

## How Hydroponics Works

By Bambi Turner

### Introduction to How Hydroponics Works

If you've ever placed a plant clipping into a glass of [water](#) in the hopes that it will develop roots, you've practiced a form of hydroponics. [Hydroponics is a branch of agriculture<sup>1</sup> where plants are grown without the use of soil.](#) The nutrients that the plants normally derive from the soil are simply dissolved into water instead, and depending on the type of hydroponic system used, the plant's roots are suspended in, flooded with or misted with the [nutrient<sup>2</sup>](#) solution so that the plant can derive the elements it needs for growth.

The term hydroponics originates from the ancient Greek "hydros," meaning water, and "ponos," meaning work. It can sometimes be mistakenly referred to as [aquaculture](#), or aquiculture, but these terms are really more appropriately used for other branches of science that have nothing to do with gardening.

#### Plant Growth

- Grow Houses
- Greenhouses
- Does fertilizer hurt or help my lawn?

As the population of our planet soars and [arable<sup>3</sup>](#) land available for crop production declines, hydroponics will offer us a lifeline of sorts and allow us to produce crops in [greenhouses](#) or in multilevel buildings dedicated to agriculture. Already, where the cost of land is at a premium, crops are being produced underground, on [rooftops](#) and in greenhouses using hydroponic methods.



David Sanger/The Image Bank/Getty Images

A hydroponics garden. See more [pictures of gardening.](#)

Perhaps you'd like to start a garden so that you can grow your own [vegetables](#), but you don't have the space in your yard, or you're overwhelmed by pests and insects. This article will arm you with the knowledge you need to successfully set up a hydroponics garden in your home and provide suggestions of plants that will grow readily without a big investment.

### History of Hydroponics and Soil-less Gardening

While it's easy to imagine this kind of process being labeled as a bunch of new age [science fiction](#), hydroponics has actually been in use for thousands of years. The famous Hanging Gardens of Babylon, one of the [seven wonders of the ancient world](#), are largely believed to have functioned according to hydroponic principles. Built around 600 B.C. in Babylonia, or Mesopotamia, the gardens were situated along the Euphrates River. The area suffered from a dry, arid climate that rarely saw rain, and it's believed that the lush gardens were watered using a chain pull system, which carried [water](#) up from the river and allowed it to trickle down to each step or landing of the garden structure.

<sup>1</sup>agriculture: producing crops

<sup>2</sup>nutrient: a source of nourishment

<sup>3</sup>arable: capable of being farmed productively

During the 10th and 11th centuries, the [Aztecs](#) developed a system of floating gardens based on hydroponics. Driven out of their land, they settled at Lake Tenochtitlan. Unable to grow crops on the lake's marshy shore, they built rafts out of reeds and roots. These rafts were topped with a bit of soil from the bottom of the lake, and then floated out to the center of the water. Crops would grow on top of the rafts, their roots reaching through the rafts and down into the water. [Marco Polo's](#) writings indicate he witnessed similar floating gardens while visiting [China](#) in the late 13th century [source: [Indianetzone.com](#)].

Formal research and publications on hydroponics didn't begin until the 17th century. Sir Francis Bacon, a British scientist, philosopher and politician did research on soil-less gardening in the 1620s. His work on the subject was published posthumously in 1627 and sparked an incredible wave of research into hydroponics.

In 1699, another English scientist, John Woodward, performed tests involving [spearmint](#) growth in various water solutions. He attempted to grow spearmint plants in rain water, river water and water that had been mixed with soil and then drained. He found that the mint grew faster and produced healthier plants in the water solution that had been mixed with soil. His conclusion was that plants would grow better in less pure water than they would in distilled water. We know today that his results were due to minerals that remained in the water after it had been mixed with the soil [source: [Glass](#)].

