OPCOM® Farm
Advanced Hydroponics + STEM

BY: STATE RENEWABLE ENERGY

CHAPTER 1

INTRODUCTION TO HYDROPONICS

Hydroponics is the process of growing plants in a soilless environment using nutrient solutions dissolved in water. Variations of hydroponic technologies date back to ancient times. The term hydroponics was created in the 1930s, when significant research led to functional hydroponic systems that were used by commercial airlines and the United States military to provide food for crews and soldiers in remote locations. In this chapter, we will cover the basics.

Section 1

What are Hydroponics?

STEM Topics to be Covered

- What are Hydroponics?
- History of Hydroponics
- Controlled Environment Agriculture
- Hydroponic Basics
- Functions of Indoor Hydroponics

Every growing plant needs three basic things: ***light, water, and nutrients***. In traditional agriculture, plants grow outside and the sun provides the light, irrigation systems supply the water, and the soil provides the nutrients the plants need to grow. Hydroponics is a different form of agriculture that is done indoors and it refers to the cultivation of plants in nutrient-rich water without the use of soil. Since hydroponics are an indoor technology, lighting is essential. Hydroponic systems can be integrated into greenhouses where they use natural lighting from the sun or they can be integrated in any building through the use of artificial lighting. Also, since soil typically provides growing plants the nutrients they need, in hydroponics, it is necessary to supplement the water with the fourteen essential nutrients and minerals plants need. In Latin, Hydroponics stems from the words “hydro,” meaning water, and “ponos,” meaning work. Literally translated, hydroponics means “working water.”

> In Latin, Hydroponics means “working water.”

HISTORY OF HYDROPONICS

The concept of growing plants without soil dates back to ancient times. Considered one of the Seven Ancient Wonders of the World, the Hanging Garden of Babylon, which date back to around 600 BC, were considered to be terraced gardens of "hanging" plants that utilized an ornate irrigation system and water from the nearby Euphrates River.

John Woodward, a British botanist, physician, and geologist in the late 1600s, published his experiments with growing spearmint in various environments, including soil and soilless conditions. He determined water alone was not the only contributor to plant growth rates, but that plants specifically needed components from soil for growth.

In the late 1700s, English Scientist, Joseph Priestly, discovered that plants release oxygen into the air during photosynthesis, the process by which plants turn carbon dioxide and water into glucose for food. Priestly's experiments showed that plants emit enough oxygen into an atmosphere void of oxygen to keep a mouse alive. This was an important development in reference to lighting that has been developed for modern-day hydroponic systems.

During the mid 1800s, numerous scientists did research into what nutrients plants needed to successfully grow in water. In 1860, Professor Julius von Sachs of the University of Wurzburg published the first standard formula for water soluble nutrients to grow plants in water without soil. By the early 1900s, commercial greenhouse farmers began looking into the technology since it used significantly less water than traditional farmer and also reduced the risk of pests that are commonly found in soil. However, it wasn't until the late 1930s that the term hydroponics was actually used to describe growing plants in nutrient water without soil. During the late 1920s and early 1930s, Dr. William F. Gericke of the University of California expanded his research into growing plants in water, and he used the term "hydroponics" to describe these technologies.

As the technology advanced, it was determined that hydroponics were ideal for use in arid climates and remote locations. During the 1930s, Pan-AM airlines used hydroponic technologies to grow beans, tomatoes, and vegetables to feed the airline's staff and crew at a refueling station on Wake Island in the Pacific Ocean.

> Pan-Am Airlines used hydroponics in the 1930s.

In 1945, the United States Air Force used hydroponic technologies to provide fresh vegetables to American troops stationed on barren islands in both the South Atlantic Ocean and Pacific Ocean.

CONTROLLED ENVIRONMENT AGRICULTURE

Growing produce indoors changes many things, including planting cycles, harvesting, weather conditions, and pest management. Controlled environment agriculture is the term used to describe the practice of growing food indoors in a controlled environment, whether it be in a greenhouse, a building, or even a warehouse. Indoor growing uses either natural light from the sun or artificial light to provide plants with the protons they need to photosynthesize, or simply put, grow. Controlled environment agriculture, or indoor growing, is a rapidly growing industry that is helping to bring fresh, high-quality, local produce to people all over the world.

HYDROPONIC BASICS

There are many types of hydroponic technologies, however, they all operate with a few things common. Hydroponic systems typically feature pumps to circulate water, lights to provide plants with the photons they need to grow, nutrients to give the plants the right elements, a basin for holding water, and growing medium for securing the planted seeds. Each of these elements can be designed in a way that caters to growing a specific type of plant.   OPCOM Farm offers a variety of hydroponic technologies for a wide range of uses.

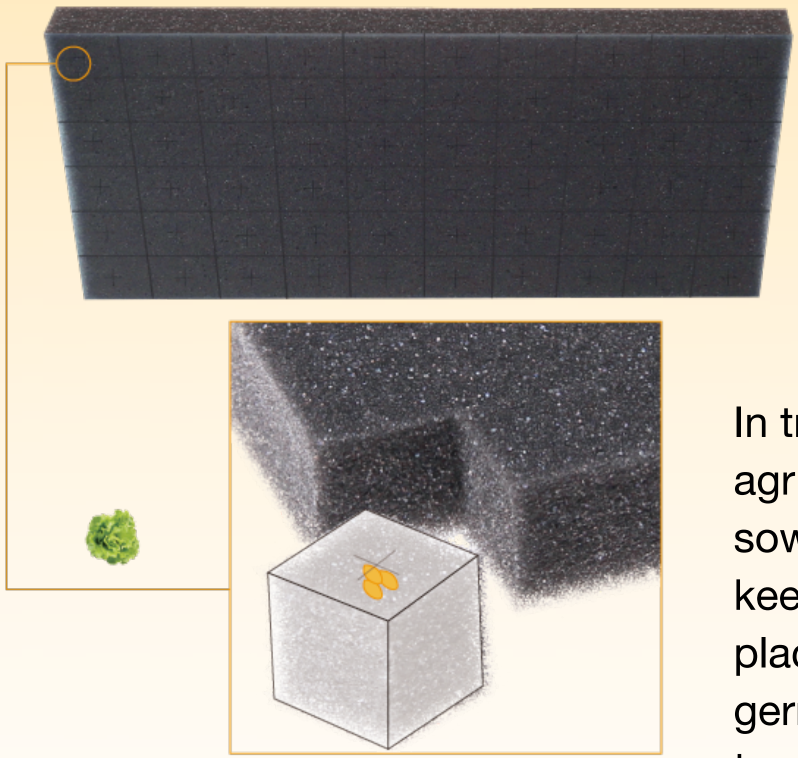
FUNCTIONS OF INDOOR HYDROPONICS

Studies show that plants naturally filter air. Plants grown indoors can help remove toxicants and absorb pollutants by metabolizing them into harmless by-products. In addition to purifying air, plants also add an aesthetic element to indoor spaces. The vibrant green color can beautify the indoor environment, which has been shown to increase alertness and release eye fatigue. Furthermore, hydroponically grown plants are bring fresh, local produce to places that with limited resources.

Hydroponic Growing Mediums

STEM TOPICS TO BE COVERED

- Hydroponic Growing Mediums
- Organic Growing Mediums
  - Coconut Fiber, Rice Hulls, Peat Moss, Sphagnum, Sawdust, Tree Bark
- Inorganic Growing Mediums
  - Gravel, Expanded Clay Aggregate, Rockwool, Vermiculite, Perlite, Plastic Fiber, Foam Sponges



In traditional agriculture, seeds are sown in soil. The soil keeps the seeds in place while the seed germinates and begins to sprout. As the seedling develops, so does that plant's root system, which sprawls out in the soil to anchor the plant in place. Since hydroponics systems do not rely on soil to hold a plant securely in place, most will use some form of growing medium to do this task. This growing medium, also called a growing substrate, takes the place of soil and helps secure the growing plant in place. Growing mediums can also help surround roots with nutrients for healthy plant growth. Growing mediums come in many varieties of materials and sizes, but they all perform basically the same functions; hold the seed in place as it begins to grow and provide a buffer reservoir of nutrient solution to the plant roots. Good growing mediums have an adequate pore size and will not affect the nutrient solution.

ORGANIC GROWING MEDIUMS

Many of the growing mediums available are made up of organic materials such as coconut fiber and peat poss.

Coconut fiber is a very common material used as a hydroponic substrate because it allows for good air flow, drainage, and nutrient saturation for newly planted seeds. Also referred to as coco coir, or coco peat, coconut fiber substrates are a biodegradable medium made from the coconut hull, which is the fibrous material between the outer husk and the actual coconut. Although it is organic, it breaks down very slowly. Another fibrous substrate that breaks down slowly is rice hulls and they are often processed or aged before using in hydroponic systems.

Peat Moss, also called sphagnum peat moss, is an organic substrate that can be a little acidic in nature, which is important to keep in mind. Sphagnum peat moss comes from the dead plant materials that accumulate beneath the living Sphagnum moss that grows in bogs. Living sphagnum moss can also be used as a growing medium.

Sawdust and tree bark are additional types of organic growing mediums, however, research from the Journal of Plant Nutrition in 2014[2] showed that using sawdust resulted in reduced leaf length, reduced photosynthetic rates, and reduced stomatal conductance, which is the passage of water vapor or carbon dioxide through the small pores of the plant, called stomata. Tree bark can be good for starting seeds but usually requires additional support for maturing plants.

INORGANIC GROWING MEDIUMS

In addition to organic growing mediums, there are a variety of inorganic substrates that can also be used for hydroponics. These options include materials such as gravel, expanded clay aggregate, rockwool, vermiculite, perlite, and plastic fiber, and foam sponges.

Light expanded clay aggregate (LECA) is a common substrate used in many hydroponic systems. It is produced by heating clay to temperatures of over 1,000 degrees centigrade (C), giving the clay its unique characteristics. LECA is lightweight, porous, non-combustible, and has a high drainage capacity. This inert, reusable substrate drains freely and is better suited to seedlings and maturing plants.

Rockwool, also called stone wool or mineral wool, is a growing substrate made from molten rock. Natural materials, such as basalt rock, are heated to temperatures exceeding 1,500 degrees (C) and then, similar to fiberglass, the molten rock is blown into a spinning chamber and stretched into fibers. The fibers are then compressed and cut into slabs or cubes. Rockwool is a widely used substrate with a high water capacity that provides good aeration for plant roots.

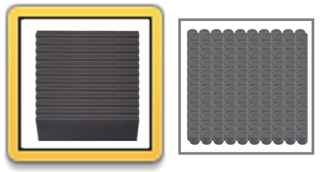
Vermiculite is another type of growing medium commonly used in hydroponic systems. It is a naturally occurring mineral found in various parts of the world including the United States, Brazil, and Australia. Vermiculite is a hydrated magnesium iron aluminum silicate that exfoliates when heated to form elongated, lightweight, incombustible, highly absorbent particles.

Perlite, another type of inorganic substrate, is a naturally occurring amorphous volcanic alumina-silicate rock that expands when heated. When mined, the crude rock ranges in color from a transparent gray to shiny black, but as it expands during the heating process, it pops and becomes white. Perlite pops when heated because of its water content, the same basis behind popped corn.

Foam sponges are a hydroponic growing medium made through a chemical process. The basic compounds used to make foam are exothermic, meaning they generate heat. The resulting foam traps pockets of gas within a solid, creating a lightweight, porous, and absorbent material suited for use in hydroponic systems. This substrate is nonreactive in nutrient solution and is good for the entire plant growth cycle from seed to maturity. OPCOM Farm hydroponic systems uses foam substrates for plant growth. These foam growing mediums come ready to plant or can also come with the seeds already planted for easy system start-up. The OPCOM Farm growing medium, called Grow Sponge, comes in square and circular configurations for use in any application.

Photo Gallery 2.2: Hydroponic Growing Mediums

Grow Sponge



Requirements for Plant Growth

STEM TOPICS TO BE COVERED

- Light
- Water
- Nutrients
- Air Temperature
- Humidity
- Air Flow

Plants require a few basic things for growth. Light, water, and nutrients are the main components to plant cultivation, however there are a few other factors that play a role, especially when growing plants indoors. These factors include air temperature, humidity, and circulation. It is important to understand each of these components as significant changes in any one element can directly affect a plant's ability to prosper.

LIGHT

Light is one of the most essential elements to plant cultivation. Light supplies plants with the requirements they need to perform photosynthesis. There are numerous aspects of light that indicate how the plant will react. This includes light intensity, spectrum, and duration of irradiation.

LIGHT INTENSITY

Light intensity influences factors such as food synthesis, stem length, leaf color, and flowering. For example, a plant grown in low light is more likely to develop thin, light green leaves, whereas a plant grown in bright light is more likely to have shorter, larger, dark green leaves. Light intensity can be expressed as μmol, also called micromoles, which is the unit of measurement used in chemistry to represent quantities of very small entities, such as atoms and molecules. There are one million (1,000,000) µmol, or 10^6, in one mole. In general, plants need a light intensity of µmol m^{-2} s^{-1}. The LED light of OPCOM growing technologies distribute light that resembles natural light intensity.

LIGHT SPECTRUM

The light spectrum also influences certain attributes of plant growth. The visible spectrum of light, which will be discussed further in Chapter 3, includes the colors of the rainbow, of which blue and red are significant for many aspects of plant growth. In general, red light is beneficial for leaves and flowers, blue light is good for stem growth, far-red light is good for fruiting, and ultraviolet light (non-visible light), is good to grow succulent plants.

Leveraging over two decades of OPCOM LED lighting expertise, OPCOM Farm offers a unique line of advanced hydroponic systems with patented technologies. The LED light of OPCOM growing technologies provide the visible light spectrum and also non-visible light, including infrared and ultraviolet light, for optimal plant growth. Also, the proportions of red and blue light can be customized in OPCOM lights to adjust to the needs of different plants.

LIGHT DURATION

The duration of irradiation, or light, needed by plants is categorized according to its photoperiod response, which is how a plant reacts to the amount of light it receives in a 24 hour period. For traditional agriculture, this is regulated by how long the sun is out and dependent upon seasons. This is one reason certain plants are only grown during specific season, which is because they require a specific amount of daylight. For indoor growing technologies, it is important to know the light requirements for a specific plant. Plants are typically identified within three different daylighting categories, long-day, short-day, and day-neutral.

Long-day plants require approximately 14-17 hours of light and include plants such as lettuce and basil. These plants initiate flower buds when the day length is longer than the critical day length over time. The critical day length is specific to each type of plant and therefore the exact number of hours will be relative to each plant's critical day length. If a long-day plant does not receive enough light, it will experience extended vegetative, or stem growth, and will be much less likely to produce flowers.

Short-day plants require about 8-12 hours of light. These plants initiate flower buds when the day length is shorter than the critical day length for a specific plant. Inversely related to a long-day plant, if a short-day plant receives too much light, it will produce more vegetative growth and less flowers.

Day-neutral plants are far less restrictive and will produce flowers over a wide range of photoperiods. In general, day-neutral plants will produce flowers once the plant reaches a certain size or stage of development. These include plants such as cucumbers and tomatoes.

OPCOM smart boxes are capable of changing the photoperiodic response time to 8 hours, 12 hours, or 16 hours, so it can be adjusted to specific plant needs.

WATER

Water is an essential element for plant growth. Water carries the nutrients absorbed through the plants roots throughout the plant and then gets used during photosynthesis and released as oxygen into the air. For hydroponic technologies, plants are grown in systems that pump or circulate water throughout the system. Different plants consume different amounts of water, which also changes during the plant's growth cycle. OPCOM provides different machines that allow the volume of water to be adjusted for different plants.

Flowing water contains dissolved oxygen, which is important for plant health. Plants use dissolved oxygen in water for respiration, which is the chemical process of oxygen reacting with glucose generated during photosynthesis for cellular metabolic function. In hydroponic systems, pumps circulate water to homogenize the nutrients and also increase dissolved oxygen. OPCOM technologies have different modes of circulation to meet the needs of different plants.

NUTRIENTS

There are fourteen elements critical to growing plants. These elements are the nutrients plants need for proper development, cell function, and chemical reactions. The main elements, also called macronutrients, needed for plant growth are nitrogen (N), potassium (K), calcium (Ca), magnesium (Mg), phosphorus (P), and sulfur (S). The additional elements, also called trace elements or micronutrients, needed for plant health are chlorine (Cl), iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni).

Different elements contribute to different functions. For example, higher concentrations of nitrogen facilitates the growth of leaves, while higher levels of phosphorus and potassium facilitate flowering. Also, different plants need different compositions of nutrients. OPCOM selects the appropriate seeds and nutrient formulas for planting and adjusting nutrients easily.

AIR TEMPERATURE

Plants grow well within a relatively limited temperature range. This range is different for each plant, but in general, most plants grow well in temperatures ranging from 41° F and 86° F. When temperatures are too high or too low, abnormal development and reduced production can occur. OPCOM offers a specialized cover to keep plants warm in temperatures below optimal.

HUMIDITY

Humidity, which is the amount of water vapor in the atmosphere, also affects plant cultivation. Humidity is classified as either absolute or relative. Absolute humidity is the actual amount of water vapor in the air. Relative humidity is the amount of water that the air could hold based upon temperature and pressure. Fog often develops when relative humidity levels are at 100%, which is commonly seen near the ocean. In general, the air surrounding plants need humidity levels of about 40% - 60% for optimal growth, however, this can change for specific plants.

When there is too much humidity in the air, it can influence plant diseases, especially fungi and mold that grow rapidly in high humidity. When humidity levels are too low, it can affect fruit production for some plants and leaves can wilt from rapid moisture evaporation. Humidity levels inside a building are often less less than outside because central heating and cooling systems remove moisture from the air. It is common for inside to have a humidity level of about 20% - 30%. In times of reduced humidity, periodically misting the plant's leaves with clean water can restore moisture and revitalize the plants.

