“Hydroponics” literally means “water works”. It is a method of growing plants in a water/nutrient-rich solution, without soil. Although in theory any plant could be grown hydroponically, in practice hydroponic gardening is usually reserved for exotic plants and flowers, or for “greenhouse” style vegetables, such as lettuce, tomatoes, peppers, cucumbers, melons and culinary herbs.

With hydroponics, plants can be grown in a completely controlled environment, free from soil-borne pests and diseases. By carefully monitoring nutrients, light levels and temperature, phenomenal yields of high quality, delicious produce can be obtained, without using dangerous herbicides or pesticides. Therefore, hydroponic gardening is gaining popularity for both commercial and home gardening applications around the world.

Hydroponics Around the World

Although the hydroponics industry is growing in the United States, the US still lags behind much of the industrialized world in commercial hydroponics technology. In Northern Europe, the majority of greenhouse vegetables are already grown in hydroponics, and in the Netherlands hydroponics and zero run-off greenhouses are the national standard. Australia not only produces vast amounts of hydroponic vegetables, it even grows fodder for animals in 50-foot, hydroponic trailers, each trailer producing a ton of feed a day, every day, 365 days per year. Closer to home, Essex County in Canada, just 50 miles from the US border, produces more hydroponically-grown vegetables than the entire United States, and Mexico has more acreage in hydroponics than the United States and Canada put together!

It’s about time for the United States to catch up with the rest of the world in hydroponics technology. Hydroponics conserves water and natural resources, protects our rivers and ground water from fertilizer run-off, and produces bumper crops of nutritious fruits and vegetables in a sustainable manner. If the US could grow locally what we are now importing from other countries, many new jobs would be created and all would benefit from improved nutrition. Hydroponic gardening is interesting and fun, but on a larger scale it may be important for the future health and vitality of our nation.

Hydroponics in Education

Hydroponics also has an important place in the classroom. Experimenting with hydroponics helps students better understand how plants grow. For example, by withholding certain nutrients from the hydroponic solution, students can observe firsthand how plant growth is affected, then take steps to correct the deficiencies. Other experiments can be done with water quality, lighting, temperature and humidity control, and even carbon dioxide levels. In short, a hydroponic garden is a practical way for any school to set up an excellent botany lab in a controlled environment.
Many primary and secondary science and agriculture programs are already experimenting with hydroponics. In some cases, teams of students build, plant and maintain their own systems, and even market the harvests that they produce. One group of 5th grade students in Chicago started their own business, Basil Buy Us. They produce hydroponically-grown basil in the classroom and sell it to local restaurants, and they process left over basil into pesto sauce and other secondary products. Not only are the students becoming intimately acquainted with the science of growing, they are also learning business and accounting skills, and they even produced their own television infomercial! Hydroponics provides a hands-on approach to learning, and many of the life science educational objectives are reinforced.

A few universities teach environmentally controlled agriculture with an emphasis on hydroponics, but there is still a great need for hydroponics education at the post-secondary level. Most of the agricultural universities in the Midwest, for example, don’t even have a single hydroponic teaching greenhouse on campus. Considering the fact that the US imports more hydroponically-grown produce than we produce domestically, there is an obvious technology gap in our colleges and universities, and local commercial growers are hindered because of it.

One exception is the University of Arizona in Tucson. They offer a four-year degree in Computer Environmentally Controlled Agriculture, and they have specific courses in hydroponic vegetable production. Graduates from the program are in high demand and command wages commensurate with engineers, scientists and other high-paid professionals. Some are even offered profit sharing bonuses as an incentive to manage some of the large hydroponic greenhouse complexes currently being established in the Western United States.

Whether a hobby gardener or a professional grower, education is the key to successful growing. So to better understand how hydroponic gardening works, let’s first review the basics of plant growth.

**Basic Life Processes**

Plants are composed of roots and shoots. Water and minerals are absorbed by the root system, but plants can’t take up large organic molecules. In soil, minerals and organic matter must first be broken down into very small particles through erosion and the digestive enzymes of microorganisms. The root hair cells, found on the root tips, can then absorb water and minerals into the plant in the form of ions, tiny electrically-charged particles. In hydroponics, water and nutrients are absorbed in exactly the same way, except the minerals are already in their ionic, water-soluble form. Upon demand by the plant, the water and minerals are quickly absorbed into the root xylem, where they are transported upward into the plant.

