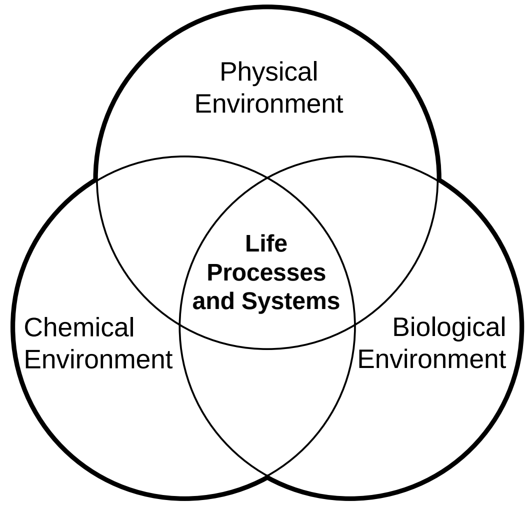
Understanding the Environment

Three broad categories of environmental components interact to influence all life: 1) physical, 2) chemical and 3) biological. Understanding the many environmental factors and how they interact with each other to influence life is essential for good investigative science and is the key to successful experimenting with Fast Plants. In plant science investigations, scientists and engineers have worked together to develop technology that will create an environment to support normal plant growth.



Some environmental factors influence plant growth more than others. If one or more factors is reduced or increased such that normal functioning is disrupted, that factor is said to be *limiting*. When a factor that can be quantified becomes limiting, its observed effects can also be quantified.

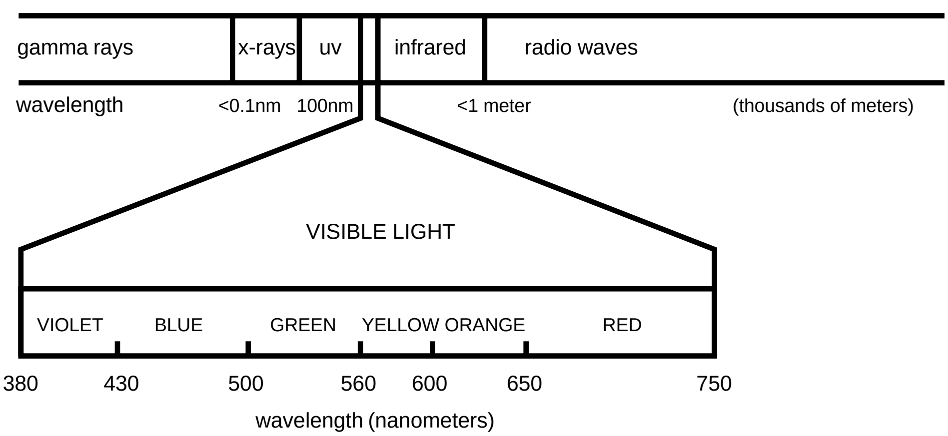
The Physical Environment

Light

Appropriate lighting is perhaps the most critical component of a plant's growing environment. Plants use energy from various regions of the visible spectrum to perform a number of functions essential to their growth and reproduction. Some seeds require red light to activate germination. Blue light is important for regulating elongation of stems and in guiding the direction of plant growth. Red and blue are the primary energy levels used for photosynthesis, whereas red and far red are important in the regulation of leaf expansion and certain pigment production systems.

Light for Fast Plants is produced by fluorescent lamps which emit a mix of photons in the visible range that appear as white with warm (red) or cool (blue) tones in the mix. The quantity of photons reaching a surface is known as *irradiance* or *photon flux density* and is measured in micromoles (µM) or microEinsteins (µE) of photon flux per square meter per second.

Spectrum of electromagnetic radiation.



Irradiance of greater than 200 $\mu Em^{-2}s^{-1}$ is ideal for Fast Plants. Less than 100 $\mu Em^{-2}s^{-1}$ is inadequate.