A Berkeley scientist, William Gericke, promoted the use of hydroponics in commercial agriculture. Using a process he called "[aquaculture](#)," he touted the benefits of soil-less gardening by growing massive [tomatoes](#) in his home via water and nutrient solutions. After finding that the term "aquaculture" was already being used to describe the study of aquatic organisms, he coined the term "hydroponics," which we still use today [source: [Jensen](#)].

Two other Berkeley scientists, Dennis Hoagland and Daniel Arnon, later expanded upon Gericke's research. In 1938, they published "The Water Culture Method for Growing Plants without Soil," which is widely considered to be one of the most important texts ever published about hydroponics. Several of the nutrient solutions they developed are still used today.

According to a 1938 Time magazine article, one of the first commercial uses of hydroponics occurred during this period based on the research taking place at Berkeley. Tanks of mineralized water were used to grow beans, tomatoes, and vegetables on tiny Wake Island, a small piece of land in the Pacific Ocean. This island was used as a refueling stop for [Pan-Am Airways](#), and the food grown there was used successfully to feed the airline's staff and crew. Similar situations occurred during [World War II](#), as hydroponics was used to grow crops for troops on barren Pacific Islands [source: [Time Magazine](#)].



Khin Maung Win/AFP/Getty Images  
Farmers from Myanmar's Intha tribe pick tomatoes from a floating garden in the famous Inle Lake. These gardens are probably similar to the ones cultivated by the Aztecs on Lake Tenochtitlan.

### Hydroponic Scandal

William Gericke is credited with giving hydroponics its name, but his work is often clouded by scandal. Though his hydroponic research was done while he was employed at UC Berkeley, he claimed that his work on the theory was done off the clock, in his own time. He therefore refused to share any of his work or research, and left the university before publishing his famous work on the subject, "Complete Guide to Soil-Less Gardening." Hoagland and Arnon were given the job of trying to replicate his research, and fortunately for the future of hydroponics, they're credited with many of their own contributions to the science [source: [Time Magazine](#)].

## Why Use a Hydroponic System?

So why go through all the trouble of setting up a hydroponic system? After all, people have been growing **food** just fine for thousands, if not millions of years using good old-fashioned dirt. Hydroponics offers some significant benefits over traditional farming, and as word about these benefits spreads, more people will turn to hydroponics for their agricultural needs.

First, hydroponics offers people the ability to grow food in places where traditional agriculture simply isn't possible. In areas with **arid**<sup>4</sup> climates, like **Arizona** and **Israel**, hydroponics has been in use for decades. This science allows the people of these areas to enjoy locally grown produce and to expand their food production. Similarly, hydroponics is useful in dense urban areas, where land is at a premium. In **Tokyo**, hydroponics is used in lieu of traditional soil-based plant growth. Hydroponics is also useful in remote locales, such as **Bermuda**. With so little space available for planting, Bermudians have turned to hydroponic systems, which take around 20 percent of the land usually required for crop growth. This allows the citizens of the island to enjoy year-round local produce without the expense and delay of importation. Finally, areas that don't receive consistent **sunlight** or warm **weather** can benefit from hydroponics. Places like **Alaska** and **Russia**, where growing seasons are shorter, use hydroponic greenhouses, where **light** and temperature can be controlled to produce higher crop yields.



VisionsofAmerica/JoeSohm/Digital Vision/Getty Images  
These plants yield tomatoes in a place where they normally wouldn't grow.

We also must consider the significant environmental benefits to hydroponics use. Hydroponics systems require only around 10 percent of the water that soil-based agriculture requires. This is due to the fact that hydroponic systems allow **recycling** and reuse of water and nutrient solutions, and the fact that no water is wasted. This can have quite an impact on areas where water is scarce, such as in the Middle East and parts of Africa. Similarly, hydroponics requires little or no pesticides and only around 25 percent of the nutrients and fertilizers required of soil-based plants. This represents not only a cost savings but also benefits the environment in that no chemicals are being released into the air. Finally, we must consider the environmental impacts of transportation. As hydroponics allows produce to be **grown locally** and requires fewer areas to import their crops, there is a reduction in both price and greenhouse gas emissions due to reduced transportation requirements [source: **Jensen**].

