impacts of the environment. The restoration ecologist works to reverse environmental impacts caused by human disturbance. Conservation biologists focus on preserving and maintaining existing habitat. There is often a focus on policy change. In many circumstances these two fields overlap with one another and overlap with other disciplines. Many government employees who focus on the environment are involved in restoration, conservation, and promote education, public engagement, and awareness of the environment.

Contributors and Attributions

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1.1.6: Chapter Summary

Biology is the science that studies living organisms and their interactions with one another and their environments. **Plant biology** is the study of plants and their interactions with their environment. **Science** (from the Latin scientia, meaning “knowledge”) can be defined as knowledge of the physical or natural world through observation or experimentation. Science attempts to describe and understand the nature of the universe in whole or in part by rational means. Science has many fields; those fields related to the physical world and its phenomena are considered **natural sciences**.

Scientists seek to understand the world and the way it operates. To do this, they use two methods of logical thinking: inductive reasoning and deductive reasoning. **Inductive reasoning** uses particular results to produce general scientific principles. **Deductive reasoning** is a form of logical thinking that predicts results by applying general principles. The common thread throughout scientific research is the use of the **scientific method**, a step-based process that consists of making observations, defining a problem, posing **hypotheses**, testing these hypotheses, and drawing one or more conclusions. The testing uses proper controls. Scientists present their results in **peer-reviewed** scientific papers published in scientific journals.

Science can be basic or applied. The main goal of **basic science** is to expand knowledge without any expectation of short-term practical application of that knowledge. The primary goal of **applied science**, however, is to solve practical problems.

A scientific **research paper** consists of several well-defined sections: introduction, materials and methods, results, and, finally, a concluding discussion. **Review papers** summarize the research done in a particular field over a period of time.

Plants are vitally important to the world. Plants start the majority of food and energy chains, they provide us with oxygen, food and medicine. Most plants are what you typically think of: multicellular eukaryotic organisms that are ancestrally terrestrial and photosynthesize. They have a **haplodiplontic life cycle**, which alternates between two multicellular life stages: the haploid **gametophyte** and the diploid **sporophyte**. Fungi, photosynthetic prokaryotes, algae, and some heterotrophic "protists" are also commonly studied as part of **botany**.

The history of life on Earth goes back more than three and a half billion years. A unifying theme that can be employed throughout this course to boost biology from an overwhelming sea of facts to a coherent study of life is the **theory of evolution**. Evolution explains both the diversity and unity of life. Through time, some species evolved adaptations that increased their ability to survive and reproduce in their environment. This gave them an evolutionary advantage to other species. **Natural selection**, the most dominant evolutionary force, is a main mechanisms that is responsible for the diversity of species on Earth today.

A few examples of subfields of plant biology are **ethnobotany**, **agriculture science**, **phytochemistry**, **systematic botany**, and **plant ecology**.

After completing this chapter, you should be able to...

- Identify the shared characteristics of the natural sciences.
- Summarize the steps of the scientific method.
- Compare inductive reasoning with deductive reasoning.
- Describe the goals of basic science and applied science.
- Describe the importance of plants in the study of botany and list other organisms that typically included in the study of botany.
- Describe the role of evolution in the history of life.
- Describe the role of natural selection in evolution.
- Describe the role of ploidy in the haplodiplontic (alternation of generations) life cycle of plants.
- Compare and contrast gametophyte and sporophyte generations.
- Describe the various subdisciplines of plant biology.