The shoot system consists of stems and leaves. Xylem in the veins of the plant transports water and minerals to chloroplasts in the leaf cells, where water combines with carbon dioxide from the air in a process called photosynthesis. Chlorophyll (the green pigment in plants) uses light energy from the sun
to convert the water and carbon dioxide into simple sugars called photosynthates. The waste products of photosynthesis, oxygen and water vapor, are transpired from the leaves, and the photosynthates are transported throughout the plant by phloem vessels.

Some of the photosynthates are used for plant growth, reproduction and repair, and the rest are stored in the roots, stems and fruit as sugars and starches. It is these stored carbohydrates which, in food crops, are edible. Generally speaking, the more efficient the uptake of water and minerals by the plant, the higher the sugar content in the sap. Sugars in the sap are measured as “brix” %. Higher brix readings generally mean healthier plants with better flavor and nutritional quality.

Hydroponic gardening optimizes the nutritional and environmental conditions for plant growth, thus improving the flavor and nutritional value of food. For example, it is a scientific fact that herbs grown hydroponically have 20-30% more essential oils than field grown. Therefore, herbs grown in water can actually have more aroma and flavor than plants grown in rich, farm soil. Hydroponically grown vegetables, if managed properly, can have higher vitamin and mineral content, too. By carefully adjusting the concentration of mineral nutrients, tomatoes can be grown with twice the lycopene content (red pigment) and 50% more organic acids and vitamin C. With hydroponics, abundant harvests of premium-quality produce can be grown time after time, if you know the basics.

**Propagation**

Hydroponic gardening starts at the propagation stage. One of the most popular hydroponic growing mediums is rockwool, a fibrous material with a high air and water holding capacity. Rockwool propagation cubes are first soaked with a slightly acidic nutrient solution, drained, then seeded directly into the medium. The tray can then be covered and put into a propagation station under fluorescent lights until the seeds germinate.

Cuttings can also be propagated in rockwool. The cuttings are simply dipped in a protective rooting gel such as Clonex. Special rooting hormones, nutrients and antimicrobial agents in the gel seal the wound and help the root system get started. Simply cut a branch tip with three or four sets of leaves, remove the bottom leaves, dip the cut end into the cloning gel, and stick the cutting into your favorite growing medium just deep enough to support the plant. Then lightly mist the clones with water, cover them with a humidity dome and place them in a propagation station under fluorescent lights.

Once the seedlings are well rooted and actively growing, the plants can be transplanted. Simply take the new plant, rooting cube and all, and place it into your favorite growing medium. The small rockwool starter cubes can also be transplanted into larger rockwool growing blocks, especially for long-term crops such as tomatoes or long-stem roses. The growing block will eventually be transplanted again onto a three-foot rockwool slab, where it will be fed through a drip line for the entire duration of the crop. Since rockwool provides such excellent drainage and root aeration, it is almost impossible to overwater and kill the young plants.
Hydroponic Systems

There are many hydroponic systems available for commercial and home use. For vine crops, most commercial growers prefer the rockwool medium in a continuous drip, recirculating system. The Rockwool slabs are placed on a flat surface with individual emitters at each site to irrigate each plant. Troughs run underneath the slabs to catch the nutrient solution and return it to the reservoir. A submersible pump in the reservoir continuously re-irrigates the slabs and the recirculation process continues.

Another popular system uses an “ebb and flow” style of recirculation. The plants are anchored in a soilless mix, such as expanded clay, perlite or vermiculite. Volcanic perlite is an inexpensive material, with good capillary action and aeration properties. Perlite is often mixed with vermiculite, a spongy material that tends to retain nutrients, while providing excellent aeration for the roots. In an ebb-and-flow system, the nutrient solution is contained in a reservoir underneath the grow tray. A timer clicks a pump on, raises the solution to moisten the roots, then recedes back down, pulling fresh oxygen to the roots. The process is repeated three or four times a day.

