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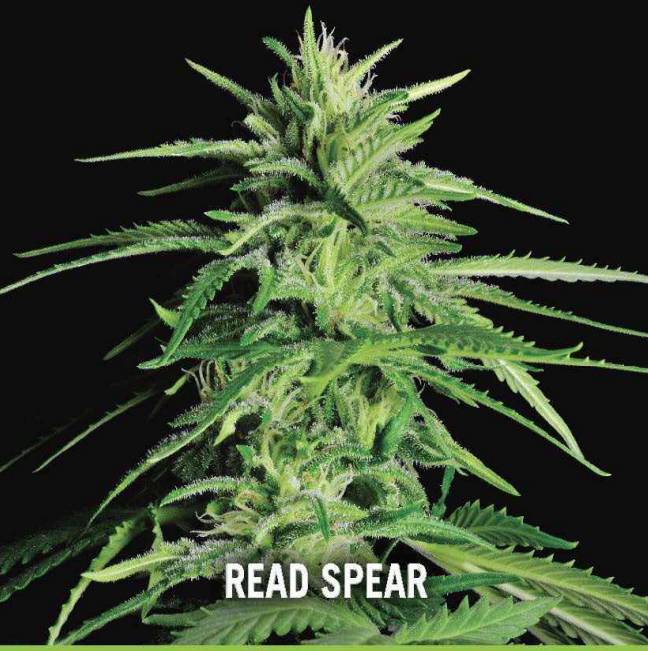
THE SCIENCE AND TECHNIQUES FOR HUGE INDOOR YIELDS



READ SPEAR

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Marijuana Cultivation Reconsidered

The Science and Techniques For Huge Indoor Yields

by Read Spear

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Disclaimer

I am fortunate to live in the great state of Colorado which just recently, under Amendment 64, legalized the small-scale cultivation and use of marijuana for adult residents 21 and older.[1] Coloradans grow under legal conditions,[2] but you may not enjoy the same protections. Do not break your local laws, wrong as you feel they may be. You can end up in lots of legal hot water, especially if you grow more than 99 plants or also have a firearm on your grow premises.[3]

Prologue and Dedication

You are to be congratulated. Growing your own marijuana is a powerful thing. Politically, it is the most important thing you can do to help end marijuana prohibition. We in Colorado, for example, now enjoy what is our birthright:[4] [5] the un-harassed use and consumption of any plant we find growing on what my grandfather called God's Green Earth. Well, amen.

People now speak with optimism of the day *when* marijuana prohibition will end in their own home state, not *if*. Growers like you are the reason why we are now, in 2014, watching that horrendous idea called Prohibition bleed to death on Main Street. Prohibition is wrong. Period. When you grow your own, you are doing exactly what good Americans have

always done in the face of injustice: Leading whzen your leaders have lost their way.

Activism is great. Don't get me wrong. The people who are writing the ballot initiatives, collecting signatures and conducting brilliant social acceptance campaigns are indispensable and we all owe them a debt of gratitude (and maybe a bag of top-shelf homegrown). But there's no comparing it to the subversive act of civil disobedience. Without growers there is nothing for the activists to talk about. Without the availability of pot to help sick people, there is no argument for its medicinal use--there is nobody to point to and say, "Here! This person lives more comfortably because of pot."

Growers--home growers--are the backbone of the movement to eliminate bad marijuana laws. When enough

people grow their own, the futility of criminalizing a normal activity is made apparent. (Not incidentally, home growers are also our best bulwark against big business entering, and ruining, the production of cannabis products--do you really want to see the marijuana equivalent of cheap beer?)

The truth of the matter is that the prohibition of this plant was doomed from the start; we Americans grew it anyway, and the government cannot successfully legislate against culture for very long. This victory is a moral one. Prohibition's misguided goal (to regulate the self-regarding behavior of other people) and its sole achievement (the incarceration of vast numbers of innocent, mostly non-whites[6]) are steadily moving behind us, and we can finally get on with the enjoyable pastime of growing our own marijuana without the threat of having Big

Brother ruin our lives and without the stress and paranoia that goes along with such a threat.

As an activist myself, I can attest to the hard work and dedication that went into bringing this change about in Colorado and wish to dedicate this volume not only to those who fought in the trenches of the drug war and won, but to those victims still paying for their "crimes" in US prisons and around the world.