Next, hydroponics offers us the benefit of a shorter harvest time. Plants grown in this manner have direct access to water and nutrients and therefore, are not forced to develop extensive root systems to allow them to find the nutrients they need. This saves time and produces healthier, lusher plants in about half the time as traditional agriculture.

So why isn't hydroponics taking over? This is due to several distinct disadvantages associated with these systems. The first is the high capital investment when compared with soil farming. Though hydroponics is typically much cheaper over time, it does require a substantial upfront cost to establish any sort of larger system. Next, there's the threat of power failure, which can cause pumps to stop working and ruin crops. Finally, many people fear that hydroponics requires substantial know-how and research, when in fact, it's very similar to traditional gardening. After all, plants rely on certain nutrients in order to grow, and these nutrients don't change, no matter which system you're using.

<sup>4</sup>arid: dry

## The Science Behind Hydroponic Nutrients

Before we can take a look at how hydroponics works, we must first understand how plants themselves work. Generally speaking, plants need very little to grow. They can **subsist**<sup>5</sup> on a simple blend of **water**, **sunlight**, carbon dioxide and mineral nutrients from the soil. Plants are able to transform **light** energy into chemical energy to form sugars that allow them to grow and sustain themselves. Thus, plants convert carbon dioxide, water and light into sugars and oxygen through a process called photosynthesis. The photosynthesis process requires that the plant has access to certain minerals, especially nitrogen, phosphorus and potassium. These nutrients can be naturally occurring in soil and are found in most commercial **fertilizers**. Notice that the soil itself is not required for plant growth: the plant simply needs the minerals from the soil. This is the basic premise behind hydroponics -- all the elements required for plant growth are the same as with traditional soil-based gardening. Hydroponics simply takes away the soil requirements.

There are several different types of hydroponic systems, though each is based on the same initial concepts. Here, we'll examine each type, discover how and why it's used and see which kinds of plants respond best to each method.

**Ebb and Flow Systems** require a medium, such as perlite, which serves no purpose other than to provide stability for the plant's roots. The plant derives no nutrients from the medium itself. Ebb and flow systems include a tray in which the plant is placed in a medium; below the tray in a separate container is a reservoir containing water and mineral solutions. The water from the reservoir is periodically pumped up into the tray. This floods the tray and allows the plants to absorb water and nutrients. Gradually, the water drains back into the reservoir due to gravity. Ebb and Flow systems work best with small plants like **herbs** and are typically used in smaller hydroponic setups, such as those in the home.

**Nutrient Film Technique (NFT)** is a water-based system that requires no soil or mediums. They're built using wooden channels, which support polyethylene film liners. Plants such as **tomatoes** and **cucumbers** are placed on the channels, and the nutrient enriched water is pumped to the high end of each channel. The channels slope down, and water is collected at the end to be pumped back through the system and reused. Only plants with large established root systems will work with this technique.

**Drip Systems** are set up almost identically to an ebb and flow system, although instead of water being pumped through one large tube, it's pumped through many small tubes and drains onto the top of the plants. This system is ideal for plants that don't yet have a developed root system, and like an ebb and flow system, works best with smaller plants.

**Aeroponics** is another water based system, which, like NFT, requires no medium. Plants are suspended on a tray, with their roots freely dangling below. The entire tray is placed into a box that has a small amount of water and nutrient solution in the bottom. A pump system is used to draw the water up, where it's sprayed in a fine mist onto the entire plant and root in a continuous manner. This system is the most difficult to set up and manage, but it has great potential for large commercial uses.

**Wick Systems** are similar to ebb and flow systems in that they're medium-based. Plants are placed into a tray filled with a medium such as perlite or rockwool. At the base of each root, a nylon rope is placed, which is allowed to dangle freely, extending beyond the bottom of the tray. The entire tray is then placed on top of a reservoir. The nylon ropes absorb the water and nutrients, wicking them up to the plant's roots. This system is desirable because it requires no pumps or other equipment to be purchased [source: **Roberto**].