Aeroponics, a system in which the roots are suspended in air, is another system gaining in popularity. Phenomenal root growth is made possible, with excellent results to the plant. For example lettuce plants can be rooted in web pots and fitted into individual holes. A sprinkler creates a mist chamber, and the roots grow directly in the highly oxygenated nutrient solution. NASA and other research facilities are doing extensive experimentation with such systems.

Nutrient Solutions

Precise nutrient control is a major advantage with hydroponics over soil-based growing. Some soils have nutrient deficiencies, but once fertilizer salts are added, there is no easy way to change or reduce their concentrations. Hydroponics, on the other hand, makes nutrient manipulation easy. During the vegetative growth stage, a nitrogen-rich Grow Formula is used. At the fruiting and flowering stage, the Grow Formula is drained, and a phosphorous and potassium-rich Bloom Formula is used in its place. The results? Bumper crops of delicious fruits and vegetables every time.

Plants require 17 essential elements to grow and reproduce. The first three are free. Hydrogen, oxygen and carbon come directly from water and air and are essential for photosynthesis and sugar production. These three elements account for more than 95% of a plant’s dry weight. The other 14 essential elements are minerals and are provided in the hydroponic nutrient solution.

Macroelements, those elements used in greatest quantity by the plant, include:

Nitrogen- a critical component of all proteins and enzymes. During the first half of a plant’s life, the plant will assimilate more than 80% of the nitrogen needs for its entire life. So nitrogen is particularly important during the vegetative growth stage.
Phosphorous-provides the high-energy phosphate bonds of ATP, an energy molecule essential for life. Phosphorous is used throughout the life of the plant, but is particularly important for root, fruit and flower development.

Potassium—a catalyst in carbohydrate metabolism and an activator of many key enzymes. It is particularly important during the fruiting and flowering stage to maintain fruit quality. During heavy fruit development, a tomato plant can strip most of the potassium from the nutrient formula in a matter of days. Adding a little extra P-K Boost (phosphorous/potassium supplement) during the reproductive stage can help keep fruit quality high.

Calcium—strengthens cell walls and produces strong stems and shoots. A strong vascular system makes it easier for the plant to take up water and all the other essential elements. Calcium must be kept separate from the sulfates and phosphates in concentrated form, or it can react to form lime scale.

Magnesium—the central element in chlorophyll, the green pigment that is essential for photosynthesis. Magnesium also activates the enzymes that release the energy of phosphate bonds. So adequate levels of magnesium are required throughout the entire life cycle of the plant.

Sulfur—present in some amino acids, co-enzymes and vitamins. Sulfur also enhances the flowering process and contributes to some flavors and aromas.

Microelements are also essential for plant growth and reproduction, but they are used in much smaller quantities than the macroelements. Many of the trace elements are metal ions that turn on enzymes in the plant. Without them, the chemistry of life could not function at normal temperatures and the plant would die. In hydroponics, the essential metal ions are usually provided in their “chelated” form. “Chela” means “claw”. So chelates are organic molecules that attach to metal ions like a claw, holding them strongly enough to keep them from reacting with other molecules, but weakly enough to release them to the plant on demand.

The microelements include:

Iron
Manganese
Copper
Zinc
Boron
Chlorine
Molybdenum
Nickel
A full-spectrum hydroponic nutrient solution must contain all of the essential macro and microelements. Most commercial nutrient solutions come in a 2-part, A/B concentrated form. Part A is measured and added to the water first. The reservoir is then filled almost to full and Part B is added. A and B mixtures are kept separate in their concentrated forms to prevent chemical reactions that could lock out nutrients and make them unavailable to the plant. Once diluted in water, however, the elements remain in balance.

**pH Control**

Just adding plant food to the water isn’t enough. The pH levels of the nutrient solution should be monitored daily to insure optimal utilization by the plant. pH is a measurement of the acidity or alkalinity of the nutrient solution. A pH of 7 is neutral, under 7 is acidic and over 7 is alkaline or basic. The ideal pH level for absorbing nutrients by the plant roots in hydroponics is between 5.8 and 6.4, or slightly acidic. If the pH is too high, iron and some of the other metals may become unavailable to the plant. If the pH is too low, the uptake of calcium, magnesium and other macroelements may be hindered.