As you use the information contained within this book to produce your favorite herbal medicine or recreational drug, please reflect on the following:

- The US is the world's number 1 incarcerator.[7] Nobody else imprisons a larger percentage of its people than we do here in the

Land of the Free. Nobody. We can and must reverse that. Politicians will follow if the people lead.

- Our prisons are increasingly private and for-profit,[8] misaligning the motives of proper governance with those of for-profit industry. This should induce nausea; instead, it is little-known. Imagine the size of the voting block consisting of the families of the more than one million individuals who are either incarcerated or on probation for drug-related crimes.[9] We need only to help them overcome their (needless) shame for having an incarcerated family member, and then we can help them organize and become vocal.

- The vast majority of drug prisoners are African American or Latino.[10] The incarceration industry is racist. Blacks are 10 times more likely to go to prison for drug use, even though five times as many whites use drugs as do blacks.[11]

- Federal prosecutors are in it for the numbers, and they do not answer to anyone for their mistakes.[12] The prosecutors, the DEA, police departments, politicians and corporations are all in on the take.[13] [14] Only you have the ability to lead our country out of this mess.

Celebrate your new freedom, but do not rest on your laurels. Please visit the Drug Policy Alliance, Americans for Safe Access, NORML, the Marijuana Policy Project, DrugSense

and any of the many other like-minded organizations to educate yourself and offer your help; if you cannot donate, please become vocal. Talk about the insanity of incarcerating people for committing crimes that involve either no one else or only other, consenting, adults. Thanks for letting me take up my soapbox. Now onto the fun stuff: growing lots of weed!

Thanks and Acknowledgements

I wish, foremost, to thank the people who make me look better than I am: my talented editor, Meg Stefanac, whom you are well-advised to retain should you need an editor, and the master of graphical presentation, Nigel Ellis, a man of considerable skill. Without their help this book would be much less readable and a helluva lot uglier. Thanks, also, to all of my clients with whom I have had the privilege of working to further the cause of bringing more people into the industry. Thanks to the fabulous crew at The ArcView Group, Canna Advisors, and to Danny Danko at High Times for giving the first edition of this book a solid Danko Bump in the March 2014 issue. My undying gratitude belongs to the fiery, big-hearted Wendi Shaver for her continual love and support; also to the amusingly-paranoid and always-high

David Richey for keeping my dog happy while I flew off to write this in Oaxaca this past winter and, finally, to my late friend and mentor, Dr. John W. Adams--the original international man of mystery--you will be missed.

Introduction to the Second Edition: How to Use This Book

This is the second edition of *Small Spaces, Big Yields*. All of my readers who bought the first edition made the writing of this edition possible: Thank you!

This version of the book is significantly different from the first. (So different, I have had to give it a new title.) I have greatly expanded its scope, but have tried to maintain its compact and succinct character, which many people have told me they appreciate. This is a book for the home grower, though it draws on techniques I have used in large-scale grow operations.

I do not intend to put another marijuana-growing technique Bible on bookstore shelves. We have three good

ones already (Cervantes, Green, Rosenthal). My purpose in writing this book is twofold.

First, I have striven to write a *useful* book. By that, I mean a practical guide to getting some pot in your pipe as quickly and as cheaply as possible. I do this by getting right to the best, most efficient ways of doing things and cutting out that which is unnecessary or counterproductive. It is, I hope, a practical guide to understanding plants, growing them well, and solving problems.

Second, in this edition, I have attempted to fill in the gaps with things that are not addressed by other books, to challenge conventional orthodoxy and to contribute to growers' understanding of plant function. Let me explain what I mean by that.

As I was writing the last chapter of this edition I popped onto a Colorado newspaper website and read an article about the difficulty of growing pot indoors for oneself. The bulk of the article was written in question-and-answer format. The questions had been put to some local growers and the answers varied significantly from one grower to the next. To my surprise, these professional growers got some of the answers wrong. Not just a little bit off, but wrong enough to betray their ignorance of botany. It was clear that they needed a better grasp of the fundamentals of plant physiology.

Growing plants isn't an art-form with room for differing opinions. It is a scientific field of inquiry encompassing botany, horticulture, agronomy, chemistry and other disciplines. If it seems like there is room for opinion in a particular area,

what that reveals is the need for more science in that area, not opinion. The facts are out there; we need only to illuminate and elucidate them.