As with other electromagnetic forces and gravity, the inverse square relationship applies to light. That is, if the distance between the source of light and the receiving surface doubles, the intensity of the irradiance diminishes by a factor of four.

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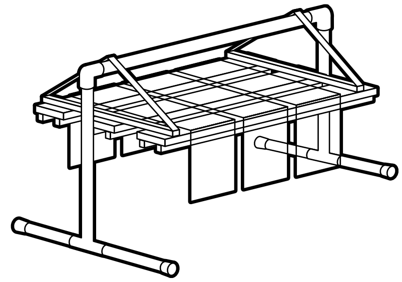
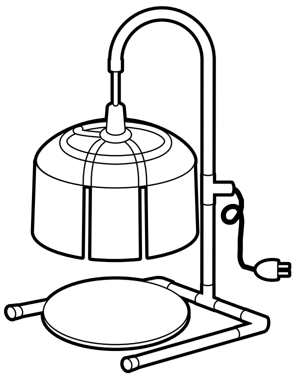
If you are using the standard four-foot Fast Plants light bank, you can use either eight 40 watt cool white or six of the newer 32 watt high efficiency bulbs which will require different fixtures than the 40 watt bulbs. Six 32 watt Sylvania Octron® 4100K FO32/741 bulbs spaced within two feet will produce ideal lighting for AstroPlants.



Fluorescent "circle" lamps can be suspended above and will adequately irradiate the plants growing within a circle of 30 cm diameter (12 inches). The Wisconsin Fast Plants Program has had the most successful growth under 30 or 39 watt circular or "folded" circular bulbs.

Reflectors made from aluminum foil or reflective mylar (available from fabric or stationery stores) greatly increase the irradiance reaching the plants, particularly those around the edges of the lamps. Aluminum foil "curtains" (15 cm x 25 cm) taped on the lamp fixture to hang down to about the soil level will contribute to uniform lighting across the plants.



Tips:

- Keeping the Fast Plants under constant 24 hour light will produce the most satisfactory results. Be sure to make arrangements (with custodians, etc.) so light banks are not turned off at any time.
- Ideally the growing tips of the plants should be kept 5 cm to 10 cm from the lights.

Formula for growing successful Fast Plants – *LIGHTING* :

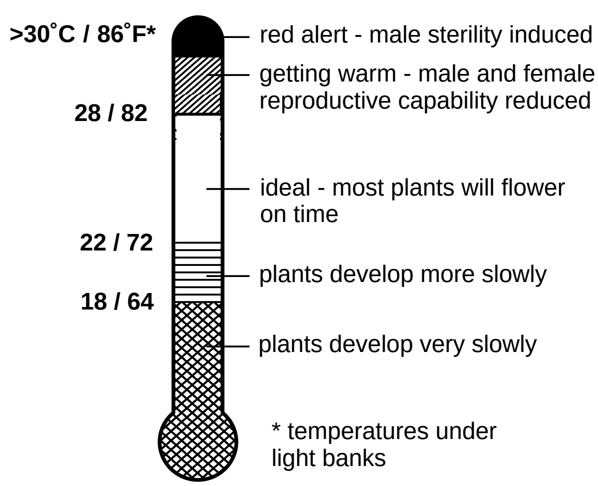
eight 40 W bulbs or six 32 W high efficiency bulbs, ***lighting 24 hours a day*** + use reflective foil curtains + keep top of PGC lid 2 to 3 cm from the lights = **Healthy Fast Plants**

Temperature

The temperature of the Fast Plants' growing environment will have an important influence on the growth of your plants. Temperatures that are too high or too low can affect the timing of developmental events such as seedling emergence and flowering. Optimal temperature is between 22˚C and 28˚C (72˚F to 82˚F).

Tip:

- Temperatures can be monitored under each bank using hi-low thermometers. Note fluctuations in the room temperature and variation in temperature among light banks.