AIR FLOW

In addition to temperature and humidity levels, plants also benefit from wind, or air flow. Wind contributes to many aspects of plant growth, from seedlings to fruiting plants. In traditional agriculture, gentle breezes help new plants develop sturdy, healthy stems. As the plants grow, wind increases atmospheric turbulence, which increases carbon dioxide and contributes to greater rates of photosynthesis. Outdoors, excessive wind can damage plants. However, this is not a concern for plants grown indoors. For indoor growing systems, it is beneficial to supplement the space with periodic air flow to stimulate plants and provide a healthy environment. Air flow can be achieved with a fan to help circulate air.

Chapter 1 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

- **A.** True
- **B.** False

Check Answer

CHAPTER 2

OPCOM FARM HYDROPONIC TECHNOLOGIES

There are numerous hydroponic techniques used to grow plants hydroponically, of which many will be covered in this chapter. They all follow the basic principles of growing plants without soil in a nutrient-rich solution, however, each technology differs. OPCOM Farm offers a range of hydroponic solutions using a variety of techniques. Let's learn more about these technologies in the next chapter.

Deep Flow Technique (DFT)

STEM Topics to be Covered

- Deep Flow Technique (DFT)
- Advantages of DFT
- DFT Technologies
- Automation and Connectivity
- OPCOM Farm GrowBox

DEEP FLOW TECHNIQUE (DFT)

There are many different techniques used to grow plants hydroponically, but they all follow the same concept, which is to grow plants without soil in a nutrient-rich solution. One hydroponic technology is Deep Flow Technique (DFT). DFT works by circulating a continuous supply of nutrient solution in a growing tank over the plant's roots. DFT is a variation of deep water culture, which is where plants grow directly submerged in nutrient solution. Although the growing tank can be relatively shallow, it is called deep flow technique because it typically utilizes larger containers with deeper reservoirs for nutrient solution than other techniques.

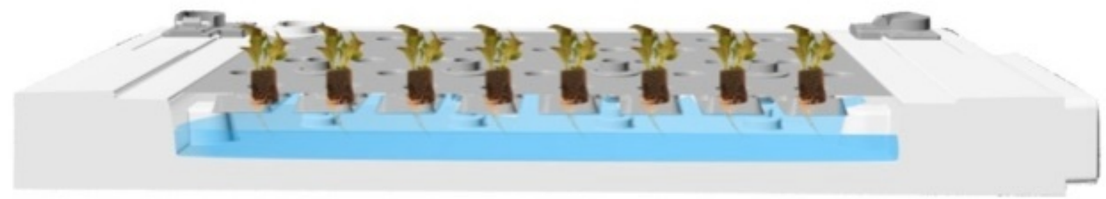
ADVANTAGES OF DFT SYSTEMS

DFT systems have some advantages over other hydroponic technologies. In DFT systems, nutrient concentrations and water temperature are more stable and slow to change. This provides an ideal growing environment for plants that do not respond well to sudden changes. Also, DFT systems are known to introduce sufficient amounts of oxygen, providing roots with an optimal environment for healthy growth. Plants with short growing cycles and shallow root systems as well as fruiting plants do well in DFT systems. Since plant roots are continuously exposed to the nutrient solution, there is less risk of plant loss due to power failure or pump malfunction.

Section 1: Deep Flow Technique (DFT)

DFT TECHNOLOGIES FROM OPCOM FARM

The OPCOM GrowBox uses Deep Flow Technique. The DFT system provides nutrients to plant roots as a pump circulates the nutrient solution in intervals throughout the day. The plants are located on a growing platform that sits slightly above the nutrient solution, allowing the roots to grow down into the reservoir. As the water is circulated, nutrients reach the plant's roots. In this system, the roots contact the nutrients directly. Automated circulation homogenizes the nutrients, increasing the amount of dissolved oxygen available to the plants.



AUTOMATION AND CONNECTIVITY

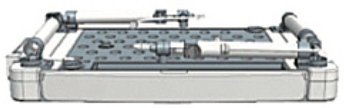
Hydroponic systems contain numerous components that need to be monitored on a routine basis. Automation technology and connectivity are making this easier than ever before. OPCOM Farm hydroponic systems feature OPCOM Link, which is specialized technology that allows the hydroponic unit to connect wirelessly via the internet. Camera attachments can also be added to provide remote monitoring capabilities. Through the OPCOM Link OPCOM Link allows the user access to turn the system on or off, adjust the settings, or view the system, all from a tablet or smart phone.

SECTION 1: DEEP FLOW TECHNIQUE (DFT)

OPCOM FARM GrowBox

The OPCOM Farm GrowBox is an all-in-one hydroponic growing system designed for year round usage. It provides a single, high capacity tray of 50 planting sites that sits above a shallow reservoir of circulating nutrient solution. It is designed to sit on a tabletop, which places it at the optimal height for planting, harvesting, and viewing.

The OPCOM GrowBox has an adjustable, open frame designed to accommodate a wide range of plant varieties, including taller, vining plants such as tomatoes and cucumbers. The height and angle of the sunlight simulating OPCOM LED grow lights can be adjusted to a specific crop and the 3.9 gallon reservoir uses up to 90% less water than outdoor farming. The system also features an automated control system that manages lighting and water circulation for easy operation.



Rotate the OPCOM Farm GrowBox to view different angles.

(double tap to reset view)

Nutrient Film Technique (NFT)

NUTRIENT FILM TECHNIQUE (NFT)

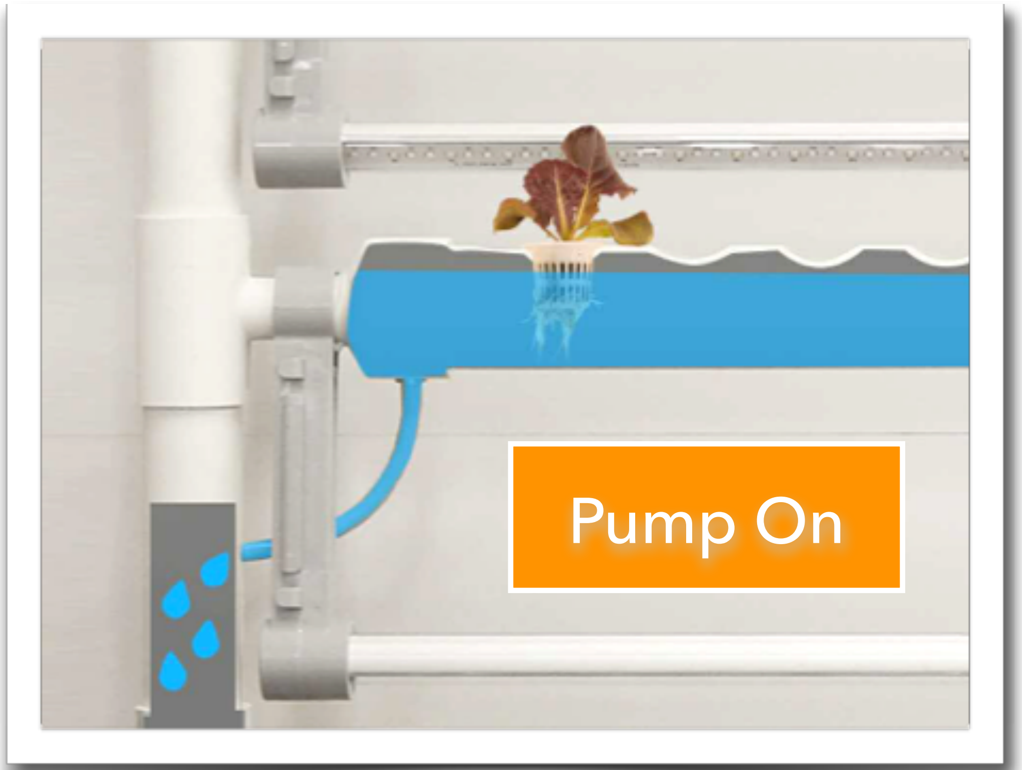
Another type of hydroponic growing technology is Nutrient Film Technique (NFT). These systems usually contain tiered rows of sloped growing platforms with numerous plant sites. The rows are connected by tubes which allow nutrient solution to be pumped from the system's water reservoir directly to the roots of the growing plants in a shallow stream. The shallow stream of nutrients, which usually flows in timed cycles throughout the day, is pumped to the highest growing tier in the system and then drains through the sloped tubes, supplying the roots with a "film" of nutrients. The nutrient solution eventually drains back into the reservoir, allowing the plant roots to aerate between cycles.

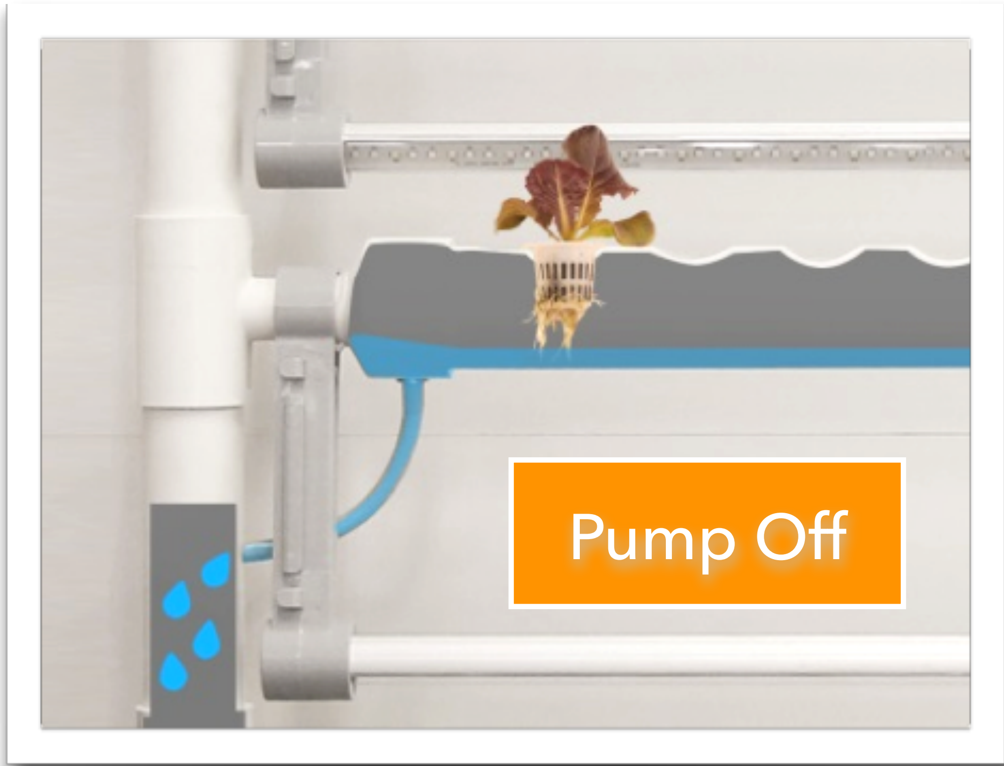
STEM TOPICS TO BE COVERED

- Nutrient Film Technique (DFT)
- Advantages of NFT Systems
- NFT Technologies from OPCOM Farm
- ....
- OPCOM Farm GrowWall

ADVANTAGES OF NFT SYSTEMS

In NFT systems, plants are usually sown in small plastic baskets which suspends the plant securely within the growing chamber. This design keeps the uppermost roots exposed to air during the pumping cycles, which provides the plant with an abundant supply of oxygen for optimum health. Also, NFT systems often operate similar to a natural growing pattern, with water cycling for about half of the day, creating a healthy growing environment for a variety of plants. Another





advantage of NFT systems, in comparison to other hydroponic technologies, is that plant roots are exposed to adequate supplies of water, oxygen, and nutrients simultaneously.

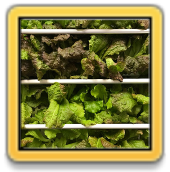
NFT TECHNOLOGIES FROM OPCOM FARM

The OPCOM Farm GrowWall uses Nutrient Film Technique. The GrowWall is a vertically designed NFT system with a water reservoir at the bottom and five tiered rows of growing channels, or tubes. The system is narrow and uses very little floor space because of its vertical design. For the GrowWall, nutrient solution is pumped from the reservoir to the five tubes in 10 minute intervals throughout the day-long cycle.

NFT systems rely on an operational pumping system to move nutrient solution to the plant roots. For this reason, if pumping is affected by an electrical outage or power interruption, plants can begin to suffer rapidly and cause plant loss if not rectified. An advantage of the automated OPCOM Link accessory is that if the system is turned off due to a power interruption, the system can be turned back on remotely through the OPCOM Link App. The adjustable LED tube lights can be situated two to thirteen inches from the growing tube to accommodate the growth stages of the plant and give optimal levels of brightness.

Photo Gallery 2.2: Nutrient Film Technique

OPCOM Farm GrowWall featuring red and green lettuce.



OPCOM FARM GrowWall

The OPCOM Farm GrowWall is an all-in-one hydroponics growing system designed for high yield production. Featuring a space-saving vertical design, the GrowWall can grow a variety of vegetables and herbs, creating a stunning visual display. The GrowWall is a high capacity system with 75 plant sites, angle and height adjustable 4‘ grow light tubes, and easy to use, one-touch AUTO mode.

Aquaponics

AQUAPONICS

Another way to grow plants indoors is through aquaponics. Aquaponic technologies are actually a combination of both aquaculture and hydroponics. Sometimes called fish farming, aquaculture is the cultivation of plants, fish, and other sea life in a water environment. As we have learned, hydroponics is the cultivation of plants using nutrient solution in a soilless environment. Putting the two together, aquaponics refers to the cultivation of fish for the purpose of providing nutrients for plants that are grown in a soilless environment. The benefit of aquaponics is that both fish and plants can be raised in a symbiotic environment.

STEM TOPICS TO BE COVERED

- Aquaponics
- Nitrosomonas Europaea
- Nitrobacter
- The Aquaponics Cycle

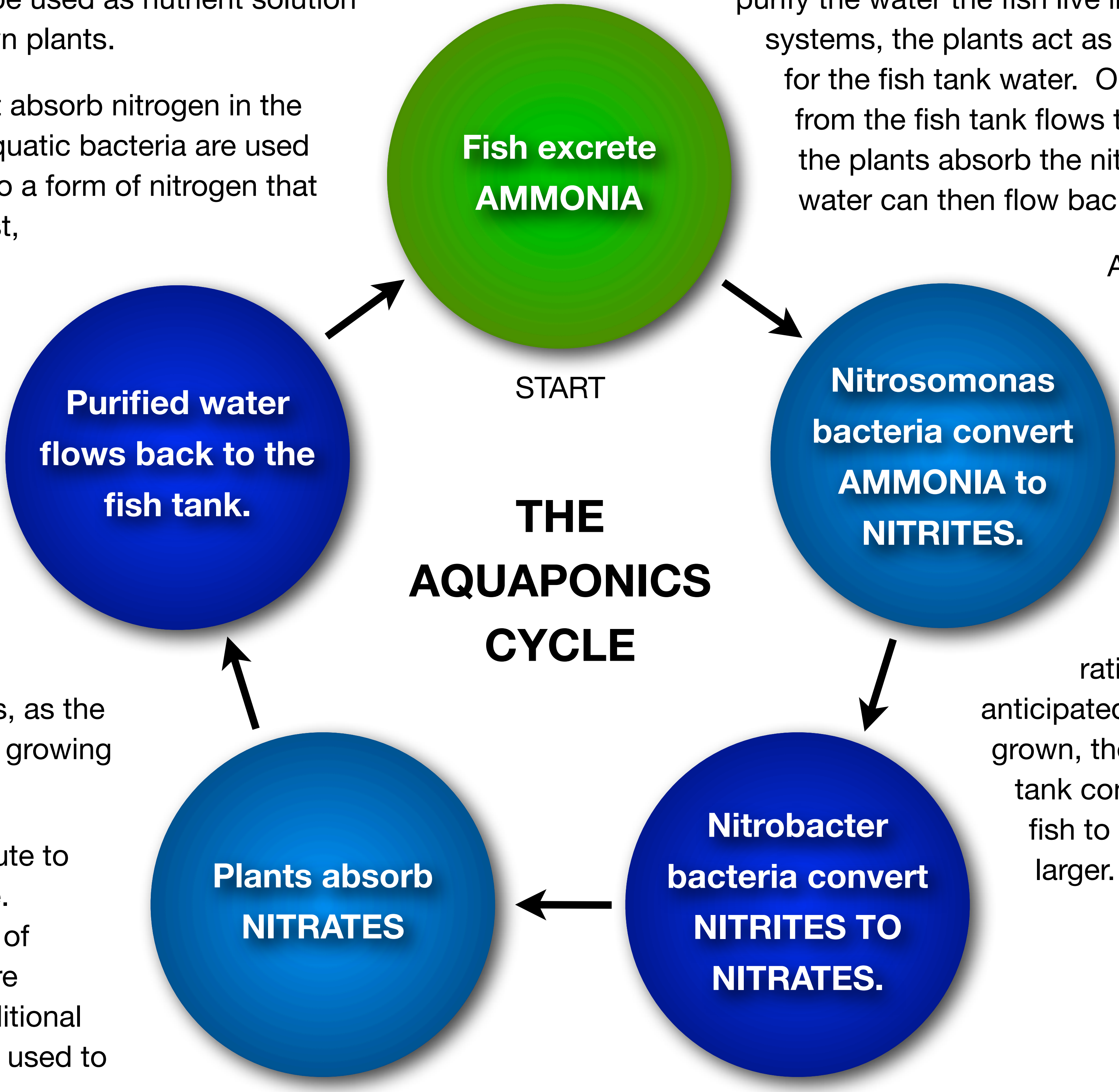
Aquaponic systems have a few necessary components including a tank for keeping fish and a platform for growing plants. Growing plants need nitrogen, a necessary nutrient for plant life. Fish excrete ammonia, primarily through their gills, which is a source of nitrogen. Therefore, the water from the fish tank becomes concentrated with nutrients that plants

AQUAculture + HydroPONICS = AQUAPONICS

need to grow and can be used as nutrient solution for hydroponically grown plants.