The problem for today's grower, then, is epistemological: how do you know which information is good and which is bad? Simply put, you must educate yourself. This guide will help you sort through the bits and pieces of information. For this second edition, I am not only explaining why I do what I do, but why I believe it to be the best way to do that thing based on available science. Everything is footnoted with sources. If I speculate, I say so. If I don't know, I say so.

I have always been interested in exploring the various heuristics that growers pass along to other growers--the received wisdom that we have all heard, that most people live by and that

now pervades growers' forums. These pearls of wisdom should not be blown off, because many of them really work. Yet, some others have more than a whiff of what Stephen Colbert calls *truthiness* about them. They sound true, but they also sound *too* good--too... packaged. Indeed, they are often only accidentally functional.

I like to test these bits of folklore to see what's behind them--if they work, why they work and which ones we should discard. Having had my own medical marijuana facility (one of the first in the state of Colorado to receive its official license), I have had the chance to grow thousands of plants and test these rules. I continue to encourage clients to conduct their own research in their facilities.

I am also interested in efficiency, since I believe that efficiency is why these

heuristics evolved in the first place. The science and art of growing pot has been conducted under the threat of legal repercussion, making the enterprise a highly risky one. Someone taking the risk to produce a crop needed to get to the finish line as quickly as possible and with the highest possible reward. Therefore, experimentation came at great cost. If the experiment failed, the clock was reset and the risk of exposure increased. If the experiment succeeded, news spread rapidly, often without anyone having rerun the experiment to test the hypotheses or assumptions about what it was that led to the success.

It is my belief that everything in this business has a performance curve--whether it's cloning, vegetating, flowering, trimming, CO_2 levels, temperature, watering, employee time

spent at various tasks, sales price, and so on. Efficiency requires experimentation. Running my own legal operation has afforded me the opportunity to experiment. I have done my best to find the peaks of these curves and report them here.

Understanding how plants function goes a long way toward understanding why we do certain things. Learning the basics is an indispensable tool for helping to sort through the information found on the Internet, much of which is not just useless, it's harmful because it perpetuates ignorance. We simply must move past the misinformation, folklore and speculation if we are to advance our collective project of growing excellent marijuana.

Instead, what I fear is happening is that the Internet has allowed for the proliferation of certain heuristics,

which are becoming (or have already become) established orthodoxy, and that as a community we are becoming calcified rather than using our collective resources to test these orthodoxies. This edition is my effort to move the dialogue past the present state of affairs and to encourage the spirit of enquiry in our community.

I have arranged the book into three sections, the first and last of which are completely unnecessary if all you want is what the first edition offers: a cut-to-the-chase guide to getting some plants under lights and getting on your way. Even if that is all you want, I hope you will come back and check out the first and third sections after you've finished with Section Two.

The first section is an introduction to plant physiology. It contains the basics of how plants function, with specific

information about cannabis physiology. If you take the time to read it, you will emerge with some practical advantages over other growers. You will no longer be susceptible to making costly mistakes, wasting time with useless experiments, or spending money on products that do not, and cannot, work as advertised. You will be rewarded with a deeper understanding of plant behavior, and you will be able to put names to concepts you probably already have in some nebulous form or another in your own head, based on observations you have made in your own garden. Most critically, you will be able to sniff out the bullshit that is so liberally sprinkled about the Internet in growers' forums and like places. If you are a serious grower, I think it's worth your effort to read Section One, which is why I went to the trouble of including it.

The second section of the book is the nuts and bolts that you threw your money down for. It is improved from the first edition, with numerous revisions, additions, improvements, re-writes and small tweaks. As a bonus, it also contains two new chapters. One of the new chapters covers a technique some friends of mine have been using for years now. It is something I call duoponics, and it combines the best of both soil growing (geoponics) and hydroponic growing. I do not take credit for this, nor is the idea new in my experience; but the apparatus these growers have developed is slick to say the least. It is inexpensive and easy to make, and they are getting great results from it. That is exactly how I like to grow, so it is offered to you as a third alternative to my two favorite techniques (soil and deep water culture). The other new chapter covers additional techniques for growing that

may be useful to you as you begin to experiment and play with new ideas you've come up with on your own. I have also expanded the troubleshooting chapter significantly, while trying to keep it simple enough that solving your problems is a trifle, not a chore--which is how it should be.