Adjusting pH is easy in hydroponics. If the pH is too high, adding a little dilute acid such as phosphoric acid will quickly bring it down. If the pH is too low, adding a base such as potassium hydroxide will bring it back up. For most plants, a pH balance of 6.0 is an ideal target. Commercially-prepared pH Lower and pH Raise mixtures are readily available in safe, easy-to-use formulas.

For best results, check the pH daily. Inexpensive pH test kits, specifically designed for hydroponics, are available at most hydroponics retailers, or they can be purchased online. Simply take a small water sample in a test tube and add a few drops of pH indicator solution. The color of the sample will change and a color chart will tell you the pH. If you are color blind or if you want more accurate readings, pH meters can be used instead. Although in many ways they are easier to use, pH meters require periodic calibration and they are fairly expensive. Most beginning gardeners can do just fine with the inexpensive pH test kits as long as they can keep the pH of their nutrient solution between 5.8 and 6.4.

**Electrical Conductivity (EC)**

The EC, or electrical conductivity, of the solution is also important for plant growth. Distilled water has an EC of about zero; it doesn’t conduct electricity. But the higher the concentration of mineral ions in the water, the more it conducts electricity. Therefore, EC is a general measurement of mineral content in the water and shows how concentrated or dilute a nutrient solution is.

A conductivity meter can be used to test EC. An EC range of 1.2-3.5 Mho (ohm spelled backwards) is generally desirable. A low EC reading means a slightly dilute concentration. Low to medium levels of EC promote vegetative growth, and should be used in the vegetative growth stage. Medium to high levels of EC restrict vegetative growth, but improve fruit quality. So medium to high EC levels should be used
during the fruiting and flowering stage. Generally speaking, use a half-strength nutrient formula for tender clones and seedlings, and use full strength nutrients when the plants are more mature.

If the EC level is too low, simply add more nutrient solution to the water. If the EC gets too high, especially on hot days, add more water to the reservoir. Since plants use different nutrients in varying degrees, the entire nutrient solution should be drained and replaced periodically to insure that the proper mineral balance is maintained. For indoor gardening, replace the nutrient solution every ten days, or so, to prevent nutrient deficiencies from developing.

**Horticultural Lighting**

Since environmental conditions regulate the rate at which plants take up nutrients, proper lighting is very important to successful hydroponic gardening. Visible light covers the full spectrum of colors. At the vegetative growth stage, the plant needs full-spectrum light but with proportionally more or the blue end of the spectrum. At the fruiting and flowering stage, plants prefer the red end of the spectrum. Many warehouse and residential lights are high in the yellow/green portions of the light spectrum. Although the yellower light may look brighter to the human eye, plants use mainly the reds and blues; so much of the energy of standard lighting is wasted. Always choose full-spectrum horticultural lamps when setting up an indoor garden.

The two most common horticultural lights are Metal Halide (MH) and High Pressure Sodium (HPS) lamps. Metal Halide lights provide both the red and blue ends of the spectrum, but they are strongest in the blue. Therefore, MH lamps are an excellent choice for the vegetative growth stage. A 400 Watt MH lamp will cover about a 4’ X 4’ area. For best results, keep the lamp about a foot to a foot and a half above the growing tips, and raise the light as the plants grow. Special ratcheting systems are available to make the job easier.

High Pressure Sodium lamps are strong in the yellow, orange and red range of the spectrum. Therefore, they work best during the fruiting and flowering stage of plant growth. Reds and far-reds stimulate the flowering process and help the plant keep track of day length. Make sure that you choose a horticultural lamp with a little blue in the spectrum, too. A standard HPS lamp with no blue will cause the plant to become tall and spindly, with poor fruit and flower production. So look for good quality HPS lamps with about 30% more blue light than standard lamps. It’s generally desirable to choose higher wattage lamps for the fruiting and flower stage. A 600 Watt lamp will cover about a 5’ X 5’ area, and a 1000 Watt lamp will cover up to a 6’ X 6’ area. The most intense light will be directly under the lamp. So try to keep the lamp as close to the plants as possible, without singeing or burning the growing tips.