However, plants cannot absorb nitrogen in the form of ammonia, so aquatic bacteria are used to convert ammonia into a form of nitrogen that plants can absorb. First, bacteria, called nitrosomonas europaea, convert ammonia to nitrites. Then another bacteria, called nitrobacter, converts nitrites to nitrates. Aquaponic systems work by using the water from the fish tank, now full of nitrates, as the nutrient solution for the growing plants.

The plants also contribute to the this symbiotic cycle. Concentrated amounts of ammonia and nitrites are toxic to fish, and in traditional aquaculture, filtration is used to purify the water the fish live in. In aquaponic systems, the plants act as the filtration system for the fish tank water. Once nitrate-rich water from the fish tank flows through the plants, the plants absorb the nitrates and the filtered water can then flow back to the fish tank.



Aquaponic systems use freshwater fish and need about one pound of fish for every five to ten gallons of fish tank water to produce the right concentration of nutrients. This ratio is based upon the anticipated size of the fish full grown, therefore, when the tank contains new fish, the fish to water ratio will be larger.

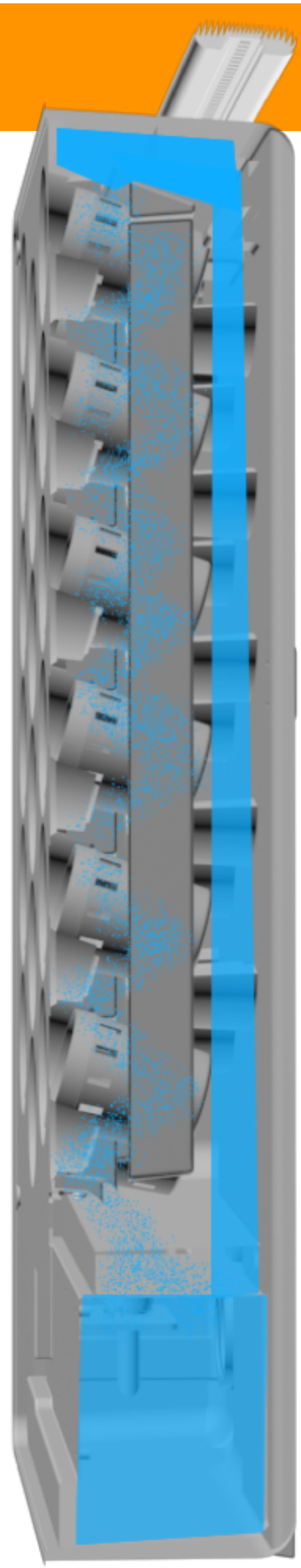
Aeroponics

STEM TOPICS TO BE COVERED

- Aeroponics
-

AEROPONICS

Another way to grow plants in an indoor, soilless environment is through aeroponics. Aeroponic technologies use a misting system to supply nutrients to plant roots, rather than a circulating or streaming reservoir of nutrient solution, as with other hydroponic technologies. In aeroponic systems, plants are usually situated in a growing tray or vertical growing wall and nutrient solution is held in a separate or attached tank. Nutrient solution is then pumped from the tank to nozzles that spray, or mist, the plant roots with nutrients in intervals throughout the day. This growing technology can use even less water than other forms of hydroponics since it delivers water and nutrients directly to the plants roots. In these systems, the nutrient solution



Chapter 2 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

- **A.** True
- **B.** False

Check Answer

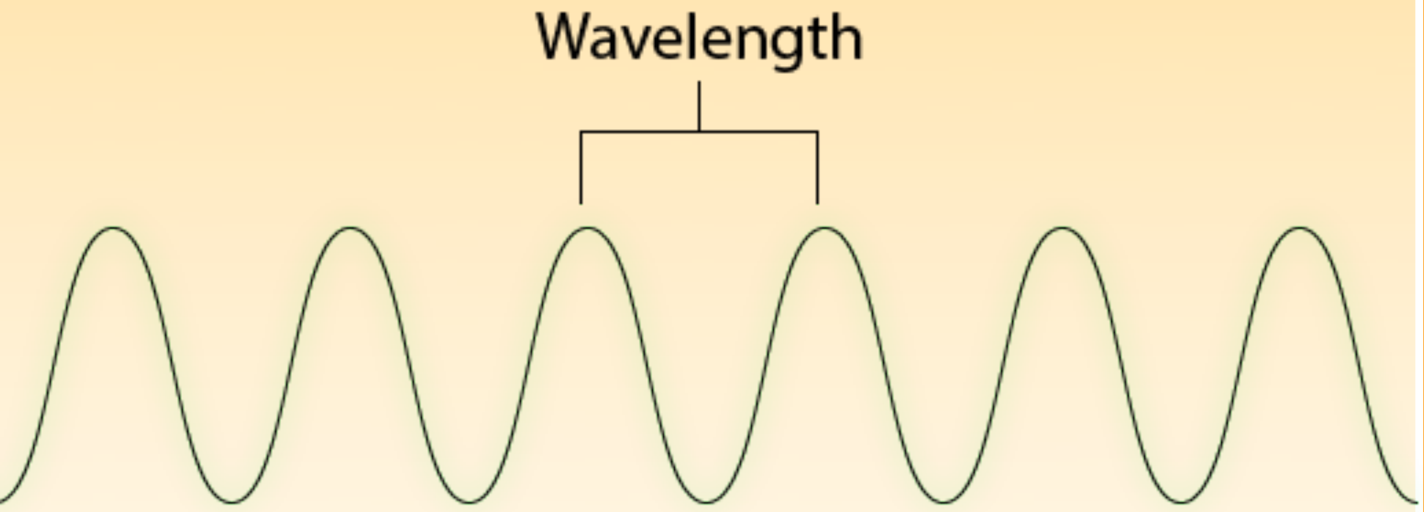
CHAPTER 3

LIGHT

Light is one of the most essential components to all living things. Photons, which are the tiny particles that make up light, travel at the speed of 186,000 miles per second, delivering the energy plants need to grow. In this chapter, we will learn about light, where it comes from, and how plants use it to produce their own food.

Section 1

Electromagnetic Radiation

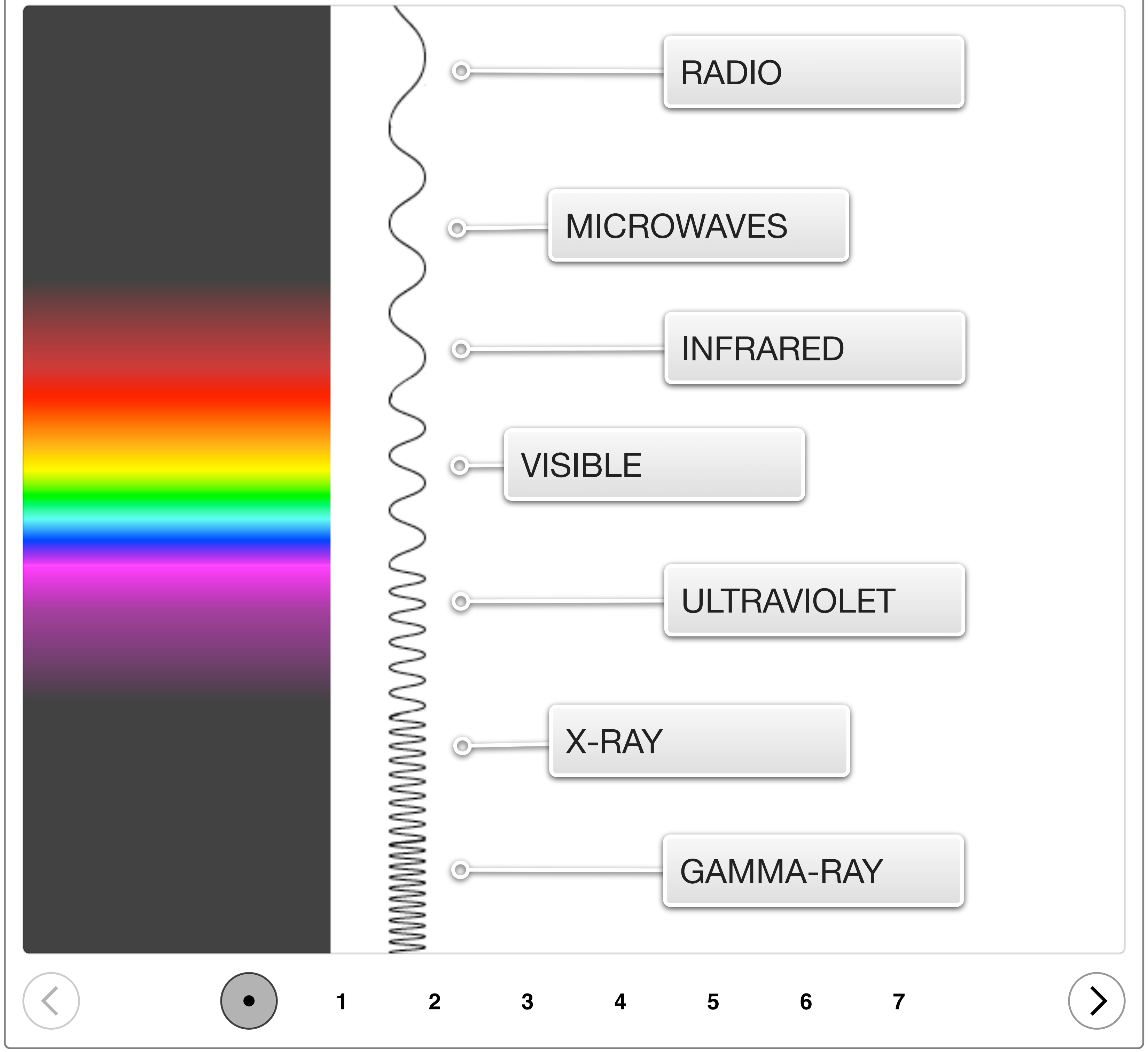


Topics to be Covered

- Electromagnetic Radiation
- Radio Waves
- Microwaves
- Infrared Light
- Visible Light
- Ultraviolet Light
- X-Rays
- Gamma Rays

All plants need light to survive. Even plants thriving in the ocean are using diffused light shining through the water for the process of photosynthesis. We discussed certain attributes of light in the first chapter, but what is light? Light is a form of electromagnetic radiation. There are seven distinct categories of electromagnetic radiation, of which only one can be seen by the human eye and it is called visible light, also called the visible light spectrum. Plants use a combination of visible and non-visible light for the chemical processes it performs. OPCOM Farm lighting technologies are designed to simulate sunlight, providing full spectrum grow lights for efficient plant growth. The range of all types of electromagnetic radiation is referred to as the electromagnetic spectrum. Sometimes the terms electromagnetic radiation and electromagnetic spectrum are used interchangeably. Electromagnetic (EM) radiation is measured in terms of wavelengths and frequency. As EM radiation travels through space, they make characteristic patterns in the form of waves. These waves are identified by specific shapes and lengths, with peaks and valleys. The peak is the highest point of the wave and the valley, called a trough, is the lowest point. The distance between peaks is called wavelength. Wavelengths are measured in meters (m), specifically in nanometers or picometers, which are very small.

Interactive 3.1 Electromagnetic Spectrum



Frequency is how often, or frequent, something takes place. Sound waves, alternating electric current, and EM radiation all have frequency, which is measured in hertz (Hz). Hertz represents the number of cycles, or waves, that take place per second. For EM radiation, frequency measures the number of wavelengths that pass by a certain point in a given length of time. This means shorter wavelengths have a higher frequency, as more wavelengths pass by during a cycle.

RADIO WAVES

The human eye can detect electromagnetic radiation that falls between 400 nm and 760 nm. This is the visible spectrum of light. The human eye can detect electromagnetic radiation that falls between 400 nm and 760 nm. This is the visible spectrum of light.

MICROWAVES

Most of us are familiar with microwaves as the popular kitchen appliance that heats food quickly. The appliance is called a microwave because it uses actual microwave radiation to operate. When turned on, microwave appliances emit.

INFRARED LIGHT

Infrared light, also called infrared radiation, is a form of non-visible light that indicates heat is present. Although humans cannot see infrared with the unaided eye, some animals see infrared waves, which helps them find food and navigate during the night. Infrared light is an important component to plant growth and health.

VISIBLE LIGHT

The human eye can detect electromagnetic radiation that falls between 400 nm and 760 nm. This is the visible spectrum of light. Visible light is necessary for plant photosynthesis and overall health. Rainbows are diffused into the separate colors of visible light.

ULTRAVIOLET LIGHT

Ultraviolet light also plays a role in plant health. Although undetectable by the human eye, ultraviolet light strikes the surface of the earth every day in the form of UV-A, UV-B, and UV-C rays.

X-RAYS

GAMMA RAYS

Visible Light for Plant Growth

TOPICS TO BE COVERED

- Blue Light
- Red Light
- Far Red Light
- Plant Hormones

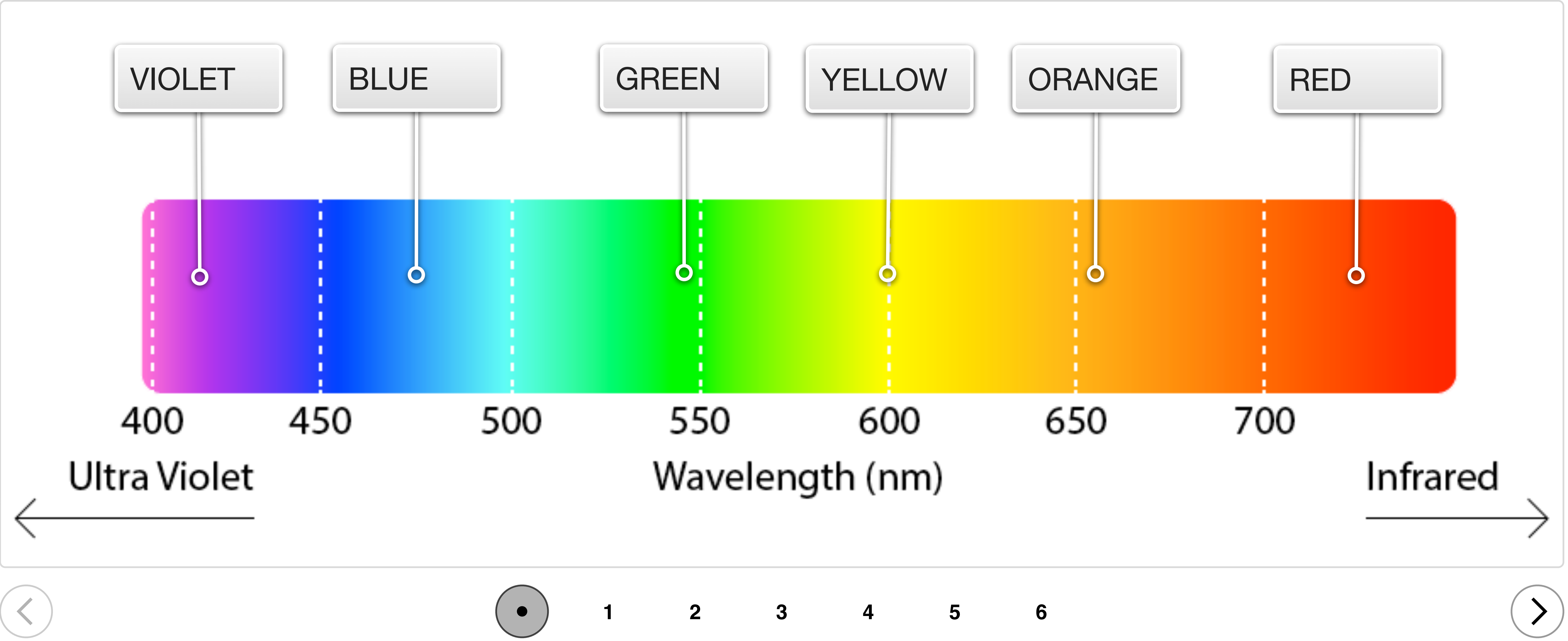
Only a small portion of the electromagnetic spectrum, also referred to as the light spectrum, is visible light. Visible light is represented as the colors red, orange, yellow, green, blue, and violet. Certain light, such as blue light and red light, play a significant role in plant growth.

Wavelengths of visible light are measured in nanometers (nm). There are one billion (***1,000,000,000***) nanometers in one meter. For reference, one meter is equal to a little over three feet. The visible portion of the light spectrum is between 400 nm and 760 nm.

The frequency of visible light is measured in terahertz (THz). There are one trillion (***1,000,000,000,000***) terahertz is one hertz unit. The visible portion of the light spectrum is between about 400 THz and 750 THz[4]. Wavelengths and frequency are inversely related. The shorter the wavelength, the higher the frequency and the longer the wavelength, the lower the frequency. By understanding the visible light spectrum, scientists and inventors have been able to develop technologies used today that allows plants to grow indoors.

The sun emits relatively similar amounts of red, blue, and green light. Electric lamps, or lights bulbs, emit light in similar proportions, with slightly higher proportions of red light being emitted by high-pressure sodium (HPS) lamps, making them popular for indoor growing. However, light-emitting diodes, commonly called LEDs, are capable of being adjusted to emit

Interactive 3.2 Visible Light Spectrum



specific light in ranges from 0 to 100. LEDs are also very energy efficient. For these reasons, LEDs are an efficient and effective source of light for indoor hydroponic technologies.