Gravity and Microgravity

Of the many environmental factors that impact on life, *gravity* is one that exists on Earth with the greatest constancy. Gravity is an environmental factor that is difficult to vary experimentally without the support of space technology.

The Soilless Root Medium

A mixture of one part peat moss and one part vermiculite, known as *peatlite*, serves as the root medium that anchors the plant roots, providing support for the stem and leaves. Physical characteristics of the root medium must be such as to provide adequate capillary wicking of water to the absorptive surfaces of the root hairs and epidermal cells, yet there must also be adequate channeling within the matrix of the root medium to enable air exchange for oxygen diffusion to the growing roots. Under conditions of Earth gravity, peatlite provides ideal capillarity and air channeling for Fast Plants.

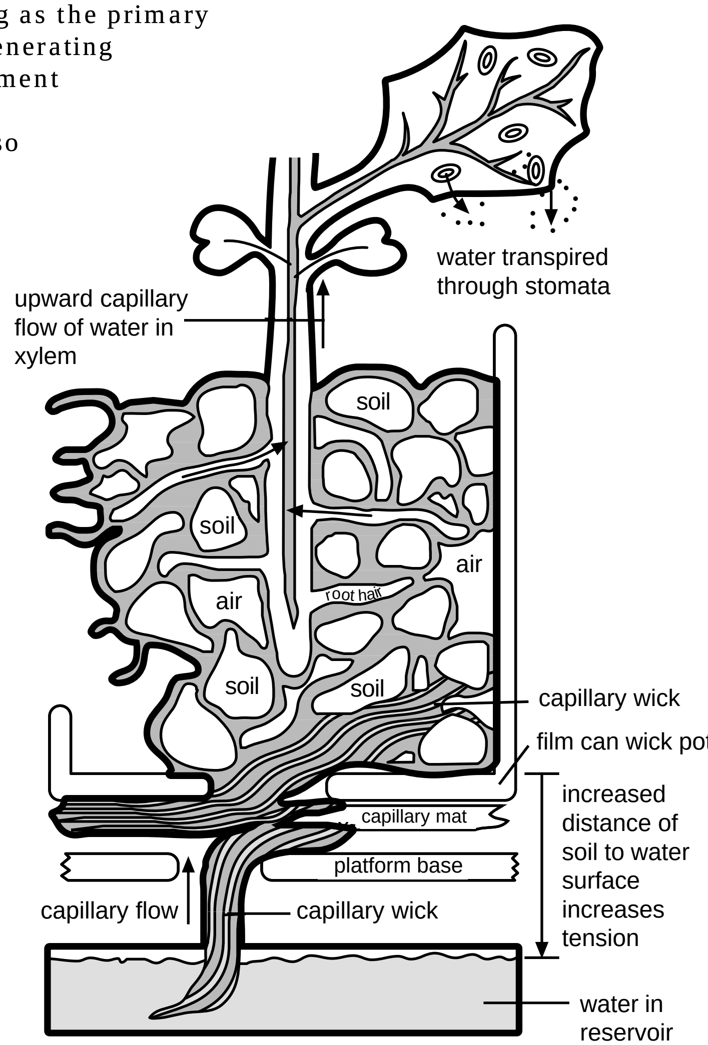
The Chemical Environment

Water

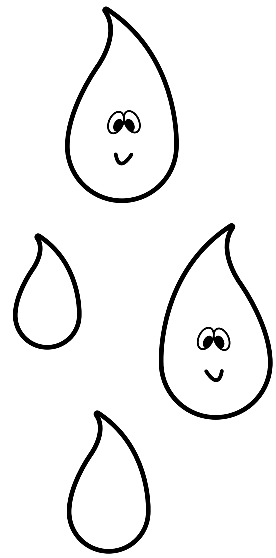
Water functions in many ways in plants, serving as the primary solvent supporting life's metabolic processes, generating *turgor pressure* (water pressure) for cell enlargement and growth, maintaining ionic balance and providing cooling via transpiration. Water is also the source of hydrogen reducing power when it is split by light energy in photosynthesis. Water enters the plant primarily through the root epidermis and hair cells, traveling through intercellular space and cortical cells to the xylem tissue where it is distributed throughout the plant.