The third and final section of the book is for the scientifically-minded and the curious growers. This is the sort of stuff you may want to read after a few puffs or when you have nothing better to do but learn about how to squeeze every last bit out of your plants and your own ability as a grower. It contains stuff like how to use Punnett Squares to solve Mendelian genetics problems, an update on CO_2 enrichment, basics of soil structure and chemistry, some studies that have been done on compost teas and how and why they may work, a section on

measuring light... Geeky stuff. Stuff you don't *need* to know, but which is exciting for those of us who want to forge ahead to find The Next Big Thing that makes growing pot that much easier, lucrative or fun. In this section you will also find a collection of useful charts, illustrations, and equations, as well as my works cited and an essay on getting into the professional marijuana business--in case you thought for some reason that would be a good idea.

One more thing about the arrangement of this book: I have placed the first instance of every term that appears in the glossary in **bold**. If you find yourself lost, simply go back to the last bolded word you did not know and then look it up in the glossary. This should resolve most confusion.

Thanks for picking this book up. I truly

hope that you enjoy reading it as much as I have enjoyed writing it. I invite you to contact me through the book's companion website, MJAdvisor.com, with any questions, comments or ideas you may have.

Together we have put cannabis at the apex of horticultural achievement--exceeded only perhaps by the science that has produced GMO crops such as corn and soybeans--and together we can continue to innovate. This book is offered in the spirit of continued exploration.

Now get growing. It's important work!

SECTION 1: BASIC PLANT PHYSIOLOGY

Let's give credit where credit is due: to you. You likely already know a lot about plants and plant function, but you might not be aware that certain behaviors you've observed have names and interesting explanations. For example, you've probably observed that your pot plants wilt when the soil is too wet or too dry, that branching patterns change as your plants mature, and that your plants tend to orient themselves toward light.

Some growers have an intuitive understanding of how plants behave. We say that these people possess "a green thumb." But ask many of those same people why a plant wilts when it has too much water, what the name of

the branching patterns are or what hormone controls phototropism, and they may be at a loss for an answer.

This section of the book is here to straighten out and organize the things you may already know intuitively, but have not yet named and filed away. If you already know this stuff, you may enjoy refreshing your knowledge or just having it here for easy reference. Many of you will probably prefer to skip this section and go straight to the how-to portion of the book: SECTION 2: LET'S DO THIS ALREADY. If you choose to do that, I highly recommend that you come back to this section later. You will be glad you did.

Cannabis Taxonomy

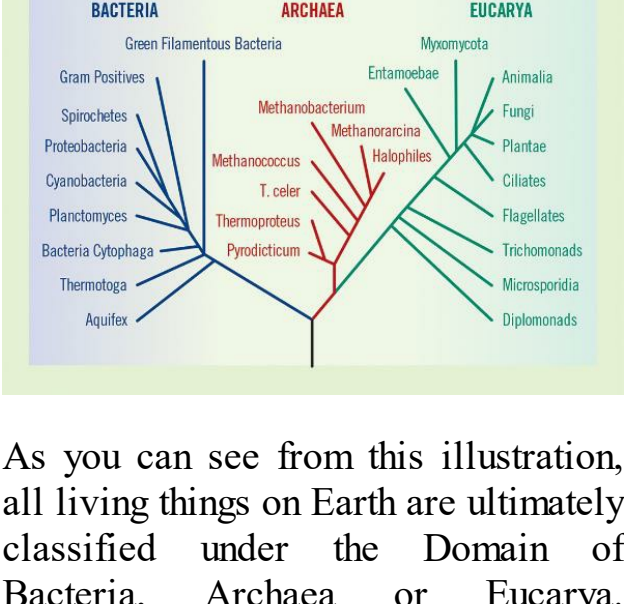
Why You Need to Know: Only when you have seen the map can you properly plot your route. All modern strains of psychoactive cannabis are created by blending the genetics of three main species. Knowing taxonomy will enable you to identify plants by their phenotype. At a minimum, this knowledge is useful when shopping; more importantly, it can guide you in your efforts to breed new strains as well as help you anticipate flowering times, plant sizes and psychoactive character.