BLUE LIGHT

The spectrum of visible light between 450 nm and 500 nm is called blue light. Plants absorb blue light, which contributes to the development of strong, healthy stems and leaves. This region of the light spectrum can be referred to as the vegetative zone as it contributes more to the beginning growth stage of producing of leaves and stems rather than to flowering, which occurs later in development. A plant's absorption of blue light is directly related to chlorophyll production in the plant's leaves. Chlorophyll is the substance that gives the plant its green color. Blue light is a necessary component of indoor lighting applications for normal plant growth. In addition to chlorophyll production, blue light regulates the opening of stomata, the tiny pores on leaves that control gas exchange[5]. For photosynthesis, only a low intensity of blue light is necessary for full functionality. Also, plants grown with blue light tend to have shorter, smaller leaves since blue light suppresses growth extension. Sufficient blue light is a key component from growing a variety of healthy ornamental and decorative plants with short stems and leaves, such as aloe and cacti.

RED LIGHT

Red light is between 610 nm and 760nm on the visible light spectrum. Plants need a sufficient amount of red light for proper growth. Red light is the most important component for the flowering and fruiting process of a plant[6].

FAR-RED LIGHT

GREEN LIGHT

The green color of plant leaves indicate that leaves reflect green light rather than absorb it. However, there are some plants that do require green light for normal production. Green light can contribute to stomatal control and phototropism and when combined with blue, red, and far-red light, provides plants with a complete range of spectral activity that is found in sunlight.

PLANT HORMONES

As plants grow, certain processes take place that tell that plant how to react to certain conditions. For example, a plant hormone called ***auxin*** tells the plant to stretch towards far red light. If a plants leaves are longer and skinnier than expected, it could be a result of insufficient light causing the plant to “reach” for it.

Photosynthesis

STEM TOPICS TO BE COVERED

- Photosynthesis
- Chlorophyll
- Oxygenic Photosynthesis
- Anoxygenic Photosynthesis
- Photoreceptor Cells

Plants are called autotrophs, which means they have the ability to synthesize, or generate, their own food supply. They do this through a process called photosynthesis.

Photosynthesis is the chemical process that occurs when plants, algae, and some bacteria are exposed to light. When light strikes the green leaves of a plant, chlorophyll causes the plant to absorb energy. For photosynthesis to occur, plants need three things: carbon dioxide, water, and light. Photosynthesis begins as the plant uses that absorbed energy to convert carbon dioxide and water into the glucose, or sugars, it uses for food. Historically, photosynthesis has always been initiated by sunlight, but an understanding of the chemical process has led to the development of advanced indoor lighting capabilities that make growing indoors possible.

OPCOM Farm indoor lighting technologies provide the full spectrum of light needed for efficient photosynthesis.

Plants use carbon dioxide for photosynthesis.

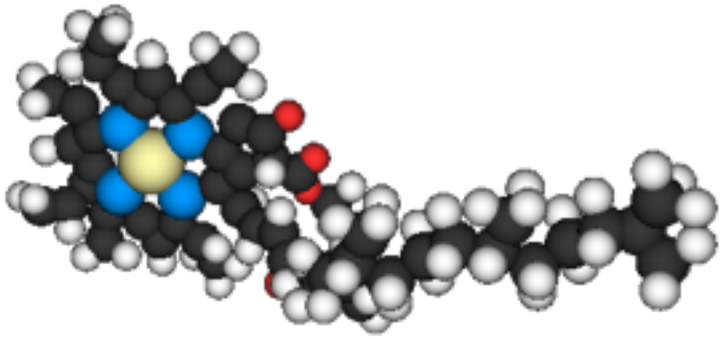
CHLOROPHYLL

Plants contain a special molecule called chlorophyll, which is the pigment that gives plants their green color. It has the chemical formula, $C_{55}H_{72}O_5N_4Mg$, and it is a key constituent to photosynthesis as it is the molecule that allows plants to absorb energy from light. Chlorophyll molecules are located within specialized organelles, called chloroplasts. Chloroplasts are found in all green parts of a plant. While photosynthesis can take place throughout the entire plant, it is most prevalent in the leaves. There are several forms of chlorophyll, of which chlorophyll "A" is present in plants, enabling them to perform oxygenic photosynthesis.

for food. During the process, electrons are extracted from the water and the plant releases molecular oxygen back into the atmosphere. This is one reason plants are good for the environment. They remove CO_2 from the air we breathe and then release oxygen back into the air, making it cleaner and healthier.

OXYGENIC PHOTOSYNTHESIS

There are two types of photosynthesis, oxygenic and anoxygenic. When the term photosynthesis is used, it is most commonly referring to oxygenic photosynthesis. This is what occurs in all the plants around us and it also occurs in algae and certain types of photosynthetic bacteria called cyanobacteria. It is called oxygenic photosynthesis because a result of the process is that oxygen gets released back into the atmosphere. Here is how it works. When a plant receives energy from light, chlorophyll molecules absorb the energy. The plant then uses that energy to turn carbon dioxide (CO_2) and water (H_2O) into the sugars it needs



CHLOROPHYLL MOLECULE

$C_{55}H_{72}O_5N_4Mg$

ANOXYGENIC PHOTOSYNTHESIS

Anoxygenic photosynthesis does not occur in plants. It only occurs in certain bacteria from four groups: purple bacteria, green sulfur bacteria, green non-sulfur bacteria, and heliobacteria. Rather than water, these phototrophic organisms oxidize inorganic compounds such as hydrogen sulfide (H_2S) and organic compounds such as malate ($C_4H_4O_5^{-2}$) to extract electrons for photosynthesis. This process does not release oxygen, and therefore, is anoxygenic. These bacteria require low levels of oxygen to survive. Instead of chlorophyll "A", anoxygenic photosynthetic bacteria rely on a similar component called bacteriochlorophyll, which strongly absorbs infrared light between 700 nm and 1,000 nm[17].

Chapter 3 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

- **A.** True
- **B.** False

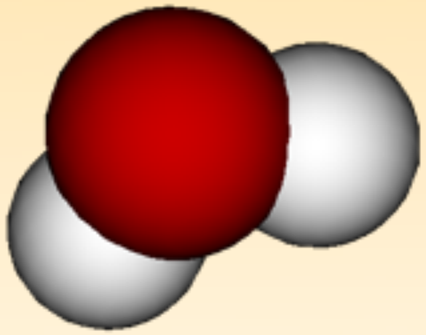
Check Answer

CHAPTER 4

WATER AND NUTRIENTS

In addition to light, water and nutrients are two of the most essential components to plant growth. Water carries necessary nutrients through the plant so the plant can perform the chemical processes that help it grow and thrive. In this chapter, we will learn why water is so important to plant growth and we will also cover what nutrients plants need, where they come from, and why they need them.

Water



WATER MOLECULE

H_2O

STEM TOPICS TO BE COVERED

- Water Usage
- Transpiration
- Evaporation
- Evapotranspiration
- Respiration

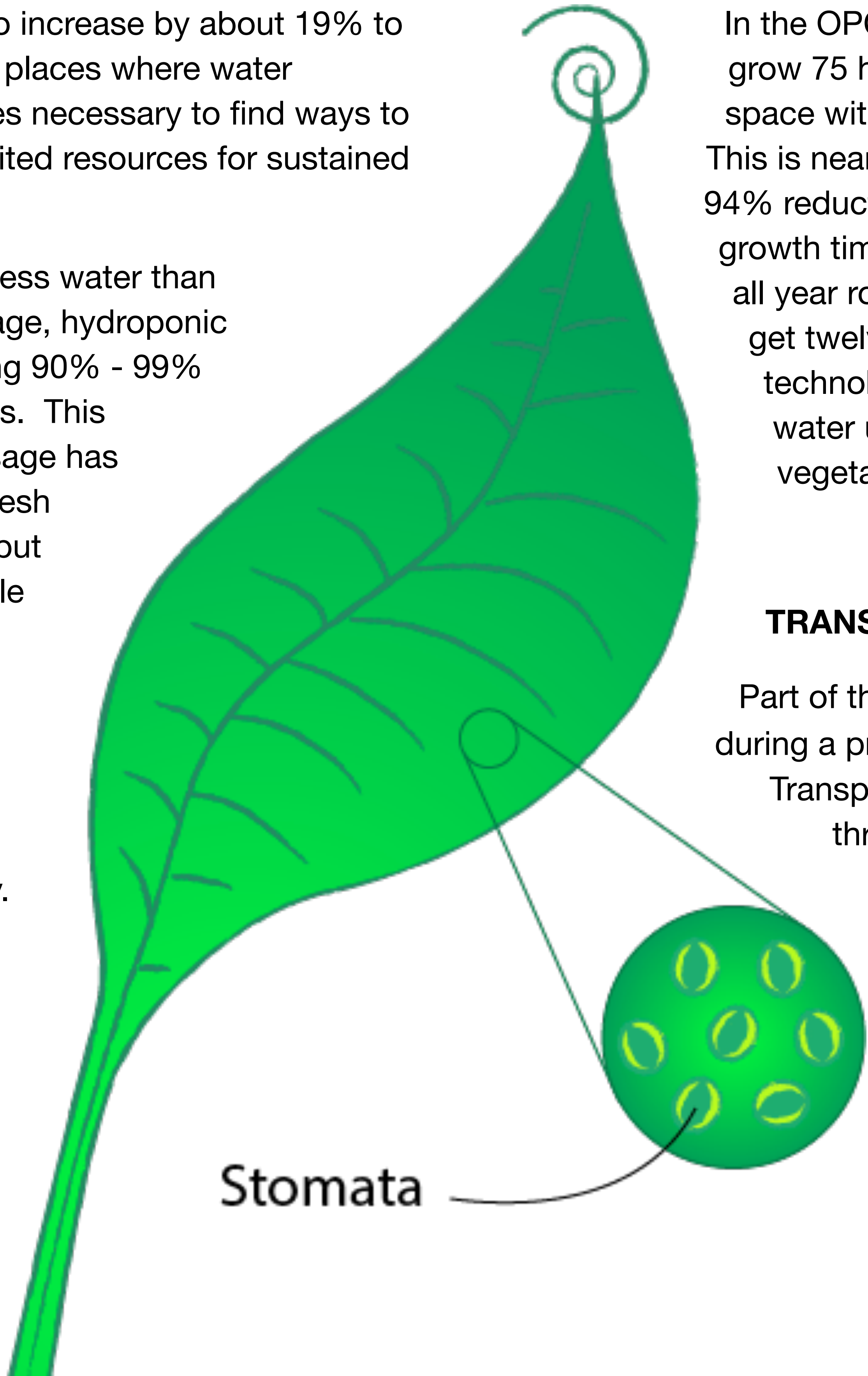
One of the most essential elements of all living things, fluid water, makes up most of a growing plant. Some mature plants contain more water than others, but generally speaking, the water content of vegetables ranges from 75% - 96%. In arid, desert climates, water is usually a limited natural resource with average precipitation rates of less than 10 inches, or 25 centimeters, a year. There are some deserts in the world that actually receive less than one inch of rain per year. Some of the most well-known arid places on Earth include the Sahara Desert in northern Africa, where less than one inch of rain falls per year in nearly half of the region, and Death Valley National Park in southern California, a place that gets over one million annual visitors and less than one inch of rain a year. There have been times where Death Valley has gone more than a year without a single drop of rain. How is this related to hydroponics? On average, an efficient hydroponics systems can use significantly less water than traditional farming methods, and in some cases, can reduce water consumption by over 90%. This means that hydroponic systems may be able to bring freshly grown produce to even some of the driest and most remote locations on Earth.

WATER USAGE

Traditional agriculture is by far the largest consumer of the Earth's freshwater resources. In 2014, 69% of the world's freshwater withdrawals were committed to agriculture[3] and that consumption is expected to increase by about 19% to 8,515 km^3 per year by 2050. In places where water resources are scarce, it becomes necessary to find ways to offset consumption of these limited resources for sustained growth.

Hydroponics uses significantly less water than traditional agriculture. On average, hydroponic systems can grow produce using 90% - 99% less water than soil grown plants. This significant reduction in water usage has made it very possible to grow fresh vegetables not only in deserts, but also in remote locations with little infrastructure.

A typical head of lettuce grown grown traditionally in a field requires about 8” x 12” of space, 3 gallons of water, and about 60 days to reach maturity. This means it would take about 50 ft^2 of space and 225 gallons of water to harvest 75 heads of lettuce. Also, lettuce is a cool season crop and only grows well during the cooler seasons of fall and spring.



In the OPCOM Farm GrowWall, it is possible to grow 75 heads of lettuce in about 6 ft^2 of floor space with about 7 gallons of water in 30 days. This is nearly a 97% reduction of water usage, 94% reduction of space, and 50% reduction in growth time to maturity. Also, they can be grown all year round, which means that it is possible to get twelve harvests annually. Hydroponic technologies offer a tremendous reduction of water usage and can assist with providing vegetables in places with limited resources.

TRANSPIRATION

Part of the water needed to grow plants is used during a process called ***transpiration***. Transpiration occurs when moisture is carried through a plant from its roots to its leaves and gets released into the atmosphere through small pores on the underside of the leaf called stomata. Stomata allow gas exchange to take place in the plant and once moisture from the roots reaches the leaves, it turns into water vapor to be released as a gas. Essentially, transpiration is the evaporation of water from the plant's leaves. Stomata also allow the plant to absorb carbon dioxide, a gas necessary for the plant to perform photosynthesis, the process by which plants make their own food.

Different plants transpire at different rates. Some plants that grow in the desert, such as cacti and other succulents, transpire less to conserve water. As the plant grows, the rate of transpiration increases as it is directly related to plant growth. If the plant receives enough water, the stomata remain open and photosynthesis is taking place. This also means the plant is losing water through the open stomata. If the plants is not receiving enough water, the stomata will begin to close, resulting in less photosynthesis and reduces rates of transpiration.

EVAPORATION

In addition to transpiration, water is also lost during plant cultivation due to ***evaporation***. For traditional agriculture, evaporation occurs when water on the surface of the soil or plant changes to vapor, in contrast to transpiration, which is where water is released as vapor from within the plant. For indoor growing, the rate of evaporation can be significantly less than traditional agriculture. Although water does evaporate from indoor growing reservoirs, temperature, humidity, and air flow can be controlled indoors, leading to much less evaporation and a more consistent growing environment.

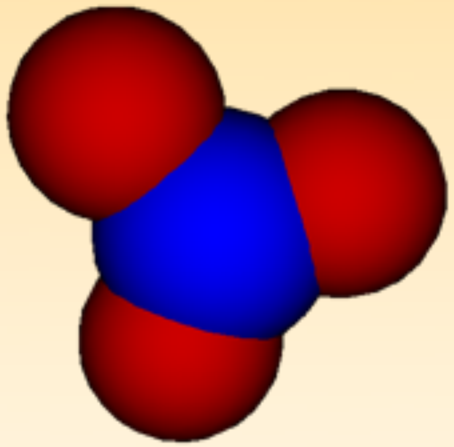
EVAPOTRANSPIRATION

The process of losing water from evaporation and transpiration is called ***evapotranspiration***. When cultivating plants outdoors, evapotranspiration rates vary widely and are affected by weather variables such as solar radiation, temperature, humidity, and wind. For hydroponically grown plants, such as lettuce, rates of evapotranspiration are correlated with the climatic condition of the indoor environment and the age of the plant[18].

RESPIRATION

Respiration occurs is all living things. For a plant, respiration is the opposite of photosynthesis. During photosynthesis, plants use carbon dioxide to generate their own food, releasing oxygen into the air. During respiration, plants cells absorb oxygen, which combines with glucose in the plant to produce carbon dioxide and water, and release energy. This enables the plant to maintain the cellular metabolic processes that keep it healthy.

Macronutrients



NITRATE MOLECULE

NO_3^-

WHAT ARE MACRONUTRIENTS?

Plants are living organisms that need certain elements for normal function and growth. These elements, or nutrients, enable the plant to perform essential chemical processes, such as photosynthesis, respiration, and transpiration. Each plant has a range for the amount of nutrients it needs and this range differs from plant to plant. When nutrient levels are outside of this optimal range, plants can become withered, stunted, or just overall unhealthy from either a deficiency or toxicity. There are fourteen essential elements for plant growth and of these elements, six are needed in higher quantities and are called macronutrients. The other eight elements are needed in much smaller quantities and are called micronutrients. In order of average required concentrations, the macronutrients are Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (Mg), Sulfur (S), and Calcium (Ca).

STEM TOPICS TO BE COVERED

- What are Macronutrients?
- Nitrogen (N)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Phosphorus (P)
- Sulfur (S)
- Macronutrient Deficiencies and Toxicities
- Mobile and Immobile Nutrients
- Identifying Macronutrient Disorders

NITROGEN (N)

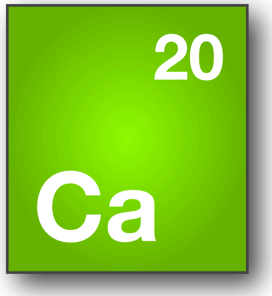
Nitrogen has the atomic number seven on the periodic table of elements. Discovered in 1772 by Scottish chemist, Daniel Rutherford, Nitrogen is a well known component of plant health. Plants need more nitrogen than any other element. Classified as a nonmetal, Nitrogen is a gas at room temperature and makes up 78% of Earth's atmosphere.