For even light distribution, a track system with a light mover can be used. A motor drives the light on a 6-foot track and pauses at the ends of its travels. In this way, the lamp can be brought closer to the plants without burning them, and the light is distributed evenly across the garden. All the plants grow at about the same rate, so they stay approximately the same size from one end of the row to the other.
Modern advances in horticultural lighting technology are providing more and more choices for indoor gardeners. High-output fluorescent lights are now available for full-spectrum horticultural lighting, and l.e.d. lamps are also making strides for horticultural use. The advantages include greater energy efficiency, lower heat output, longer lamp life and the ability to keep the lamps closer to the plants without burning. Light is the limiting factor for indoor plant growth, so choosing the best lighting combinations that you can afford is always a wise investment.

**Temperature and Environmental Control**

Temperature and humidity control is also important. Most plants prefer a temperature range of 68-78 degrees F., and a relative humidity range of 40-60%. Cool weather crops such as lettuce and spinach prefer cooler temperatures, and tropical plants such as tomatoes and peppers prefer warmer temperatures. Never allow the high temperatures to exceed 85 degrees, however, since too much heat can inhibit the transpiration process and overly stress the plant.

Good air movement can eliminate many problems in a grow room. Simple oscillating fans, positioned around the garden to keep the leaves gently moving, removes much of the excess heat and humidity from the leaf surfaces. If you have a small garden in a large room, oscillating fans may be all that you need for temperature and humidity control. But if you have a lot of plants growing in a small space, additional steps may be needed to keep temperature and humidity under control.

Installing a good exhaust fan system can help control temperature and humidity in a tight grow room and maximize the productivity of the crop. A thermostat control that automatically turns on a vent fan when temperature or humidity levels exceed a set value is a good insurance policy for your garden. Plants transpire a lot of water during the day, so relative humidity can rise significantly. A relative humidity range of 40-60% is generally safe for plants, but remember that the relative humidity goes up as temperatures fall, especially at night. If the humidity is too high, diseases such as tip burn in lettuce and blossom end rot in tomatoes may occur, and the potential for powdery mildew and other fungi goes up as well. Exhaust fans should remove most of the excess humidity, but if high humidity becomes a persistent problem, it may be necessary to install a dehumidifier, as well.

Carbon dioxide supplementation is a great addition to a grow room. Carbon dioxide is the fuel for the production of sugars by the plant. Once light is no longer the limiting factor for plant growth, carbon dioxide becomes the limiting factor. A source of fresh air for your garden is enough to sustain healthy growth, but increasing the carbon dioxide in the atmosphere can have a significant impact on quality and yield. By doubling the CO2 levels in your garden, it is possible to increase yields by 30% or more! Carbon dioxide tanks with dosers are available for small grow rooms, and carbon dioxide generators are available for larger rooms.
Automation

For the hobbyist, simple timers are all that are needed to control lights, irrigation cycles and heating/cooling devices. Use grounded timers for lights, rated at 15 amps, to control the day length in your garden. Most garden vegetables are “day neutral” and do well with light cycles of 12-16 hours per day of continuous light. But some plants are more sensitive to day length. For example, a “short-day” plant such as poinsettias will stay vegetative when exposed to 16 hour days, but will be triggered to go to flower when day lengths fall to 12 hours or less. A programmable timer can be used to set the day and night lengths specifically for your crop.

Irrigation cycles can also be controlled by simple timers. In an ebb-and-flow system, for example, the timer is set to flood the plants with nutrient-rich water for 15 minutes, 3-4 times per day. Simple thermostats can control temperature and humidity, and float valves can be installed to automatically top off the reservoirs with water/nutrients when you are away on vacation. Although it is best to keep a close eye on your garden, simple timers and controllers can make your job much easier.

In a commercial greenhouse setting, it may be necessary to install more advanced controllers to compensate for larger fluctuations in temperature, light levels and other variables. Some computer controls continuously monitor temperature, humidity, accumulated light levels, wind speed and direction, and even the pH and EC of the nutrient solution. With computerized feedback controls, the entire greenhouse can be automated for optimum quality and yield.

Back to Basics

Hydroponics is not as complicated as it seems. In fact, with the right set up it can be even easier than growing in soil. Soil is more forgiving in some ways, but there are many more variables when using soil instead of a soilless medium. Over watering, under watering, over fertilizing and under fertilizing are common problems when working in soil, and minerals can build up to toxic levels over time.