People classify and organize things. It's our way of making sense of the world around us. We've grown fairly good at it since 350 BC when Aristotle made the first documented stab at classifying species with his *History of Animals*.

The endeavor of classifying biological organisms based on shared characteristics is called **taxonomy**. One man who indisputably contributed the most to taxonomy is Carl Linnaeus, a Swedish botanist who lived from 1707 to 1778. Linnaeus spent his life giving names to as many species of plant and animal as he could. At the time of his death he had named more than 4,400 animals and 7,700 species of plants! He did this using his own system of binomial naming, a system that is still in use today.

The binomial system is as follows: Genus name, followed by Species name, followed by the Initial of authority (e.g. "Cannabis sativa L"). The authority is the person who discovered the species. The trailing L, in this case (and in about 12,000 other cases), stands for Linnaeus. Above Genus and Species are, in ascending

order: Family, Order, Class, Phylum, and Kingdom. (You can remember this using the mnemonic "Kings Play Chess On Fine Grain Sand.") Today, due to the work of a scientist named Carl Woese,[15] we have added Domain and Life at the top, and Subspecies at the bottom for a system that looks like this:



As you can see from this illustration, all living things on Earth are ultimately classified under the Domain of Bacteria, Archaea or Eucarya. Bacteria are those organisms that lack

a true nucleus (they have no surrounding **membrane** to sequester DNA); Eucarya have a true nucleus (the prefix *eu* means "true"); and Archaea are the misfits--we have that group for the weirdos that don't qualify as either Bacteria or Eucarya. These freaks produce methane, or live in extremely hot or cold or salty environments where the rest of us dare not tread. The smaller names on the diagram are all Kingdoms, and the tree continues to branch from there all the way out to Subspecies.

So where does the World's Greatest Plant fit into all of this? If you head up the trunk of the Tree of Life, you can find your way to Cannabis by following these directions:

- Take a right at Eucarya.
- Exit onto a highway called

Plantae.

- Follow Plantae to the Angiosperma Exit. (Angiosperma is the Phylum that consists of flower- and fruit-producing plants.)

- Stay on Angiosperma til you see a turn off for Eudicots. (Eudicots are true **dicotyledons**--plants whose seedlings sprout two starter leaves.)

- Turn off once again at the Rosids. (The Rosids branch has about 700,000 members.)

- And then again at a thinner branch called the Rosales. (Rosales is comprised of about 7,700 members.)

- And yet again at the family

Cannabaceae. (This is an elite group of about 170 species including the beloved genus*Humulus lupulus*, aka "hops".)

- And finally, you will arrive at the genus *Cannabis*.

It is here that the argument over whether this species contains one, three or four members (or more), and whether or not they are proper subspecies, begins. There are many taxonomical questions that people debate the answers to. These include: Is cannabis **monotypic** or **polytypic**? If polytypic, do *Cannabis sativa*, *Cannabis indica*, and *Cannabis ruderalis* comprise an exhaustive list of the species? Should we add *Cannabis chinensis* to the list, or is that a subset of indica? What about hemp (traditionally *Cannabis sativa*)?

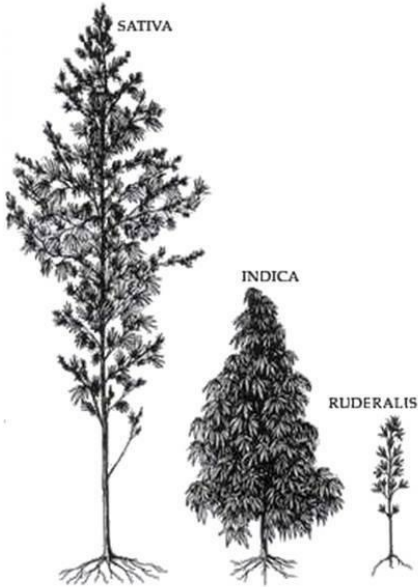
Should all the species be placed under *Cannabis sativa* L.? Should polytypic distinctions be made across **chemotypes** and if so, where do we draw the lines? A 1.0% THC/CBD ratio has been proposed,[16] but isn't that arbitrary and capricious--especially now that we know the drug benefits of CBD?