Paul S. Howell/Liaison/Getty Images  
Using a totally controlled environment, this 10,000 foot hydroponic garden grows 30 varieties of vegetables and herbs.

<sup>5</sup>subsist: exist

For more on what goes into setting up the different types of hydroponic systems, read on to the next section.

## Hydroponic Equipment

Now that we've looked at the different type of hydroponic systems, let's take a look at some of the tools and accessories that work to complement the various systems

The most important part of any hydroponic system is, of course, the nutrient solution used. Hydroponic nutrient solutions are readily available from gardening centers and nurseries and are composed of a blend of such nutrients as nitrogen, potassium, calcium, magnesium and other minerals. Different nutrient solutions are used depending on what type of plants you're trying to grow, what system you're using and what mediums, if any, you're working with.

As we've seen, hydroponics can be done with or without mediums. In cases where a medium is to be used, there are several choices available, each with its own benefits and drawbacks. One of the most popular mediums used in hydroponic gardening is rock wool, due to the fact that it's both affordable and offers easy drainage. Other popular mediums include clay, perlite, vermiculite, sand and gravel. While gravel, clay and sand are both cheap and easily available, they're heavy and don't provide the same level of [water](#) circulation as perlite and vermiculite, which are more expensive but also more effective.

Another critical aspect of hydroponics is the use of light. As we discussed earlier, plants require [light](#) in order to perform photosynthesis. In areas where natural light is not available or plentiful, High-intensity Discharge (HID) lights are used instead. There are two main types of lights used for gardening, and each provides light over different parts of the spectrum. Metal Halides (MH) offer light from the blue end of the spectrum and are used with young plants and green, leafy vegetables. High Pressure Sodium (HPS) lights are at the opposite end of the spectrum and are used for fruits or flowered plants [source: [Green Coast Hydroponics](#)].

Finally, any successful hydroponic system must be monitored so that PH levels are regulated. PH is a measure of hydrogen ion concentration, and gives us a value as to how acidic or alkaline the growth environment is. It must be kept within a certain range, depending on the plant and the medium used. The value can be measured using a PH testing kit, available at any gardening supply center.

## DIY Home Hydroponics

Are you excited about what you've read so far about hydroponic gardening? Ready to start you own hydroponic garden and put theory into practice? Here, we'll compare the benefits and drawbacks to the different types of hydroponics system, and we'll discuss what kinds of plants can be grown at home using these systems.

When designing a home hydroponics system, it's generally recommended that a medium be used. This tends to support the use of either an ebb and flow or wick system. While a wick system is incredibly cheap and simple to use, it's hard to modify over time, and thus may produce poor results. There is concern over whether the plants are getting the right balance of nutrients, and if they're not, it can be difficult to adjust the nutrient flow. For these reasons, many at-home hydroponic systems tend to be of the ebb and flow variety. Any hydroponic gardening center, and in fact, most traditional nurseries carry all of the equipment required for setting of a home system.

### Hydroponics with Mickey

Maybe you remember hearing the term hydroponics before, but you can't remember where. Would you believe it could have been on a family trip to [Walt Disney World](#) in Florida? Epcot Center's "Living with the Land" is an attraction dedicated to agriculture, with a large portion of the ride focused on hydroponics. Best of all, many fruits, vegetables and herbs, including those Mickey-shaped cucumbers, that are used in Disney restaurants are grown at the Epcot Center in the Land Pavilion, all through the use of hydroponics [source: [Fehrenbacher](#)].