Plants absorb nitrogen as either nitrate (NO_3^-) or ammonium (NH_4^+). Plant tissue consists of about 1% - 6% nitrogen. Nitrogen is essential to plant health as it is a key component of chlorophyll, the substance that makes leaves green. Sufficient amounts of nitrogen lead to high rates of photosynthesis and greener foliage. Nitrogen is also a significant component of all amino acids, which are the building blocks of protein. Hydroponic growing mediums allow ammonium to become excessively concentrated, leading to toxicity, so nitrate is the preferred source on nitrogen for hydroponically grown plants.

POTASSIUM (K)

Potassium has the atomic number nineteen on the periodic table of elements. Discovered in 1807 by Cornish chemist, Sir Humphry Davy, it is the seventh most abundant element in the Earth's crust. Potassium, which is a solid at room temperature, is classified as an alkali metal and is represented by the letter K, from the Latin word, kalium. It is the second lightest known metal and is soft enough to easily cut with a knife. Plants absorb potassium in its ionic form, K^+. Plants need potassium for many functions. It regulates the opening and closing of stomata for the process of transpiration and also promotes photosynthesis, drought and disease resistance, stem growth, and healthy reproduction.

CALCIUM (Ca)



Calcium has the atomic number twenty on the periodic table of elements. Sir Humphry Davy discovered Calcium in 1808, shortly after he discovered Potassium. Classified as an alkaline-earth metal, Calcium is the fifth most abundant element in the Earth's crust. Plants can absorb calcium as calcium nitrate, $Ca(NO_3)_2$, which is soluble. Calcium helps plants absorb other nutrients, including nitrogen, potassium, and phosphorus. Plants also need calcium for cell wall development and cell strength. This happens as calcium combines with pectin, the substance that holds plant cells together, to form calcium pectate, which makes the plant's cell walls strong.

MAGNESIUM (Mg)

Magnesium has the atomic number twelve on the periodic table of elements. It was discovered in 1755 by Scottish physicist, Joseph Black. Magnesium, the eighth most abundant element in the Earth's crust, is highly flammable and was a key component in original flash photography. It is classified as an alkaline-earth metal and is a solid at room temperature. Plants absorb magnesium as Mg^{2+}, its ionic form. Magnesium, which is the center atom of the chlorophyll molecule, is essential for plant photosynthesis. It also contributes to the production of adenosine triphosphate (ATP), which performs energy exchange within the plant. When plants metabolize sufficient amounts of magnesium, they are better able to grow strong roots and are more resistant to drought and disease.

PHOSPHORUS (P)

Phosphorus has the atomic number fifteen on the periodic table of elements. Discovered in 1669 by Germany merchant and alchemist, Henning Brand, phosphorus is a soft, waxy solid at room temperature. It is a highly reactive element that is always found in nature as a compound, such as calcium phosphate. Phosphorus is a phosphorescent element, meaning it glows in the dark, and it can be found in three forms, white, red, and black, with white being the most dangerous and black being the least dangerous. Classified as a nonmetal, phosphorus is also an essential element for plant life. Plants can absorb phosphorus as orthophosphates ($H_2PO_4^-$ and HPO_4^{2-}). Plants need phosphorus to regulate protein synthesis for cell division and the development of new tissue. Phosphorus also promotes root growth, is essential for flower and seed production, and helps plants endure colder temperatures.

SULFUR (S)

Sulfur, also spelled sulphur, has the atomic number sixteen on the periodic table of elements. It has been a known substance since antiquity and was recognized as an element in the late 1700s by French chemist, Antoine Lavoisier. Sulfur, in any form, emits a distinctly pungent and widely recognized odor. This odor can be detected by the sulfur compounds in many common household items such as matches, garlic and hard-boiled eggs. A solid at room temperature, sulfur has a recognizable bright yellow color and can be found in nature in many different forms. It can be found in sedimentary rocks, igneous basalt magma, as crystals, or as a powdery yellow coating. Classified as a nonmetal, sulfur is a necessary component to plant health. Plants absorb sulfur in the form of sulfate (SO_4^{2-}). Sulfur helps plants with the formation of plant proteins and improves the efficiency of other nutrients such as nitrogen and phosphorus.

OPCOM FARM NUTRIENTS

OPCOM Farm supplies easy-to-use, proprietary nutrient packs that are formulated to provide plants with the nutrients they need for optimal growth.

MACRONUTRIENT DEFICIENCIES AND TOXICITIES

When a plant develops abnormally, it could be a nutrient deficiency or toxicity. A nutrient deficiency occurs when a plant has insufficient amounts of a necessary nutrient required for plant growth. Toxicity occurs when a plant has too much of a certain nutrient, which can also degrade plant health. Many nutrient deficiencies or toxicities can resemble one another. Common symptoms of nutrient deficiency include stunted growth, chlorosis, interveinal chlorosis, purplish-red coloring, and necrosis[16].

COMMON NUTRIENT DEFICIENCY SYMPTOMS

STUNTED GROWTH: Nutrients are essential to many plant functions such as photosynthesis, protein production, and stem growth. Deficiencies can lead to shorter stems, smaller leaves, and weakness.

CHLOROSIS: Plants need nutrients for photosynthesis and the production of chlorophyll, the substance that makes plants green. Nutrient deficiencies can interfere with photosynthesis, resulting in less chlorophyll production. This causes chlorosis, which is the yellowing of plant tissue.

INTERVEINAL CHLOROSIS: This occurs when the plant turns yellow between the veins of the leaf and the veins stay green.

PURPLISH-RED COLORING: If plant functions are stressed, stems and leaves can turn purple from the accumulation of anthocyanin, a purple colored pigment.

NECROSIS: This usually occurs during the later stages of a deficiency and is when plant tissue turns brown and dies.

MOBILE AND IMMOBILE NUTRIENTS

Some nutrients are able to travel from older leaves to younger plant parts to help supplement that nutrient when supplies are low. These nutrients are referred to as mobile since they are able to travel within the plant. The mobile nutrients are nitrogen (N), potassium (K), magnesium (Mg), phosphorus (P), chlorine (Cl), and molybdenum (Mo). Since these nutrients travel from older leaves to newer plant parts, deficiencies of mobile nutrients will be first visible in older or lower leaves.

Immobile nutrients cannot travel throughout the plant and therefore, deficiencies will be visible in younger or upper leaves first. The immobile nutrients are calcium (Ca), sulfur (S), iron (Fe), boron (B), manganese (Mn), zinc (Zn), copper (Cu), and nickel (Ni).

Refer to the chart on the following page for more information about how to identify macronutrient disorders through observation[16].

IDENTIFYING MACRONUTRIENT DISORDERS

NITROGEN (N)

DEFICIENCY: Plants may be weaker from lack of chlorophyll production. Leaves become yellow from chlorosis, which is the loss of normal green coloration of leaves.

TOXICITY: Leaves become very dark and root development slows down. Stems can become tall and weak. Excessive nitrogen inhibits flower and fruit production.

POTASSIUM (K)

DEFICIENCY: Older leaves develop chlorosis (yellowing of leaf tissue) and eventually dead tissue starting around the leaf tips. Stems and branches weaken.

TOXICITY: Excessive potassium affects plants indirectly. It can interfere with the absorption of Mg, Mn, Zn, and Fe, causing deficiencies in these other nutrients.

CALCIUM (Ca)

DEFICIENCY: Calcium deficiency affects the youngest leaves first and can lead to small leaves, chlorosis, inhibited budding, irregular fruits, and poor root systems.

TOXICITY: Calcium toxicity rarely occurs and is not easily visible. Rather, it indirectly affects the plant by inhibiting the uptake of magnesium and potassium.

MAGNESIUM (Mg)

DEFICIENCY: Older leaves develop interveinal chlorosis, which is the yellowing of leaves between the veins while the veins remain green.

TOXICITY: Magnesium toxicity rarely occurs in plants although it can interfere with calcium and potassium absorption, causing deficiencies in those nutrients.

PHOSPHORUS (P)

DEFICIENCY: Phosphorus deficiency in plants can cause delayed maturation, stunted growth, and older leaves may turn dark green. Stems can turn purple.

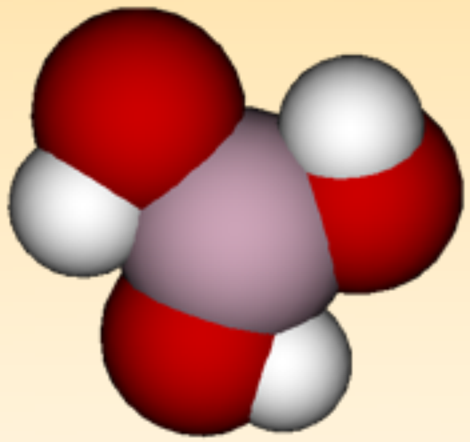
TOXICITY: Phosphorus toxicity is rare since it is usually regulated by pH limitations. However, excess phosphorus can lead to copper and zinc deficiencies.

SULFUR (S)

DEFICIENCY: For younger leaves, sulfur deficiency can cause the entire leaf to turn yellow, including the veins. It can also cause leaf tips to yellow and curl.

TOXICITY: Excessive amounts of sulfur can cause stunted growth of overall plant and smaller leaves. Leaves may also turn yellow or appear scorched at the edges.

Micronutrients



BORIC ACID MOLECULE

H_3BO_3

WHAT ARE MICRONUTRIENTS?

In addition to macronutrients, plants also require eight additional elements in much smaller quantities, and these are called micronutrients, or trace elements. These micronutrients are not necessarily less important than macronutrients, but rather, they are just required in smaller quantities and concentrations. In most cases, it is not as common to acquire a deficiency or toxicity of these nutrients, however, it can happen and they are ultimately needed in the right quantities for proper plant growth and function. In order of average required concentrations, the micronutrients are Iron (Fe), Chlorine (Cl), Manganese (Mn), Boron (B), Zinc (Zn), Copper (Cu), and Molybdenum (Mo).

STEM TOPICS TO BE COVERED

- What are Micronutrients?
- Chlorine (Cl)
- Iron (Fe)
- Boron (B)
- Manganese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Molybdenum (Mo)
- Nickel (Ni)
- Micronutrient Deficiencies and Toxicities
- Identifying Micronutrient Disorders

CHLORINE (Cl)

Chlorine has the atomic number seventeen on the periodic table of elements. The element was discovered in 1774 by Swedish chemist, Carl Wilhelm Scheele. A halogen and gaseous element at room temperature, Chlorine is one of the most abundant elements on Earth and can be found in seawater and natural sources of sodium chloride, or salt. Plants absorb chlorine in its ionic form as chloride (Cl^-). In addition to potassium, plants need chlorine for proper function of stomata and to control the plant's internal water balance. Chlorine also contributes to photosynthesis and helps transport nutrients throughout the plant.

IRON (Fe)

26
Fe

Iron has the atomic number 26 on the periodic table of elements. Classified as a transition metal, Iron has been a known element since ancient times. It is the key component to steel, the building material that revolutionized construction and is also an important element for human health and plant health. Plants absorb iron in its oxidized form as either Fe^{2+} or Fe^{3+}. Iron contributes to chlorophyll synthesis and iron deficiencies can be visually identified as chlorosis, the yellowing of plants leaves from chlorophyll loss.

BORON (B)

5
B

Boron has the atomic number five on the periodic table of elements. Discovered in 1808 by chemists, Sir Humphry Davy, Joseph Louis Gay-Lussac, and Louis Jacques Thénard, boron is a relatively rare element found on Earth in the form of compounds. It is classified as a semimetallic element, meaning it possesses characteristics of both metals and nonmetals. Plants absorb boron as boric acid (H_3BO_3). Plants use boron in numerous ways including in the formation of cell walls for stability, the transportation of sugars to growing parts of the plant, and in pollination. Boron is especially necessary for taller plants that need strong cell walls for structural stability.

MANGANESE (Mn)

25
Mn

Manganese has the atomic number 25 on the periodic table of elements. It was discovered in 1774 by Swedish chemist, Johan Gottlieb Gahn. Manganese is solid at room temperature and classified as a transition metal. When added to steel, manganese increases steel's hardness and tensile strength, which is its ability to resist breaking under tension. Manganese is absorbed by plants as Mn^{2+}, its ionic form. An important component to plant health, manganese contributes to chloroplast formation, photosynthesis, respiration, and the assimilation of nitrogen, an essential macronutrient[19]. Excessive amounts of some nutrients, such as copper, iron, nickel, and zinc, may reduce a plant's ability to absorb manganese, leading to deficiencies.

ZINC (Zn)

Zinc has the atomic number 30 on the periodic table of elements. Although it has been a known substance since ancient times, zinc was named in the 16th century by Swiss alchemist, Paracelsus. When smelted, zinc forms sharp pointed crystals, therefore, Paracelsus called the substance zink, after the old German word, “zinke,” meaning pointed. German scientist, Andreas Sigismund Marggraf is recognized as having discovered zinc in 1746, when he isolated the element in its pure metallic form. Classified as a transition metal and solid at room temperature, zinc is a necessary component for many metabolic reactions in plants. Zinc is absorbed by plants as Zn^{2+}, a positively charge ion, known as a cation. Although needed by plants in small quantities, zinc contributes to plant growth, leaf formation, and is a key constituent of many enzymes and proteins.

COPPER (Cu)

Copper has the atomic number 29 on the periodic table of elements. This element has also been known since antiquity and is easily recognizable by its distinct color.

Plants absorb copper in the form of Cu^{2+}.

MOLYBDENUM (Mo)

Molybdenum has the atomic number 42 on the periodic table of elements.

Molybdenum is absorbed by plants in the form of molybdate, $MoO_4(^{2-})$.

NICKEL (Ni)

Nickel has the atomic number 28 on the periodic table of elements.

Plants absorb nickel as nickel ions (Ni^{2+}).

MICRONUTRIENT DEFICIENCIES AND TOXICITIES

Although micronutrients are needed by plants in much smaller quantities, plants can still develop deficiencies or toxicities of these nutrients. As discussed in the last chapter, nutrient deficiencies or toxicities can lead to abnormal plant growth and function. A nutrient deficiency occurs when a plant does not have enough of a necessary nutrient required for plant growth and toxicity occurs when a plant has too much of a certain nutrient. Both instances can lead to a variety of growth implications. Refer to the chart on the following page for more information about how to identify micronutrient disorders through observation[16].

IDENTIFYING MICRONUTRIENT DISORDERS

CHLORINE (Cl)

DEFICIENCY: Chlorine deficiency may cause leaves to wilt and turn bronze. Root tips become swollen and stunted.

TOXICITY: Excessive amounts of chlorine may burn leaf tips, turn leaves bronze, and cause leaves to grow slow and split.

IRON (Fe)

DEFICIENCY: Iron deficiency causes distinct interveinal chlorosis in younger leaves and stunts plant growth.

TOXICITY: Plants with iron toxicity may develop brown spots or bronze coloration on leaf surfaces.

BORON (B)

DEFICIENCY: Leaves become affected. Root tips may become swollen and internal tissue may develop fungal disease.

TOXICITY: Boron toxicity results in chlorosis followed by dead tissue forming at the leaf tip then spreading inward.

MANGANESE (Mn)

DEFICIENCY: Plants deficient in manganese may experience stunted growth, interveinal chlorosis, and leaf shedding.

TOXICITY: Excessive amounts of manganese can cause leaves to turn blackish-brown or cause reddish spots on older leaves.

ZINC (Zn)

DEFICIENCY: Zinc deficiency can cause chlorosis, smaller leaf sizes, and distorted leaf margins, the boundary along the leaf edge.

TOXICITY: Excessive amounts of zinc can cause leaves to turn dark green, cause chlorosis, and reduce root and leaf expansion.

COPPER (Cu)

DEFICIENCY: New leaves may develop twisted, become dark green, and develop necrotic spots, or dead tissue.

TOXICITY: Copper toxicity can displace iron, leading to Fe deficiencies such as chlorosis and stunted growth.

MOLYBDENUM (Mo)

DEFICIENCY: Older leaves may develop interveinal chlorosis, which can spread. Newer leaves may grow in a twisted manner.

TOXICITY: Molybdenum toxicity is not usually serious, but may cause stunted growth and yellow-brown discoloration.

NICKEL (Ni)

DEFICIENCY: Nickel deficiency can cause chlorosis in young leaves, poor seed germination, and decreased yields.

TOXICITY: Nickel toxicity can also displace iron, leading to stunted growth and interveinal chlorosis in new leaves.

Chapter 4 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

- **A.** True
- **B.** False

Check Answer

CHAPTER 5

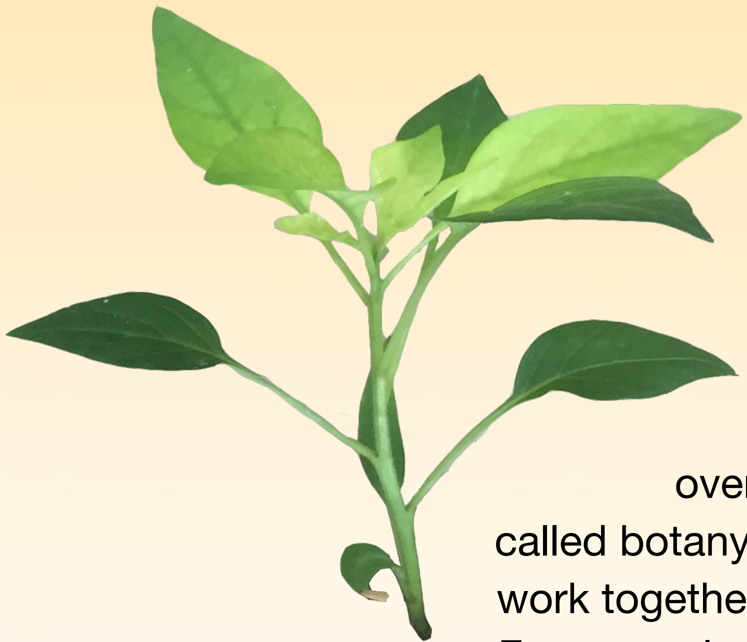
PLANTING

Growing plants using hydroponic technologies differs from traditional farming methods. Plants grown in water often require different pH than soil-grown plants and also receive their nutrients in a different way than conventional agriculture. In this chapter, we will learn more about the science behind plants to identify how to grow successfully in a hydroponic system.