For the purposes of this book, we will proceed with both chemotypical *and* regional (and their concomitant phenotypical) differences and treat hemp, sativa, indica and ruderalis as four **polymorphs** (each having different and distinct physical appearances within the species). That is, we will treat the low-drug, grown-for-fiber hemp as its own polymorph and will concentrate on the three main drug types that have each evolved in their own separate and distinct ecological niches on the planet as their own

polymorphs (the "rope versus dope" distinction). They may be something more than that--subspecies, for example. I don't know, and I don't have a dog in this race. For those interested, Clarke gives a thorough (and I do mean *thorough*) treatment to the *history* of cannabis taxonomy,[17] [18] a *key* to cannabis taxonomy[19] and even his own taxonomical argument for the classification of cannabis as polytypic.[20]

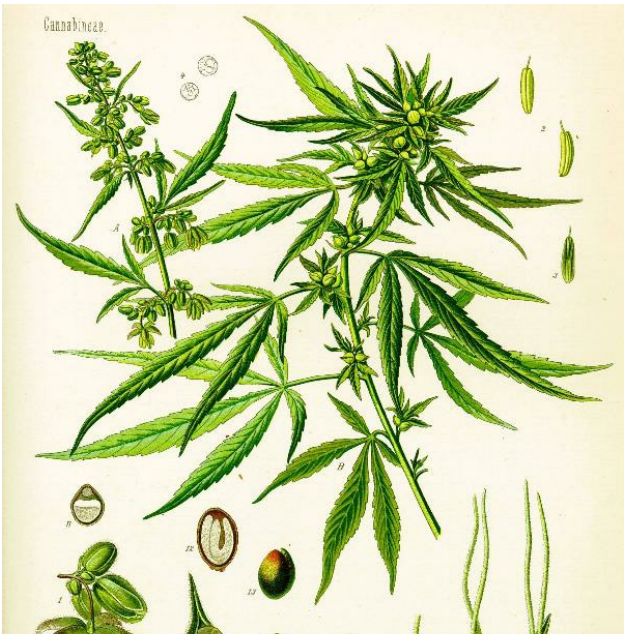
The discussion about what the different types of cannabis *are* is intriguing, but it reminds me of Wittgenstein's "family resemblance" argument about what constitutes differences: there may not be one connecting commonality at all, but rather a group of overlapping similarities. Whatever these plants are taxonomically, we need to regard them as their own entities for sake of utility.

The Three Species of Psychoactive Marijuana



Sativa (meaning "cultivated") is a form of drug cannabis that has adapted to equatorial regions where it has enjoyed long days, warm weather and barely perceptible changes in season. As a result of this, sativa is slow to both initiate and finish flowering. These plants are tall, airy and wispy in growth, have slender **leaflets** and tend to be extremely potent. They give the

user a high that is often described in terms such as "cerebral" or "heady." Sativa plants are the most common subject of old botanical illustrations of cannabis, and they are regarded by many as the most beautiful of the three types.



Indicas (meaning "of India") evolved, as their name suggests, in parts of India and central and eastern Asia. (It is postulated that all cannabis originated in central Asia.[21]) Because they developed at higher latitudes, they have been subjected to the pressures of

abrupt changes in daylength, extreme temperature variations and well-defined seasons. As a result of this, these plants are quick to respond to long nights and fast to finish flowering. They are short, stalky plants that have a pine tree shape and wide leaflets. Indica plants are also potent, but their effect is often described in somatic terms such as "heavy" and "lethargic"--in other words, they make the user stoned.

Ruderalis (meaning "rubble" because of the plant's tendency to colonize in disturbed ground) is a Russian variety of cannabis that is found in even higher latitudes than indica and under more extreme swings in temperature and daylength. It is a small, tough and opportunistic plant that is not induced to flower by length of night, but, rather by the age of the plant. It is thought by some researchers to be the ancestral

source of all cannabis.[22] Though it is not especially potent, it does produce relatively high levels of **cannabidiol** (CBD), which is rapidly becoming the medicinal superstar of cannabis' myriad **phytochemicals**. This plant, which has a tendency to pop up unsown in disturbed areas, has developed a natural resistance to disease. Ruderalis is quite useful in cannabis husbandry, not only because of its small stature, tendency to produce CBD, and disease resistance but because of its ability to "**autoflower**."