You can view Disney's "Living With The Land" attraction at: <http://home.howstuffworks.com/hydroponics.htm>

To begin building your ebb and flow system, you first must obtain the required materials. A basic system will require:

- A plastic tray capable of holding the weight of the medium, the plants and the [water](#)/nutrient solution
- A support structure to place the tray on (it can be as simple as a spare table)
- Container to be used as a reservoir (can be an aquarium, a plastic storage container or a garbage can)
- Aquarium pump capable of pumping 132 gallons per hour (500 liters per hour)
- Plant containers (make sure they have holes in the bottom to allow drainage)
- Growing medium
- Drainage tubing
- 24 hour timer
- Seeds or plant cuttings
- Nutrient solutions

If you're willing to use some materials you already have on hand, this system can be set up for as little as \$50 [source: [Bareroots Hydroponics](#)].

To build your ebb and flow system, simply place the cuttings or seeds into the plant containers, stabilize them using the chosen medium, set the containers into the plastic tray and set it on the support structure. Fill the reservoir with three teaspoons of nutrient solution diluted in three gallons of water (11.36 liters). Install your tubing so that it runs from the top tray to the reservoir, and then set the aquarium pump in place. The timer should be set so that the pump causes the top tray to flood twice a day. Monitor PH levels every two weeks, and you should have no trouble growing your own hydroponic plants [source: [Roberto](#)].

The easiest plants to grow at home hydroponically are salad greens, such as [lettuce](#) and [spinach](#). Herbs are fairly simple also, with [basil](#), mint and [parsley](#) being popular choices. [Tomatoes](#), [cucumbers](#) and [peppers](#) are possible, too, though these items require either a great deal of natural [sunlight](#) or the addition of grow lamps. Finally, any small plants and flowers can be grown using this system.

If you decide to grow plants that require a lot of light and sunlight is not readily available, consider adding an artificial lighting system. HPS lights work best for flowering plants or fruits, while metal halides work better for leafy greens like lettuce and spinach.

Certain plants can be difficult to grow using an ebb and flow system. These include [potatoes](#), berries and [bulb-based flowers](#), such as daffodils. While these items can be grown hydroponically, they work better in water-based systems, such as NFT or aeroponics, which are better suited for larger commercial applications.

## Food and Hydroponics Labeling

There's great debate over the use of [organic labeling](#) as it relates to hydroponics. As consumers become more focused on the origins of their [food](#) and its impact on their health, they frequently turn to foods labeled as organic. Requirements for organic labeling vary from state to state, with some states considering crops produced without pesticides as organic and other states qualifying the organic label to mean completely natural. In the very strictest standards, natural is defined as plants that are grown in the earth using traditional agricultural methods. Under these standards, no pesticides or chemicals may be used, and the plant nutrients that can be applied are strictly regulated.

Depending on the requirements, some food produced hydroponically can be called organic, as hydroponic systems don't necessarily require the use of pesticides or chemicals. Hydroponics does require the use of nutrient solutions, however, which generally require minerals to be extracted or

### Super Vegetables

One of the biggest questions currently on the table concerning hydroponics is the possibility of growing [vitamin-enriched](#) food. Because of the controlled environment in hydroponic gardening, enhancements are possible that would not be feasible with traditional agriculture. A small farm in Virginia called Endless Summer has just received a \$68,000 grant from the U.S. Department of Agriculture for their research and development of a "Super Lettuce." The [lettuce](#) contains the average person's daily requirements of [calcium](#) and [potassium](#) and is available locally in the Washington D.C. and Virginia areas [Source: [Murphy](#)].

Source: <http://home.howstuffworks.com/hydroponics.htm/printable>

produced, then altered to be made [water](#)-soluble. In this way, hydroponic plants are not organic by the very strictest definitions, but may be considered organic in some areas and by some people.

In deciding whether hydroponically grown crops may be beneficial for your needs, look closely at your state's requirements for organic labeling. Does "all natural" matter to you, or are you simply looking to minimize your exposure to pesticides? If organic labeling is important to you, it may be worth investigating this debate further, as hydroponics can produce crops that are considered organic in some areas, often at a much cheaper price than traditionally grown [organic foods](#).

Interested in setting up a hydroponics system in your home? Read on to the next section for step by step instructions on building your system and what you can grow.