Hydroponics, on the other hand, is like creating the perfect soil. Not only are all of the essential minerals provided in water-soluble form, but the ideal nutrient balance can be achieved for every stage of plant growth. Simply use a good Grow Formula during the vegetative growth stage and a good Bloom Formula during the fruiting and flowering stage. Check the pH and EC daily, and change the reservoir every ten days or so. That’s all there is to it. By giving the plant exactly what it needs when it needs it, the plant can grow closer to its true genetic potential. Remember, the genetic code in every cell of every living thing says the same thing, “Be fruitful and multiply.” Hydroponics provides the perfect water, oxygen and mineral balance for optimal plant growth. If you give your plants the right mineral balance, plenty of light and a relatively stress-free environment, abundant harvests of gourmet-quality flowers, fruits, herbs and vegetables can be enjoyed year round. So don’t be afraid of it. Start with the basics, apply what you learn, and enjoy the fruits of your own hydroponic gardens for many years to come.
Summary

Let’s take a moment to summarize some of the most important benefits of hydroponics:

- With hydroponics, higher yields can be achieved in a smaller space.
- Hydroponics is environmentally friendly, efficiently recycling water and nutrients.
- Nutrient balances can be precisely controlled and are immediately available to the plant.
- Grow, Bloom and Boost formulas can be used at the appropriate growth stage.
- pH and EC can be easily adjusted, creating the perfect root zone environment.
- Indoor gardens can be grown using full-spectrum horticultural lighting.
- Soil-borne pests and diseases are eliminated.
- Weeds are eliminated.
- Plants are healthier and reach maturity faster.
- Automation is possible, reducing labor costs.
- Hydroponically grown plants are nutritious and taste good.

By optimizing all of the nutritional and environmental factors necessary for plant growth, flowering, and fruit production, hydroponic gardening can provide abundant harvests for commercial and home gardeners alike. If you love gardening, and you want to continuously harvest the best of the best, set up your first hydroponics gardens and see the results for yourself!
Test Questions for Unit One: Introduction to Hydroponics

1. Hydroponics is a method of growing plants without
   a. Water
   b. Air
   c. Nutrients
   d. Soil
2. Photosynthesis converts water and carbon dioxide into
   a. Sugar, water and light
   b. Sugar, water and oxygen
   c. Sugar water and carbon monoxide
   d. Sugar water and chlorophyll
3. Water and minerals are transported to the leaf cells by
   a. Phloem
   b. Xylem
   c. Photosynthates
   d. Oxygen
4. Photosynthates are transported throughout the plant by
   a. Phloem
   b. Xylem
   c. Root hairs
   d. Carbon dioxide
5. Rockwool is a fibrous material with
   a. Low air and water-holding capacity
   b. High air and water-holding capacity
   c. Poor drainage and root aeration
   d. High electrical conductivity
6. Continuous drip, recirculating systems
   a. Are not recommended for vine crops
   b. Waste water and nutrients
   c. Cannot be used with rockwool
   d. Return water and nutrients to the reservoir
7. Ebb and flow systems
   a. Cannot use perlite or vermiculite
   b. Use timers to click a pump on
   c. Create a highly-oxygenated mist chamber
   d. Are not affected by gravity
8. Aeroponics is a system in which
   a. The roots are suspended in air
   b. The roots are dipped in a cloning gel
   c. The roots need no water
   d. The plant grows without roots
9. 95% of a plant’s dry weight is made up of
   a. Carbon, hydrogen and nitrogen
   b. Carbon, hydrogen and calcium
   c. Oxygen, carbon and hydrogen
   d. Oxygen, calcium and magnesium

10. During the vegetative growth stage, plants require proportionately more
    a. Phosphorous and potassium
    b. Iron
    c. Molybdenum
    d. Nitrogen

11. During the flowering and reproductive stage, plants require proportionately more
    a. Phosphorous and potassium
    b. Iron
    c. Molybdenum
    d. Nitrogen

12. To grow and reproduce, plants require
    a. 3 essential elements
    b. 12 essential elements
    c. 17 essential elements
    d. 24 essential elements