Within the root zone, water is found adhering to soil particles as a continuous film created through the *cohesive* forces of the water molecules. The *adhesive* forces that attract water molecules to the surfaces of soil particles and plant root cells pull the water into the minute channels within the soil and plant tissues via *capillarity*.

Typical Fast Plants growing systems use capillary wicking material to pull water from a reservoir to the root medium which has strong capillary properties. There is an unbroken continuity of water from the soil into and throughout the plants (see figure at right). Through this water course, the plant also gains access to inorganic nutrients. On Earth, gravity acts as a vertical counter force opposing the cohesive forces of water and adhesive forces of capillarity.



Atmospheric Relative Humidity



The atmospheric relative humidity of a classroom can affect the rate of *transpiration* and water uptake by plants. Under low relative humidity there can be rapid water uptake from the reservoirs. When reservoirs run dry, capillarity is broken and plants will desiccate and die. When plants begin to wilt, it is an indication that transpiration is exceeding water uptake. In some climates this occurs when there has been a rapid drop in atmospheric relative humidity. In these cases plants usually adjust by reducing transpiration and regaining their turgor pressure.

If wilting persists, check the reservoir and examine the capillary wicks and matting to be sure they have not dried out and broken the capillary connection between roots and reservoir.

If the atmospheric relative humidity is very high (>95% RH), mature anthers in flowering Fast Plants may fail to open (dehisce) to expose their pollen. This occurs when plants are grown in closed containers in which the relative humidity builds up. It can be remedied by circulating air over the plants with a fan; mature anthers will then usually dehisce within a few minutes.

Inorganic Nutrients

In addition to the elements carbon, oxygen and hydrogen which make up the main structure of organic compounds in plants, 13 other elements are required to support the range of metabolic processes that constitute life. Six elements – nitrogen, potassium, calcium, phosphorus, magnesium and sulfur – are known as *macronutrients* because they are required in relatively greater quantities than the seven *micronutrients* – iron, chlorine, copper, manganese, zinc, molybdenum and boron (Raven, Evert and Eichorn, 1992).

Inorganic nutrients are added to the root media in a balanced nutrient mixture, such as Peters® Professional All-Purpose Plant Food, water soluble 20-20-20 N-P-K plus minor elements. Peters® Professional contains available NPK at 20% by weight (20-20-20). Primary nutrient sources are urea, ammonium, phosphate, and potassium nitrate plus minor elements. A soluble blue dye is added or mixing.

Total nitrogen (N).........................20%
   5.61% nitrate nitrogen
   3.96% ammoniacal nitrogen
   10.43% urea nitrogen
Available phosphoric acid (P_2O_5) 20%
Soluble potash (K_2O) 20%
Potential acidity is 597 lb calcium carbonate equivalent per ton.

A standard Fast Plants nutrient solution contain 7 grams of Peters® 20-2-20 fertilizer powder per liter of water, The nutrient solution can be applied to the growing substrate at the rate of 2 ml of solution on days 3, 7, 14, 21, and 28 for each plant that will be grown to maturity. If nutrients are added to the water reservoir in a continuous nutrient culture, the standard Peters® solution should be diluted to 1/8 strength.

Atmosphere

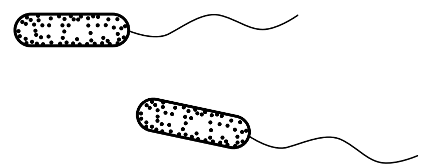
Ambient air contains nitrogen (78%), oxygen (21%), hydrogen and helium (<1%). Carbon dioxide in air is approximately 350 parts per million and is the primary source of carbon incorporated into organic molecules via photosynthesis. In closed systems such as the Space Shuttle orbiter, where humans and other organisms are respiring, CO_2 may build up to toxic levels. Plants have the potential role in space flight of extracting CO_2 from the air and converting it into edible biomass. In the Space Shuttle orbiter, CO_2 levels are carefully monitored and excess removed from the atmosphere by chemical trapping in filters.