## Hydroponics Growing and the Future of Agriculture

Hydroponics is the fastest growing sector of agriculture, and it could very well dominate [food](#) production in the future. As population increases and arable land declines due to poor land management, people will turn to new technologies like hydroponics and [vertical farming](#) to create additional channels of crop production. Currently, arable land comprises only around 3 percent of the [Earth's](#) surface, and the world [population](#) is around 6 billion people, resulting in around 1/5 hectare (2,000 square meters) of arable land per capita. By 2050, scientists estimate that the Earth's population will increase to 9.2 billion, while land available for crop and food production will decline. To feed the increasing population, hydroponics will begin replacing traditional agriculture [source: [Chamberlain](#)].

To get a glimpse of the future of hydroponics, we need only to examine some of the early adopters of this science. In Tokyo, on the island nation of [Japan](#), land is extremely valuable due to the surging population. To feed the citizens while preserving valuable land mass, the country has turned to hydroponic rice production. The rice is harvested in underground vaults without the use of soil. Because the environment is perfectly controlled, four cycles of harvest can be performed annually, instead of the traditional single harvest.

Hydroponics also has been used successfully in [Israel](#), which has a dry, arid climate. A company called Organitech has been growing crops in 40-foot (12.19-meter) long shipping containers, using hydroponic systems. They grow large quantities of berries, citrus fruits and bananas, all of which couldn't normally be grown in Israel's climate. The hydroponics techniques produce a yield 1,000 times greater than the same sized area of land could produce annually. Best of all, the process is completely automated, controlled by robots using an assembly line-type system, such as those used in manufacturing plants. The shipping containers are then transported throughout the country [source: [Organitech](#)]

There has already been a great deal of buzz throughout the scientific community for the potential to use hydroponics in third world areas, where water supplies are limited. While the upfront capital costs of setting up hydroponics systems is currently a barrier, in the long-run, as with all technology, costs will decline, making this option much more feasible. Hydroponics has the ability to feed millions in areas of Africa and Asia, where both water and crops are scarce.

Hydroponics also will be important to the future of the space program. [NASA](#) has extensive hydroponics research plans in place, which will benefit current space exploration, as well as future, long-term [colonization of Mars](#) or the [moon](#). As we haven't yet found soil that can support life in space, and the logistics of transporting soil via the [space shuttles](#) seems impractical, hydroponics could be key to the future of space exploration.

The benefits of hydroponics in space are two-fold: It offers the potential for a larger variety of food, and it provides a biological aspect, called a bioregenerative life support system. This simply means that as the



[Zomi/Stone+/Getty Images](#)  
Hydroponics lettuce farming -- possibly how all of our vegetables will be grown in the future.

plants grow, they will absorb carbon dioxide and stale air and provide renewed oxygen through the plant's natural growing process. This is important for long-range habitation of both the space stations and other planets [source: Heiney].

For more information on hydroponics, getting your hands dirty in the garden and related topics, dig through the links on the next page.

## Lots More Information

### Related HowStuffWorks Articles

- [How to Grow Plants with the Lighting You Have](#)
- [How Water Works](#)
- [How Organic Farming Works](#)
- [How to Start a Garden](#)
- [How Food Works](#)
- [What is Fertilizer and Why Do Plants Need it?](#)

### More Great Links

- [Green Coast Hydroponics](#)
- [Hydroponics Online](#)
- [Growing Edge Magazine and Community](#)

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### Hydroponics Boldly Goes Where No Man Has Gone Before

Many people may remember the use of hydroponics in the "Star Trek" television series. Several of the Enterprise ships throughout the series had a hydroponics bay used to grow fruits and vegetables. Additionally, in "Star Trek Voyager," Kes sets up a hydroponics garden in Cargo Bay 2 when food rations begin running low, and Neelix visits the hydroponics bay to obtain vegetables for his cooking in another episode [source: [Star Trek Voyager Encyclopedia](#)].