Plant Biology

STEM TOPICS TO BE COVERED

- Cotyledons, Monocots, and Dicots
- Types of Plants
- Parts of a Plant
- Pollination
- What is a Vegetable?
- What is a Fruit?



Before we begin discussing what to plant in a hydroponic system, it is important to have an understanding of overall plant biology, also called botany, and how plant systems work together in any environment. For example, natural processes, such as pollination, don't work the same indoors as they do outdoors since there are no bees or other pollinating insects or wind to do the job. Also, knowing what to look for when plants sprout help the grower identify if things are moving in the right direction. Also, what is the difference between a fruit and a vegetable? Many of the plants that are commonly referred to as vegetable are actually fruits, but the answer is actually easy to see just by identifying the parts of the plant. We will find out about these differences and how to identify these characteristics in this chapter.

COTYLEDONS, MONOCOTS, & DICOTS

The very first leaves to appear from a germinated seed are not actual leaves, but rather the embryonic first leaves of the seedling. These first leaves are called ***cotyledons*** and botanist classify plants based on whether they sprout one or two embryonic leaves. Species that sprout one cotyledon are called ***monocots***, which is short for monocotyledon, and literally translated, means one cotyledon. Plants that produce two cotyledons are called ***dicots***, which is short for dicotyledon, and translated means two cotyledons.

Monocots and Dicots also exhibit distinctly different structural features. Leaf venation of a monocot is usually parallel while dicots feature more of a netlike pattern. Vascular bundles within the stems of a monocot are typically complex while dicots are often feature vascular bundles arranged in a ring. The roots of a monocot are usually fibrous while dicots are noted for large taproots. Lastly, the floral components of a monocot are usually seen in multiples of three while dicots can be seen in multiples of four or five.

TYPES OF PLANTS

There are two basic types of plants, ***tracheophytes*** and ***bryophytes***. Tracheophytes are vascular plants, meaning they are made up of conductive tissue that transports water and nutrients throughout the plant in a system of tubular cells. Bryophytes are non-vascular plants as they do not posses the structure needed to transport water and nutrients to higher tissue in the plant. For this reason, bryophytes grow close to the ground and include mosses, hornworts, and liverworts. Most plants are tracheophytes and are made up of roots, stems, and leaves.

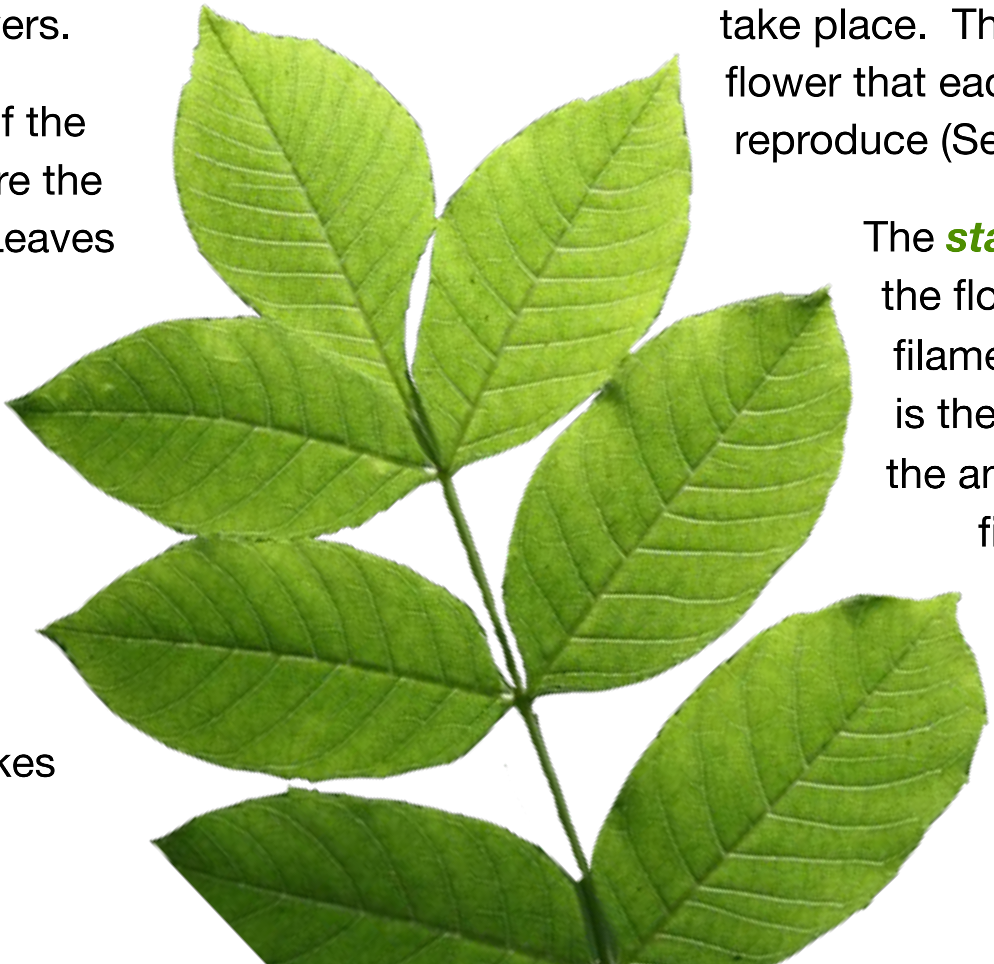
Tracheophytes can be grouped into three categories, flowering plants called ***angiosperms*** and non-flowering plants called ***gymnosperms*** and ***ferns***. Angiosperms produce fruits that hold the plant's seeds for reproduction and therefore the additional components of an angiosperm include the flower, the fruit, and the seed. Gymnosperms are tracheophytes that produce seeds in cones that remain closed until maturity. Ferns do not have seeds, but rather reproduce through spores that are produced on the underside of the fern's leaves. Most of the plants that are consumed as food are angiosperms and are often categorized by their edible parts, such as by the roots, stems, leaves, fruits, or seeds. Pine nuts are an example of an edible gymnosperm. Many types of angiosperms can be cultivated in hydroponic systems.

PARTS OF A PLANT

As mentioned, most plants are made up of roots, stems, leaves, flowers, fruits, and seeds. The ***root system*** of a plant is part of the plant's vascular system, which provides the nutrients to the rest of the plant. Water and dissolved minerals are absorbed by the roots and can then travel through the stem and to the leaves. In addition to supplying the plant with food, roots help keep the plant anchored in place, or "rooted." The sprawling fibrous roots continue to extend and travel through the soil or growing medium to establish stability and seek nutrients. In hydroponic technologies, root systems are often more consolidated since nutrients are brought directly to the plant.

The ***stems*** are also part of the the plant's vascular system as they carry nutrients and water from the roots to the plant's leaves. Nutrients, water, and glucose are carried through the plant by two types of vascular transport tissue called ***xylem*** and ***phloem***. Xylem and phloem are usually found together, forming vascular bundles that travel through the plant stems. Xylem carries nutrients and water from the plant's roots up through the stem and to the leaves while phloem carries glucose produced in the leaves back through the plant as needed for food. Stems also provide a support structure for the plant's leaves and flowers.

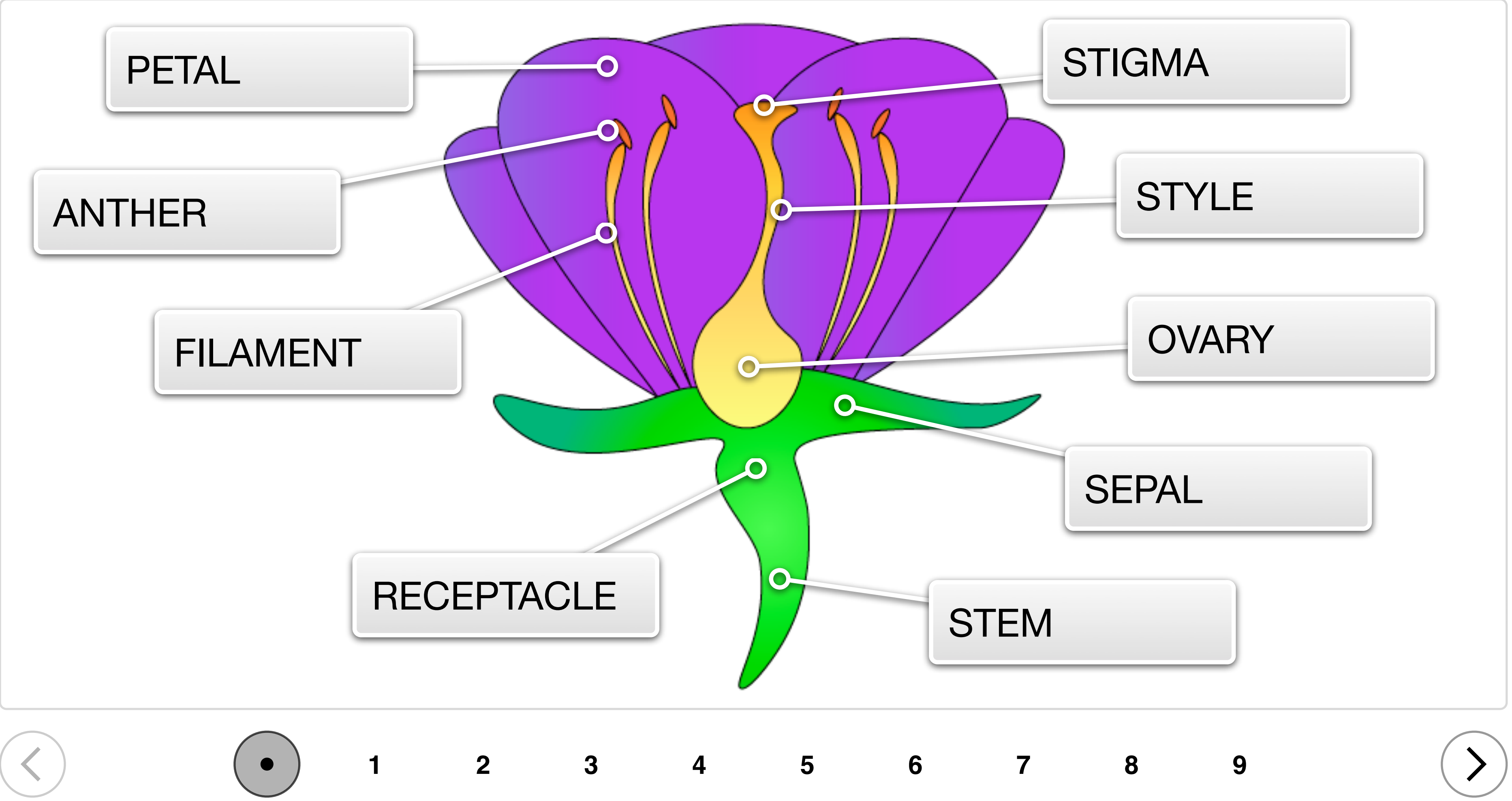
The ***leaves*** of a plant are the last part of the plant's vascular system and this is where the plant actually produces its own food. Leaves are connected to the stem by a ***petiole*** and either simple, being made up of a single leaf blade, or compound, being made up of separate leaflets. As mentioned in the section, "Photosynthesis," plants are called ***autotrophs***, which means they have the ability to synthesize, or generate, their own food supply. This process takes place in the leaves. ***Chlorophyll***, the substance that makes the leaves green, causes the plant to absorb energy from light. Through ***photosynthesis***, the plant uses this energy to create glucose from carbon dioxide in the air and water taken up from the plant's roots. When photosynthesis takes place, plants release oxygen into the air. It is often thought that the nutrients supplied to the plant's roots provide the plant with food, however, it is actually the glucose produced in the leaves through photosynthesis that supplies the plant with the carbohydrates it needs to survive.



The ***flowers*** on plant are the seed-bearing receptacles that produce fruit. When a flower blooms, the internal structure of the flower is revealed and the process of pollination can take place. There are many distinct parts of a flower that each contribute to the plants ability to reproduce (See Diagram 5.1).

The ***stamen*** is the male reproductive part of the flower and it is composed of a slender filament, anther, and pollen. The ***filament*** is the thin, hair-like structure that supports the anther. The ***anther*** sits atop the filament and it is where the pollen is produced in tiny sacs. ***Pollen***, a dust-like substance consisting of tiny grains necessary for reproduction, gets released from

Interactive 5.1 Parts of a Flower

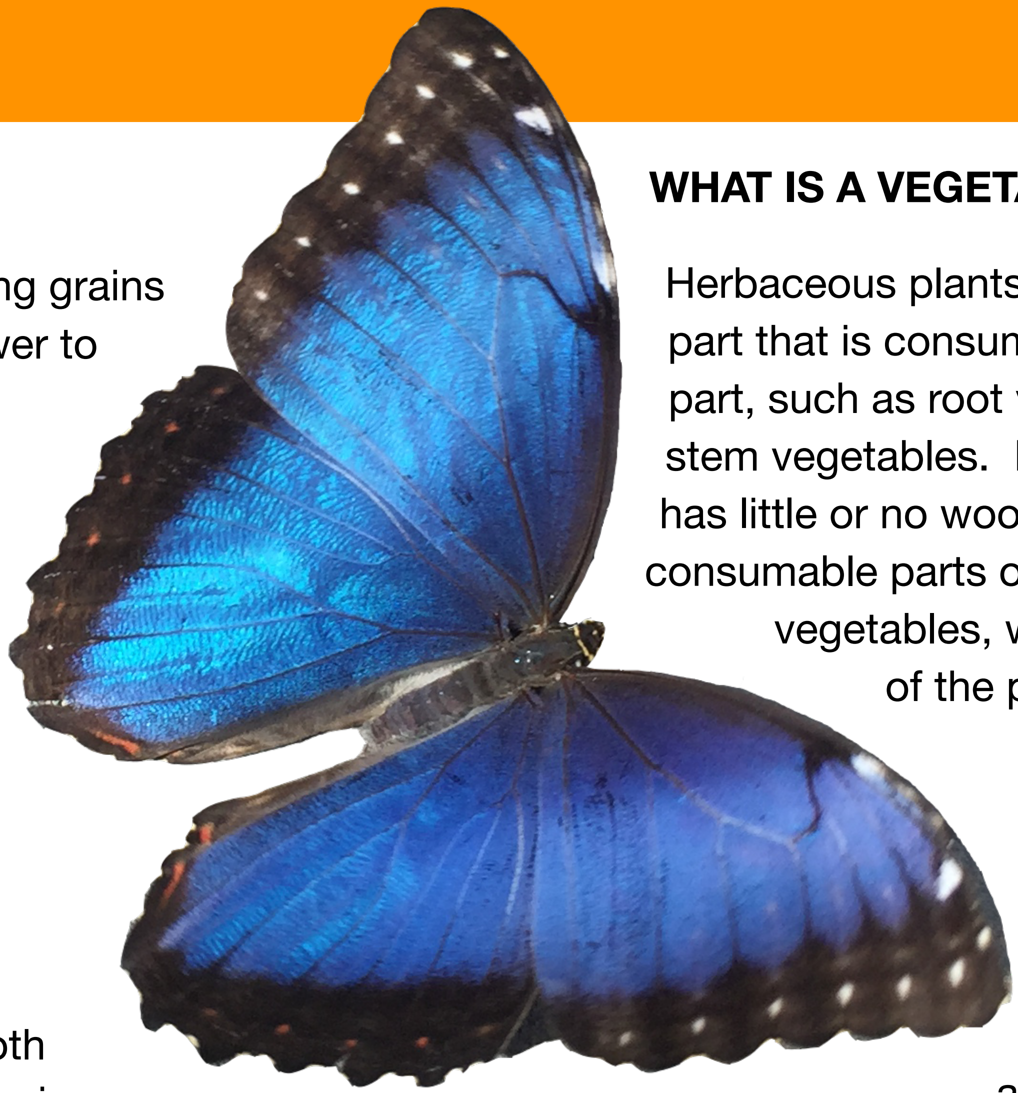


which are the female egg cells which become fertilized during the process of pollination. It is the ovary that, once fertilized, turns into the plant's ***fruit***. In an angiosperm, it is this fruit that contains the seeds that can be sowed to grow more plants.

Other parts of a flower include the petals, sepals, and receptacle. The ***petals*** act as a barrier to protect the reproductive organs of the flower and they also attract pollinators such as bees, hummingbirds, and butterflies through their vibrant colors. ***Sepals*** are the tiny, often green and leaf-like outer part of the flower, that surround a developing bud. The ***receptacle*** is the enlarged part of a flower located at the apex of the stem from which the flower grows.

the sacs to cover the anther.

The ***pistil*** is the female reproductive part of the flower and it is composed of the stigma, style, ovary, and ovules. The ***stigma*** is the sticky nodule located at the top of the pistil and it is where the pollen fertilizes the flower. The stigma sits atop the ***style***, which is the long, tubular structure that leads to the ovary and ovules. The ***ovary*** contains the ***ovules***,



POLLINATION

Pollination is the process of transferring grains of pollen from the male anther of a flower to the female stigma. This fertilizes the ovule and creates reproduction. Pollination can occur in a number of ways and this depends upon the type of flower being pollinated. Flowers are either perfect or imperfect. ***Perfect flowers*** contain both male and female parts while ***imperfect flowers*** are missing one or the other. Perfect flowers, such as those on a tomato plant, are considered self-pollinating plants since they contain both male and female organs and do not require pollen from a different flower for fertilization to take place. However, for fertilization to occur in an imperfect flower, imperfect female flowers, such as those on a cucumber plant, require pollen to be brought from a male flower in order for pollination to occur.