In Summary: The three species of psychoactive marijuana are *sativa*, *indica*, and *ruderalis*. Sativas produce a high, have long flowering times---- often upwards of 120 days, and have airy, tall growth patterns. Indicas are more compact plants with dense foliage, leafier buds, shorter flowering

times and make the user feel stoned. Ruderalis are diminutive plants used primarily for breeding in small stature and auto-flowering characteristics.

Let's Relax: Pot Terminology

I use the words cannabis, marijuana, pot, weed and other terms interchangeably.

A few years back, I was at a town-hall meeting convened to decide dispensary regulation when a well-meaning, but misinformed gentleman stood up to make the point that "marijuana" was invented as a pejorative term in the days leading up to its prohibition 75 years ago. He requested that the Board of Trustees use the word "cannabis" instead. This was not the first time I had heard this argument, nor was it the last.

While it is true that the term "marijuana" was frequently used by detractors because its foreign-sounding origins played upon social prejudices,[23] the word itself comes

from Latin-American Spanish[24] and it's a great word that we all recognize and understand. It's okay to call cannabis "marijuana."

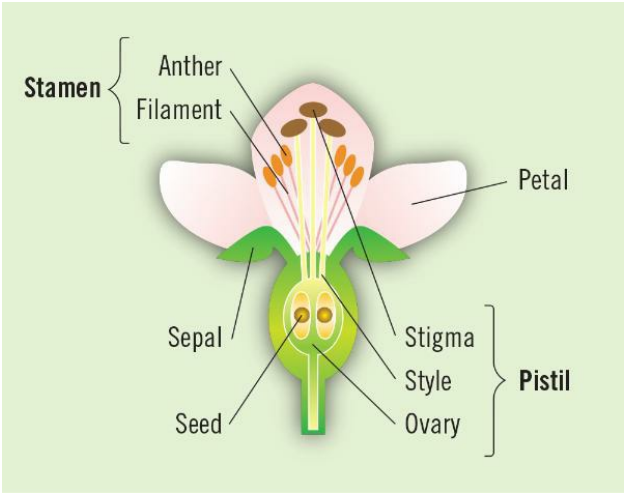
Anatomy of Flowers

Why You Need to Know: Sexing and breeding plants requires a fundamental knowledge of their make-up. Just as a mechanic must know the parts of a car, you, as a grower, need to know the parts of a plant.

Angiosperms, as mentioned earlier, are plants that produce flowers and fruits--this is as opposed to gymnosperms, which produce spores but not seeds or fruit. Angiosperms evolved about 100 million years ago and they are of incredible social and economic importance. The flowers they produce can be colorful (as with roses) or they can be green (as with pot). The fruits can range from large, spectacular things such as mangoes to small, simple seeds. All angiosperms are divided into**monocotyledons** (monocots) or dicotyledons (dicots),

depending on the number of cotyledons, or embryonic "starter" leaves, they have when they sprout. Cannabis is a dicot. When it sprouts, there are two starter leaves.

All plants are either **monoecious** or **dioecious**, meaning that their male and female parts either reside on the same plant or on separate plants, respectively. But before we get too much into that, let's have a quick peek at angiosperm anatomy. Below is a simplified illustration of plant sex organs.



Note that the **stigma**, **style** and **ovary** are parts of the **carpel** (**pistil** when there is more than one), or female sex organ. The stigma is where the pollen lands; the style is the stalk upon which the stigma rests; and the ovary, which will become the seed or the fruit, rests at the base of the style near the support structure called the **receptacle**. The leaf-like structures below the**petals** are called **sepals**. Sepals protect the flower when it is a **bud**.

The **anther** and **filament** are two parts of the **stamen**, or male sex organ. The anther is where pollen is produced. It is easy to think of pollen as the sperm of the plant, and you'd not be too far off if you did. Although it is technically a **gametophyte**, it does carry what will become sperm at the pollination event and therefore it does transfer genetic information.

This illustration is of a monoecious (**hermaphroditic**) plant, meaning that both the female and male sex organs are on the same organism. As we already know, this is not always the case. Dioecious plants have either **pistillate** or **staminate** organs, but not both, and must therefore grow in reasonable proximity to one another in order for the pollen from the male plant to contact the pistil of the female plant. Marijuana is dioecious. This has significant implications for the use and

husbandry of this plant, which we shall see.