13. The pH level of the nutrient solution should be monitored
    a. Every day
    b. Every week
    c. Every ten days
    d. Every month

14. A pH level of 7 is
    a. Acidic
    b. Alkaline
    c. Neutral
    d. None of the above

15. For most hydroponically-grown plants, the ideal pH range for absorbing nutrients is
    a. Zero to 4.5
    b. 5.8 to 6.4
    c. 7.8 to 8.4
    d. 12.5 to 14.0

16. If the pH is too low, add a pH adjusting solution containing
    a. Nitric or phosphoric acid
    b. Dilute vinegar
    c. Potassium hydroxide
    d. Iron and vitamin supplements
17. Distilled water has an electrical conductivity (EC) level of
   a. Zero mho
   b. 5 mho
   c. 10 mho
   d. 12 mho
18. Lower to middle levels of EC
   a. Promote vegetative growth
   b. Restrict vegetative growth
   c. Are desirable during the fruit production stage
   d. Inhibit the transpiration process
19. At the vegetative growth stage, plants prefer light strong in
   a. The green end of the light spectrum
   b. The red end of the light spectrum
   c. The blue end of the light spectrum
   d. The radioactive end of the light spectrum
20. High pressure sodium (HPS) lamps are strong in
   a. The yellow, orange and red range of the spectrum
   b. The blue range of the spectrum
   c. The entire spectrum of visible light
   d. The ultraviolet range of the spectrum
21. Lack of blue light will
   a. Promote strong fruiting and flowering
   b. Make plants tall and spindly
   c. Kill the plant
   d. Make plants reddish in color
22. Increased carbon dioxide levels will
   a. Eliminate condensation and plant disease
   b. Allow the plant to flourish at slightly higher temperatures
   c. Saturate the environment with negatively charged ions
   d. Eliminate the need for full-spectrum light
23. Too much heat in a grow room can
   a. Spread fungus and plant disease
   b. Inhibit the transpiration process and stress the plant
   c. Make plants tall and spindly
   d. Make plants lean away from the light
24. If the EC gets too high, it can be corrected by
   a. Adding more fertilizer to the water
   b. Vigorously stirring the water
   c. Adding phosphoric acid to the water
   d. Adding more water to the reservoir
Answer Key for Unit One: Introduction to Hydroponics

1. Hydroponics is a method of growing plants without
d. soil
2. Photosynthesis converts water and carbon dioxide into
   b. sugar, water and oxygen
3. Water and minerals are transported to the leaf cells by
   b. xylem
4. Photosynthates are transported throughout the plant by
   a. phloem
5. Rockwool is a fibrous material with
   b. high air and water holding capacity
6. Continuous drip, recirculating systems
   d. return water and nutrients to the reservoir
7. Ebb and Flow systems
   b. use timers to click a pump on
8. Aeroponics is a system in which
   a. the roots are suspended in air
9. 95% of a plant’s dry weight is made up of
   c. oxygen, carbon and hydrogen
10. During the vegetative growth stage, plants require proportionally more
    d. nitrogen
11. During the flowering and reproductive stage, plants require proportionally more
    a. phosphoruous and potassium
12. To grow and reproduce, plants require
    c. 17 essential elements
13. The pH level of the nutrient solution should be monitored
    a. every day
14. A pH level of 7 is
    c. neutral
15. For most hydroponically-grown plants, the ideal pH range for absorbing nutrients is
    b. 5.8 to 6.4
16. If the pH is too low, add a pH adjusting solution containing
    c. potassium hydroxide
17. Distilled water has an electrical conductivity (EC) level of
    a. zero mho
18. Lower to middle levels of EC
    a. promote vegetative growth
19. At the vegetative growth stage, plants prefer light strong in
    c. the blue end of the spectrum
20. High Pressure Sodium (HPS) lamps are strong in
   a. the yellow, orange and red range of the spectrum

21. Lack of blue light will
   b. make plants tall and spindly

22. Increased carbon dioxide levels will
   b. allow the plant to flourish at slightly higher temperatures

23. Too much heat in a grow room can
   b. inhibit the transpiration process and stress the plant

24. If the EC gets too high, it can be corrected by
   d. adding more water to the reservoir