In nature, pollen is usually transferred by the wind or animals such as bees, butterflies, moths, and hummingbirds. Indoor environments that do not have wind or animals can be manually pollinated to transfer pollen when growing plants with imperfect flowers, such as squash and melons.

WHAT IS A VEGETABLE?

Herbaceous plants are many up of many parts. Each part that is consumed is generally referred to as that part, such as root vegetables, leafy vegetables, and stem vegetables. Herbaceous refers to any plant that has little or no woody stem above ground. All consumable parts of the plant are referred to as vegetables, with one exception, the flower portion of the plant, which is called the fruit.

WHAT IS A FRUIT?

There are many misconceptions about what is classified and a fruit and what is classified as a vegetable. As described above, most parts of an edible plant are called vegetables. However, the clarification is simple. Any vegetation that develops from a flower is called a fruit. Fruits always contain seeds. Therefore, many of the things we eat everyday that are often referred to as vegetables are specifically fruits. This includes tomatoes, cucumbers, eggplants, bell peppers, and all produce that encases the seeds.

Tomatoes are a fruit!

Hydroponic Plants

STEM Topics to be Covered

- Asteraceae
- Brassicaceae
- Lamiaceae
- Apiaceae
- Cucurbitaceae
- Solanaceae
- Rosaceae

Specific plants need specific growing environments and there are certain plants that grow well within a hydroponic system. OPCOM Farm offers a select variety of non GMO seeds that grow well in their hydroponic systems. OPCOM is currently offering thirty different kinds of seed and is always researching new seeds for success cultivation indoors.

LEAFY GREENS

Lettuce belongs to the plant family, ***Asteraceae***, commonly known as the sunflower family. Asteraceae is one of the largest plant families containing over 23,600 species and consisting of many ornamental plants such as chrysanthemums and marigolds and also culinary plants such as artichokes, endive, and sunflowers. Typically, lettuce is a cool season crop that grows well with shorter days, cooler temperatures, and sandy loam soils with plenty of humus and good drainage. However, lettuce, and other leafy greens, are among the varietals of plants that grow extremely well in hydroponic environments. Containing over

> Lettuce contains over 96% water.

Herbs such as basil and oregano can be grown hydroponically.

96% water, lettuce can be grown quickly and efficiently in an indoor hydroponic system. Many leafy greens succeed in soilless environments including red and green leaf lettuces and butter lettuce and also cruciferous leafy greens such as arugula, kale, cabbage, broccoli, bok choy, and watercress. Cruciferous vegetables belong to the plant family, ***Brassicaceae***, which is commonly referred to as the mustard family and contains over 3,000 species. Plants in the mustard family are known for being a rich source of sulfur-containing compounds called glucosinolates.

HERBS

In addition to greens, an abundant variety of herbs grow excellent in hydroponic systems. Herbs that do well include those belonging to the plant family, ***Lamiaceae***, commonly known as the mint family, such as mint, basil, oregano, lemon balm, and lavender. Containing over 7,000 species, the Lamiaceae family consists of plants that are cultivated for use as food, fragrances, and medicine. Traditionally, these herbs grow well in mild temperatures with adequate sun and well-drained soil. However, the ability to cultivate these plants indoors means they can become available year round.

In addition to the mint family, herbs such as parsley and dill also prosper in hydroponic systems. These plants belong to the plant family, ***Apiaceae***, also called the carrot family. It contains over 3,700 flowering plants such as parsley, dill, coriander, and carrots. Each of these vegetables can be cultivated hydroponically, providing access to these types of plants without some of the challenges that are often associated with traditional gardening, such as burrowing animals, harsh weather, and soil-borne pests.

FRUITS

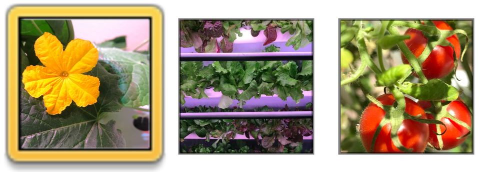
Other edible plants that grow well in hydroponic technologies include fruits such as cucumbers, tomatoes, green peppers, and strawberries. Cucumbers, tomatoes, and green peppers are often thought of as vegetables, but since they contain the plant's seeds, they are classified as a fruit. Belonging to the plant family, ***Cucurbitaceae***, also called the gourd or squash family, cucumbers are known for producing long taproots and numerous branching roots that reach for nutrients and minerals. The squash plant family contains almost 1,000 species and includes other plants such as pumpkins, zucchini, and watermelon.

Tomatoes and peppers belong to the plant family, ***Solanaceae***, commonly called the nightshade family, which contains over 2,500 species. A majority of plants in the nightshade family are tropical, however, there are an abundance of species that do grow well in temperate regions.

Another type of fruit that can be cultivated indoors is the strawberry. A part of the ***Rosaceae*** family, also called the rose family and containing almost 5,000 known species, strawberries are characterized by a fibrous root system and the edible component actually develops in the center of the plant's flowers. Not actually a true berry in botanical terms, the part we call the fruit is actually a receptacle for the plant's seeds, which can be seen surrounding the strawberry. Through hydroponically technologies, it is possible to grow varieties of these plants in places they have never been grown before.

Photo Gallery 5.1: Hydroponically Grown Plants

A new flower blossoming on a cucumber plant in the OPCOM Farm GrowBox



DECORATIVE PLANTS

Fruits and vegetables are not the only types of plants that can be grown in hydroponic systems. Other plants such as ornamentals, flowers, and even cacti can also prosper growing indoors. Decorative plants that can be grown hydroponically include various species of ivy, Boston fern, asparagus densiflorus, selaginella, begonia, sansevieria, cactus, aloe, and the common poinsettia.

Maintenance

STEM TOPICS TO BE COVERED

- Electrical Conductivity
- pH Testing
- Water Quality
- Pest Management

There are a few key aspects of growing hydroponically that need to be maintained. This includes routine maintenance of the hydroponic system to include cleaning the system and verifying pumps are circulating properly. It also includes making sure the plants are receiving enough nutrients and that their water source is at the proper pH level for growing. OPCOM offers a few simple tools to help make this process easier, include a handheld, digital pH tester and electrical conductivity meter. These devices make routine tests simple and help keep the hydroponic environment ideal for healthy plants and fruits.

TESTING ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) is routine test necessary for checking the salt concentration of hydroponic nutrient solutions. All hydroponic nutrients are made of mineral salts dissolved in water. Testing the EC of a nutrient solution indicates the strength of the solution and determines if the plants are receiving the nutrients it needs. The amount of nutrients needed by each plant differs and EC levels will indicate if the plant needs additional nutrients or is receiving too many. Larger, fruiting crops typically use more nutrients than leafy greens, such as lettuce and herbs. For higher use crops, nutrients need to be added more frequently and for light use crops, it may be necessary to dilute nutrient solutions with water to bring EC levels to the optimal range.

In general, seedlings need an EC level about 0.5 - 1.0, leafy plants needs an EC level of 0.8 - 2.0, flowering plants need an EC of 0.6 - 1.3, and fruiting plants need an EC of 0.7 - 3.5.

OPCOM Farm provides proprietary nutrient formulas which can be added to the hydroponic system's reservoir for EC management. These formulas automatically adjust nutrient levels, providing the plants with the nutrients they need for health. EC should be tested on a frequent basis to ensure the plants have a healthy growing environment. For OPCOM Farm systems, EC should be checked about once a week. If EC results are too high, add plain water to the nutrient solution to dilute the soluble mineral salts and bring the concentration down. If EC levels are too low, add additional OPCOM Farm nutrients to raise EC levels.

pH TESTING

One routine test necessary for plant health is pH monitoring. A pH test determines how acidic or how basic a solution is. The pH scale ranges from 0 - 14, with zero being the most acidic and fourteen being the most basic. The optimal pH range for hydroponic plants can be different than for the same plant grown in soil. In general, most hydroponically grown plants prefer a pH level between 5.5 - 6.5 for optimal growth. In most places, tap water has a pH level of around 7.5, right near the middle of the pH scale. When the pH level is too high or too low, it needs to be adjusted to the correct pH for plant health. If the pH level remains too high, the plants may... and if it is too low, the plants may experience.... Incorrect pH levels can affect nutrient uptake, leading to a nutrient deficiency or toxicity. On the other hand, it is also possible to detect nutrient inefficiencies through a pH test. When pH is too high, it can be the result of nutrient deficiencies in iron (Fe), manganese (Mn), and phosphorus (P). On the other hand, of the pH is too low, it can be the result of low calcium (C), magnesium (Mg), and potassium (P). OPCOM offers specialized pH capsules for adjusting the pH levels of water quickly and easily.

There are numerous factors that can cause pH levels to change. In most cases, higher temperatures and increased light can raise pH levels while lower temperatures and reduced light can lower pH. Also, different plants absorb different ions and this will affect pH as well. As lettuce and strawberries grow, they tend to lower the pH of the circulating water while cabbage has been known to increase pH levels as it grows.

WATER QUALITY

Water quality is also important when growing plants in a hydroponic environment. Different places have different water qualities, so it is necessary to test the water and adjust it as necessary. OPCOM provides pH capsules for increasing or decreasing pH levels of the water for optimal plant health. Over time, plant hydroponic systems can develop algae, a green substance that produces rapidly when water is exposed to light. In addition, roots can turn brown and begin to rot, so routine maintenance of the system is necessary to keep the environment clean and in good working condition. Algae growth can be inhibited through the use of a photocatalyst, which is photoactive chemical capable of initiating a photochemical response that would not normally occur. Photocatalytic coatings can be used to reduce the photosynthetic response of algae when exposed to light by nearly 90%, a significant reduction. The new product series from OPCOM Farm provides a photocatalysis coating, which inhibits algae from growing in the machine to keep water pipes clean and promote better plant growth.

PEST MANAGEMENT

Growing plants indoors significantly reduces the amount of pests that are commonly associated with traditional agriculture. Soil-borne insects, rodents, and other animals that can damage outdoor crops are easily abated through indoor growing. However, there are some insects that can still infiltrate an indoor hydroponic system. There are numerous ways to discourage insects indoors. If insects are spotted on a plants, the plants can be removed to prevent further infestation of the entire system. When necessary, there are certain treatments for insects that can also be used to eliminate the problem. In some cases, natural forms of insect control can be used to stave off growing insect populations. For example, introducing lady bugs to a hydroponics system can help inhibit aphids in controlled environment agriculture. OPCOM Farm offers an anti-insect net for systems that are susceptible to insects. The net prevents insects from entering the system and causing damage to the plants, creating a healthy environment.

DISSOLVED OXYGEN

Dissolved oxygen is a critical component to any hydroponics system. OPCOM Farm hydroponic technologies are designed to incorporated sufficient amounts of dissolved oxygen into the hydroponic growing environment. This is accomplished through pumps that keep water circulating.

TEMPERATURE

It is necessary to maintain both the air and water temperature of indoor hydroponic growing systems. Most plants prefer an ambient air temperature somewhere between 41° F and 86°

F, however, optimum air temperature can vary from one plant to another. Water temperature is also important and the optimum range can vary from plant to plant. Most plants prefer water temperatures between 60° F and 80° F, with the ideal range being 65° F - 70° F.

Chapter 5 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

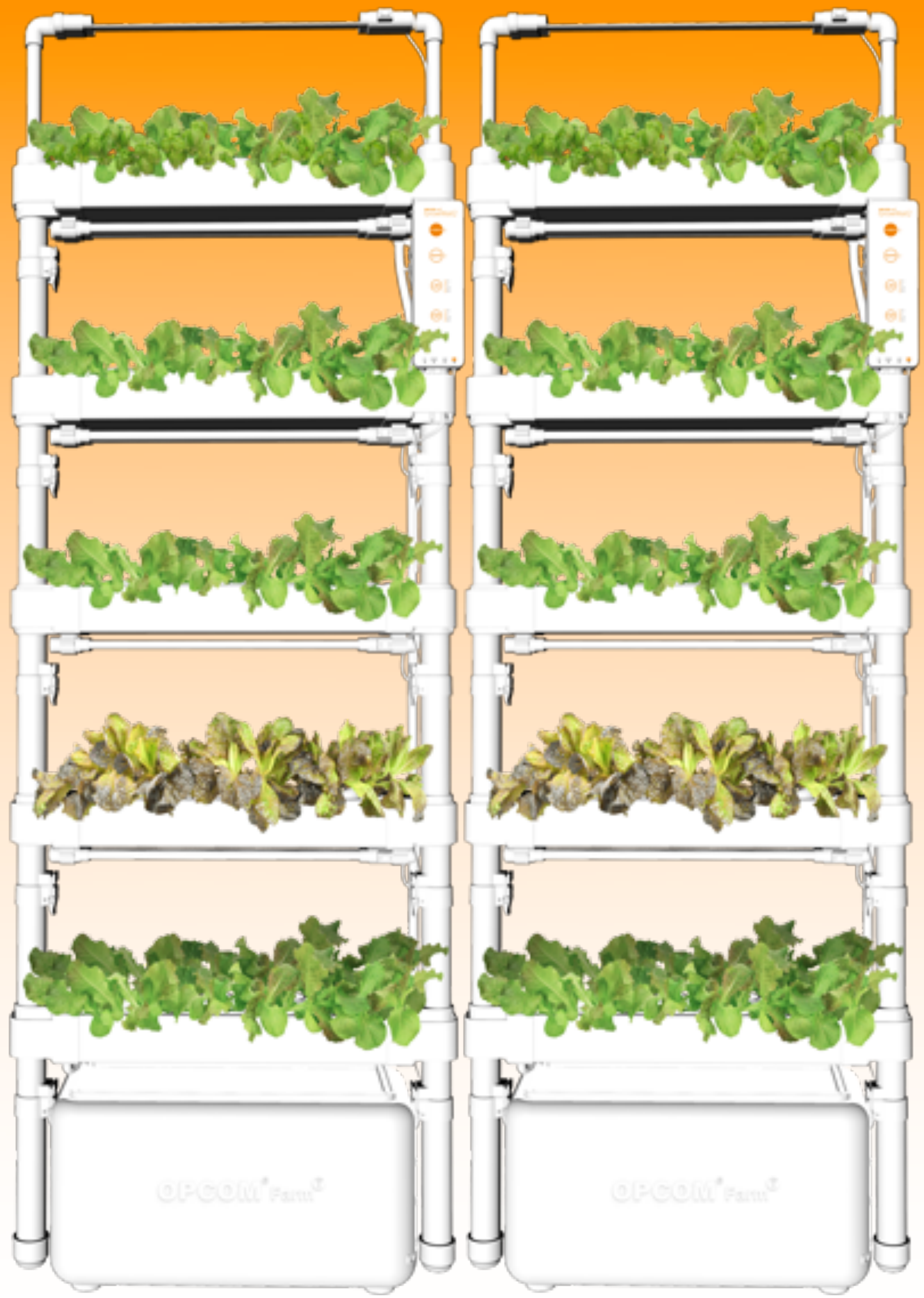
- **A.** True
- **B.** False

Check Answer

CHAPTER 6

HARVESTING

Knowing when and how to harvest hydroponically grown produce is its own science. When harvested, some hydroponically grown food react differently than if they were grown in soil. In this chapter, we will learn about different techniques that can help harvest time be the most successful.



How to Harvest Hydroponics

Write...

STEM Topics to be Covered

- Etc.

Storage

HOW TO STORE HARVESTED PRODUCE

Write...

SHELF LIFE

Have you ever noticed that some refrigerators have a special compartment for storing fruits and vegetables. Sometimes that compartment comes with a lever for adjusting its humidity levels. This is because different types of vegetables can be kept for longer when stored in the optimal range of humidity. Storing fleshy vegetables, such as strawberries, lettuce, and cucumbers, in higher humidity can increase shelf life by preventing water loss from the fruit. Root vegetables, such as carrots and beets, prefer drier environments for prolonged shelf life.

STEM TOPICS TO BE COVERED

- Etc.

Keep fruits and vegetables that release ethylene gas separate from the rest. Examples of produce that release ethylene gas are tomatoes, apples, and pears. The gas tells the fruit to decompose, so store separately to keep other produce from turning bad prematurely.

Nutrition and Recipes

STEM Topics to be Covered

- Lorem ipsum dolor sit amet
- Consectetur adipisicing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.
- Ut enim ad minim veniam, quis exercitation ullamco laboris nisi ut aliquip ex commodo consequat.
- Duis aute irure dolor in in voluptate velit esse cillum dolore eu fugiat nulla pariatur.