The Biological Environment

Types of Organisms

There can be many types of organisms associated with the plant's environment, from algae to insects. These organisms may reside together in various *symbiotic* relationships, from mutually beneficial to *parasitic* (one partner benefits) and even *pathogenic* (one partner harms the other). Some symbioses may be strictly neutral. Controlling undesirable organisms in the plants' environment requires continuous attention. Possible residents include:

- various soil *microflora* (bacteria, fungi) and *microfauna* (nematodes, worms, insect larvae) which may colonize the root zone or *rhizosphere*;



- *phytophagous* (plant-eating) arthropods which may be found on stems, leaves and flowers (mites, thrips, aphids, leaf-eating beetles, moth and butterfly larvae);

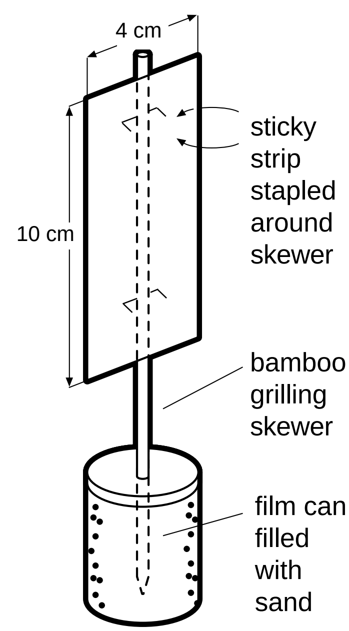
- the larvae of fungus-eating (*mycophagous*) flies which may exist in large numbers, emerging from the root medium and water mat as small black gnats; and

- various algal populations which may live on the moist root media, capillary wicking material and in the nutrient solution reservoirs. Most common are blue-green algae (*cyanobacteria*) on root media and mat surfaces and green algae in reservoirs.

Controlling Undesirable Organisms

Fungi and Bacteria: Fungi and bacteria rarely attack the above-ground parts of plants as long as the relative humidity is less than 95% and there is good air flow. The best control for fungi and bacteria is sanitation. Be sure to use pathogen-free root media – most commercially available peatlite mixtures are sanitized and pathogen-free. Keep the root media well aerated and drained by not packing it in the growing containers. After growing, it is important to rinse, then soak all pots, reservoirs, capillary mats and wicks for at least 30 minutes in a 10% chlorine bleach solution. Do not reuse root media.

Insect Pests: The continuously illuminated plants can be attractive to many insects, especially at night. Daily surveillance and removal of insects is good practice. Sticky yellow pest control cards work well to trap incoming insects and flies emerging from the soil. The sticky strips available from garden stores can be cut and stapled to bamboo grilling skewers and mounted in film cans filled with sand and placed among the plants. These are very effective for white flies, aphids, fungus gnats and thrips.



If colonies of aphids, white flies or thrips appear or evidence of larval feeding is observed (holes chewed in leaves or flowers), plants may be sprayed with insecticidal soap or another safe chemical control agent. Read labels carefully before applying chemicals. Surveillance and careful removal by hand is the best control practice.

Algae: The most common residents with Fast Plants are green and blue algae. Most do not affect plant growth but can become unsightly and occasionally will build up in reservoirs and wicking to consume nutrients and retard water flow. Algae growth can be suppressed by adding copper sulfate ($CuSO_4 \cdot 5H_2O$) to the nutrient solution at a final concentration in the reservoir of between 50 and 100 parts per million (milligrams/liter). Darkening the reservoirs by spray painting the outside with black opaque paint or wrapping them with foil will retard algal growth.