Chapter 6 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

A. True

B. False

Check Answer

CHAPTER 7

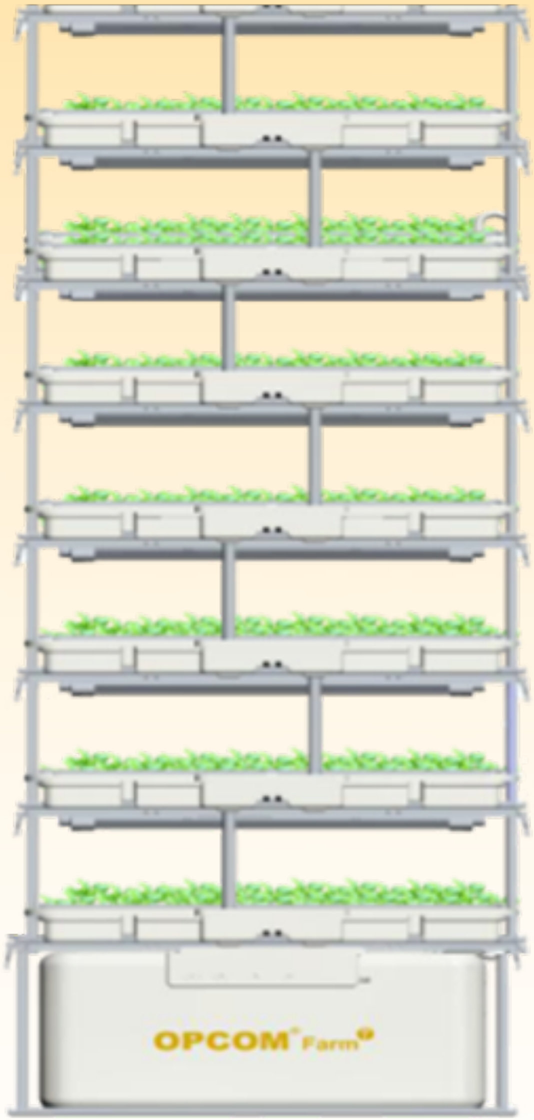
ENVIRONMENTAL BENEFITS

Growing plants hydroponically promotes sustainability in a variety of ways. Plants remove toxins and pollutants from the air we breathe, which is especially important for indoor environments. Indoor growing can also help reduce food miles, which reduces dependency on fossil fuels and creates cleaner air. In this chapter, we will learn more about how advanced hydroponics helps the environment and helps supply food to remote locations.

Indoor Air Purification

STEM Topics to be Covered

- Energy Efficiency
- Indoor Air Pollution
- Benzene
- Formaldehyde
- Ammonia
- Xylene
- Trichloroethylene
- Plants for Cleaner Indoor Air



ENERGY EFFICIENCY

Energy efficiency is a word we hear a lot these days, and for many reasons. Reducing energy needs means reducing energy consumption, and that means reducing air pollution and dependency of fossil fuels, among other things. Energy efficiency can save people money on utility bills such as power and gas. Overall, energy efficiency is viewed as a good thing. But is there a downside?

One of the most common methods of reducing energy demand and increasing efficiency is to super insulate buildings. This addresses the largest consumer of residential energy usage, which is heating and cooling the home, by reducing fresh air exchange to maintain inside temperatures. During temperate months, utility bills go down and people enjoy opening windows and spending time in the great outdoors. However, during hot summer and cold winter months of the year, which for many places endures for much long than fair weather, heating and cooling bills rise significantly and people spend more time indoors. This means higher energy usage and energy demand.

Super insulation techniques became popular following the 1970s Energy Crisis. During this time, oil prices jumped 350% as a result of the OPEC oil embargo of 1973, immediately making energy efficiency a matter of high importance[8]. However, it was soon determined that super insulating buildings contributed significantly to various health problems of those occupying the buildings. Elements such as building materials, synthetic fabrics, and heating fuels release, or off-gas, volatile organic compounds (VOCs) into the air we breathe. By 1984, it was believed that super insulated buildings contributed to deteriorating indoor air quality and led to the development of “sick building syndrome,” the condition of sicknesses related to exposure to indoor VOCs. August, 1989, the U.S. Environmental Protection Agency (EPA) researched the indoor air quality of ten public access buildings, including hospitals and office buildings. The report stated more than 900 organic chemicals were identified in newly constructed buildings and that some chemical levels were one hundred times greater than normal levels[10]. The report also stated sufficient evidence exists to conclude that indoor air pollution may pose serious acute and chronic health risks[10]. The EPA submitted their findings to Congress.

Advanced ventilation systems have made it more possible to super insulate modern buildings, however, the importance of these ventilation systems working properly is significant. In addition to ventilation, plants plants actually degrade toxic organic chemicals, and can be used indoors to help purify stale, toxic air. In 1989, NASA performed research indicating that indoor plants could significantly reduce indoor air pollution for many of the common toxins emitted in typical indoor environments.

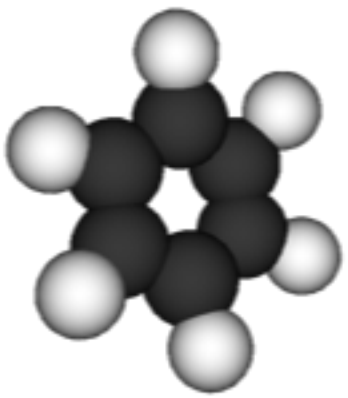
INDOOR AIR POLLUTION

Plants naturally purify the air we breathe. They take carbon dioxide from the air for the process of photosynthesis and release oxygen from small openings underneath their leaves in the process. In addition to removing the greenhouse gas, carbon dioxide, plants also purify the air from many other common pollutants. Hydroponic plants grown indoors can play a significant role in reducing harmful VOCs from the air within buildings, such as schools, offices, and even our homes. Substances such as benzene, formaldehyde, ammonia, xylene, and trichloroethylene emit VOCs commonly found in indoor environments, which can be removed from the air by plants. But what are these pollutants and how do they affect us?

ELEMENTS TO KNOW		
C	=	CARBON
H	=	HYDROGEN
O	=	OXYGEN
N	=	NITROGEN
Cl	=	CHLORINE

BENZENE

Benzene is one of the most widely used chemicals in the United States. It is an organic, aromatic, highly flammable hydrocarbon that is a colorless or pale yellow liquid at room temperature. The ring-shaped, cyclic compound has a chemical formula of C_6H_6, meaning it has six carbon atoms and six hydrogen atoms. It evaporates very quickly in the air and sinks to low-lying areas as its vapors are heavier than air. Benzene is a natural component of crude oil, gasoline, and tobacco smoke and is widely used in the production of inks, resins, paints, plastics, rubber, and synthetic fibers. It is a toxic substance associated with many health risk factors including but not limited to skin and eye irritation, embryonic activity, carcinogenicity, and leukemia. Benzene interferes with proper cell function and has also been known to cause dermatitis, respiratory diseases, kidney damage, headaches, nervousness, anemia, and paralysis[7]. Benzene is found outdoors and indoors, although indoor air generally contains higher concentrations of benzene than outdoor air[12]. One way to mitigate benzene from indoor environments is through hydroponically grown plants that are able to absorb the contaminant.

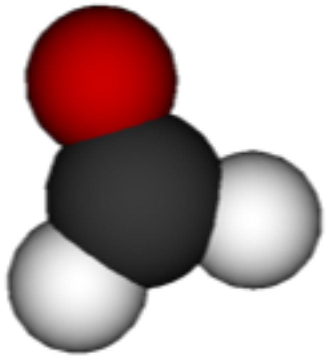


BENZENE MOLECULE

C_6H_6

FORMALDEHYDE

Formaldehyde, a naturally occurring organic compound, is widely used in a variety of chemical manufacturing processes. It is a colorless, highly reactive, hazardous gas formed by the incomplete combustion of hydrocarbons. Formaldehyde has the chemical formula CH_2O, also written H_2CO. The compound is comprised of two hydrogen atoms and one oxygen atom bonded to one central carbon atom. Formaldehyde is a highly toxic systemic poison[14] that can be found in nearly all indoor environments from materials such as particle board and pressed wood products; consumer paper products such as paper bags, waxed paper, and power towels; many common cleaning agents; permanent-press fabrics and wrinkle resistors; adhesives; tobacco smoke; and cooking fuels such as natural gas. Formaldehyde is an eye, nose, and throat irritant, can cause dermatitis, irritates the upper respiratory tract, and causes headaches and asthma. Also, the Environmental Protection Agency conducted research which indicates that formaldehyde is strongly suspected of causing a rare type of throat cancer in long-term occupants of mobile homes[7].

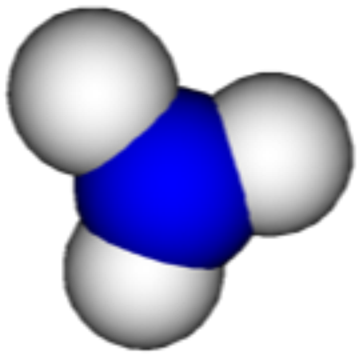


FORMALDEHYDE MOLECULE

CH_2O

AMMONIA

Have you ever used window cleaner and noticed it has a distinctive, pungent odor? That odor is coming from the chemical, ammonia. Ammonia, a colorless gas that occurs naturally and is produced by human activity, is used in many products and industries for its unique characteristics. It is soluble is water and evaporates quickly, which is how it leaves that streak-free shine on the bathroom mirror. It has the chemical formula NH_3, meaning it has one nitrogen atom and three hydrogen atoms. Emitters of ammonia include fertilizer manufactures, fossil fuel combustion, livestock management, and refrigeration methods. In the home, ammonia can be found in window cleaners, floor waxes, and garden fertilizers. Typical environmental concentrations of ammonia have not been found to affect human health, although higher levels of ammonia can cause irritation to the eyes, nose, and throat[9]. Ammonia is poisonous if inhaled in very high quantities and people with asthma may be more sensitive to breathing ammonia than others[13]. Ammonia is actually a good source of nitrogen for plants, an essential nutrient needed for proper plant growth, which is why it is used in fertilizers.

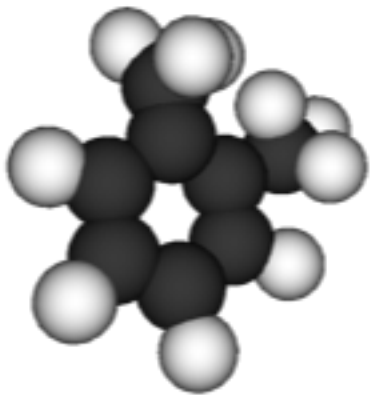


AMMONIA MOLECULE

NH_3

XYLENE

Xylene is a colorless, flammable, aromatic liquid hydrocarbon commonly used as a solvent in the printing, rubber, leather, and paint industries. It is almost insoluble in water, but mixes well with oily substances, making it an effective solvent. Xylene exists in three forms, meta-xylene (m-xylene), ortho-xylene (o-xylene), and para-xylene (p-xylene), which are referred to as isomers. The chemical formula for xylene is C_8H_{10}, which means it consists of eight carbon atoms and ten hydrogen atoms. This chemical formula can also be written as $C_6H_4(CH_3)_2$, giving more indication of its molecular structure. In addition to its uses as a solvent, xylene is also used as a cleaning agent, paint thinner, and in varnishes. Other sources of xylene include tobacco smoke and vehicle exhaust. Although it is a toxic substance, normal environmental exposure to xylene is not known to be a health risk. Higher levels of xylene can cause irritation of the skin, eyes, nose, and throat, difficulty breathing, impaired lung function, delayed response to visual stimulus, and affect the nervous system[11]. Very high levels of xylene, even for a short period of time, is poisonous. Indoor levels of xylene can be higher than outdoor levels.

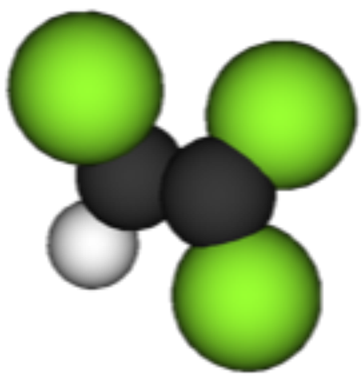


XYLENE MOLECULE

C_8H_{10}

TRICHLOROETHYLENE

Trichloroethylene is a synthetic, highly toxic, carcinogenic chemical primarily used as a solvent to remove grease from metal parts. The chlorinated hydrocarbon, or halocarbon, is a colorless, nonflammable liquid with a slightly sweet odor. The chemical formula for trichloroethylene is C_2HCl_3, meaning it has two carbon atoms, one hydrogen atom, and three chlorine atoms. In addition to its use as a solvent, trichloroethylene is also used in printer ink, paints, lacquers, adhesives, and paint remover[7]. The volatile substance is listed by the EPA as carcinogenic to humans and affects organ development the nervous system. Exposure to high levels of trichloroethylene can cause irregular heartbeat, liver damage, and kidney damage and breathing high levels of the toxic chemical can cause facial nerve damage. According to the New York State Department of Health, almost all exposure to trichloroethylene is from indoor air[15]. Indoor plants can be used to help remove this toxic chemical from buildings, improving the air quality of schools, offices, pubic buildings, and homes.



TRICHLOROETHYLENE MOLECULE

C_2HCl_3

PLANTS FOR CLEANER INDOOR AIR

Some plants have been studied to determine how many VOCs they can remove from polluted indoor air. Species that are proficient at removing these toxins include marginata (dracaena marginata), green spider plant (chlorophytum elatum), peace lily (spathiphyllum “Mauna Loa”), golden pothos (scindapsus aureus), bamboo palm (chamaedorea seifrizii), pot mum (chrysanthemum morifolium), gerbera daisy (gerbera jamesonii), and Boston fern (nephrolepis exaltata “Bostoniensis”). The Boston fern is the single most effective indoor plant for removing formaldehyde from an enclosed environment[10]. In addition to these ornamental plants, many leafy green plants such as lettuce and basil, also contribute to the removal of these toxins from indoor air. A variety of the ornamental plants as well as leafy greens can be grown in an indoor hydroponics system. OPCOM hydroponic systems can be used to create a cleaner, healthier environment in any indoor settin

Resource Conservation

STEM Topics to be Covered

- Food Miles
- Water Savings
- Energy Savings
- Energy Usage and the kWh
- How to Calculate Electricity Usage

In 2050, it is estimated that there will be 2.5 billion more people on Earth than there are today. It is estimated that 80% of them will be living in cities and that 70% more food will be required to feed eveyone. Yet today, 80% of cultivated land is already in use. At the same time, extreme climate is anticipated to hurt agricultural resources, resulting in higher food prices. In addition, pollution of soil and water resources have been known to cause food toxicity. For these reasons, and many more, indoor growing technologies will be essential to helping meet the agricultural needs of our growing society.

FOOD MILES

Growing food locally is a huge benefit to the environment. Most of the food we eat has to travel long distances from the places it is harvested and processed, and those distances they travel are known as food miles. On average, the foods that make up a typical meal travel ... miles, which equates to oil, gas, air pollution, etc.

SECTION 2: RESOURCE CONSERVATION

WATER SAVINGS

ENERGY SAVINGS

ENERGY USAGE AND THE kWh

HOW TO CALCULATE ELECTRICITY USAGE

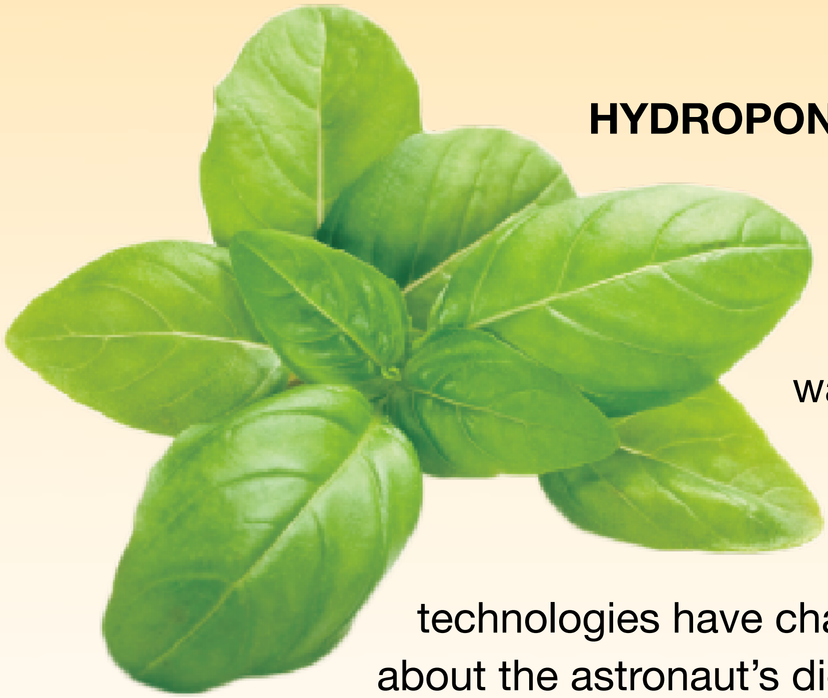
OPCOM Farm can grow fresh, healthy, plants in a hydroponic way. Its use of energy saving LEDs and energy efficient pumps decreases the energy consumption needed for ordinary hydroponic systems. In addition, OPCOM Farm is cultivated indoors, meaning less land and space is needed than for traditional agriculture.

OPCOM Farm looks toward the future and is dedicated to providing the best service possible to its customers. Through OPCOM Farm's advanced hydroponic technologies, it is possible to meet the critical food demands of a growing population.

Distributed Hydroponics

STEM Topics to be Covered

- Etc.



HYDROPONICS IN SPACE

The concept of eating fresh fruits and vegetables in space was once just a far out thought. But recent advances to hydroponic technologies have changed everything about the astronaut's diet. It costs millions of dollars per pound to send payloads to outer space, which immediately rules out sending up bags of soils. Also, there is less space in space, meaning there isn't enough room on the international space station to plant seedlings 4 inches apart to start a traditional farm. Growing hydroponic fruits and vegetables has opened the door to revolutionary possibilities including deep space travel. Astronauts ate the first hydroponically grown red leaf lettuce aboard the international space station in February of 2015. Close proximity of growing plants and significantly reduced water consumption makes growing in places like space more possible than ever before.

HYDROPONICS IN RURAL AREAS

Write...

HYDROPONICS IN URBAN AREAS

Write...

Chapter 7 Review

INTRODUCTION TO HYDROPONICS

Question 1 of 5

Indoor agriculture can only be done using natural light?

- **A.** True
- **B.** False

Check Answer