In Summary: Plants have male and female sex organs that can appear together on the same (monoecious) plant or separately on different (dioecious) plants. Marijuana is dioecious and this gives us great control over its life-cycle, which is good news for cultivators.

Dioecy

Why You Need to Know: Marijuana plants are either male or female. Few things could be more fundamental to your understanding of cannabis husbandry.

There is a running scientific discussion about why a plant would evolve to have sexes on separate plants. At first glance, it seems a bit risky and does not appear to provide any obvious advantages. Long-standing arguments are that dioecy is the result of too much inbreeding, that separating the sexes was a way to solve the problem of **autogamy** or "**selfing**" (when a plant pollinates itself). What this does not explain is the absence of great numbers of dioecious plants, which make up only about four-percent of plant species.[25] In other words, if this is such a great way to avoid inbreeding,

why isn't it more popular? (Note: monoecious plants have mechanisms for avoiding self-pollination, for example, the timing of the maturity of the male and female organs. This ensures **outcrossing**, also called **allogamy**.)

Others theorize that the coevolution of insect species enabled plants to give the job of pollination to insects that were willing to do the work. Because insects can move, the plants could separate their sexes into male and female individuals.[26] Still another idea concerns the sexual apparatus of the plant itself, specifically the physical development of the stigma/style and anther/filament structure.[27] Male parts tend to be suspended by flexible structures that are susceptible to movement by wind, which often carries pollen, while female structures tend to be mounted on sturdier

structures. This structural arrangement could be more easily accomplished by putting sexual organs on separate plants. Whatever the reasons for its evolution, this characteristic has implications--some obvious, some less-so--for how we must go about cultivating this type of plant.

Charles Ainsworth writes, "Where dioecy has evolved from monoecy, one prediction would be that the species

might show some sex lability..."[28] Sex lability refers to the degree to which sexual expression is changeable in an individual specimen. If you have ever accidentally exposed a female pot plant to light stress, only to find some male flowers popping up a few days later, then you know that sex lability is exactly what we find with marijuana (to greater or lesser degrees of "instability," depending on strain). We will discuss more about the separation of sexes in marijuana throughout the book; but for now, let's turn our attention back to more fundamental aspects of plant physiology.

Male flowers. By H. Zell (Own work) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Female flower. By Stuntmanmike (Own work) [Public domain], via Wikimedia Commons

In Summary: Marijuana is a dioecious plant. Its sexes are separated on different individual plants. We do not know why dioecy has evolved, but our best guess is that it has to do with reproductive strategy. Marijuana displays a high level of sex lability.

Cannabis Inflorescences: Bract, Calyx, Stipule--What's Going on Here?

There is some confusion on Internet forums about what the following terms refer to when applied to cannabis. They each refer to specific parts of the plant and are not interchangeable.

- **Flower:** A group of plant parts that is comprised of sepals, petals, and either carpel, stamen or both reproductive parts.

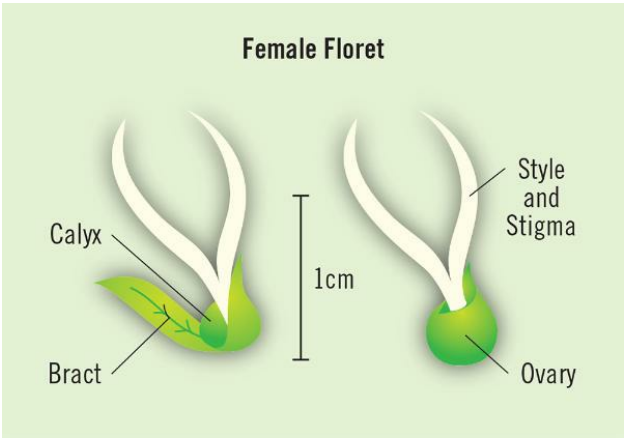
- **Inflorescence:** A collection of reduced flowers (florets) on a stem. Cannabis has inflorescences of florets.

- **Calyx:** The collection of sepals on a flower or floret. In the case of female cannabis florets, there is one sepal; therefore the calyx

is this sepal. It surrounds the fruit and is the structure from which the two styles emerge.

- **Bract:** A modified leaf or scale situated below the flower (and therefore below the calyx). There is one bract beneath a female cannabis floret. It is extremely difficult to see.

- **Stipule:** A leaflike appendage growing (usually in pairs) at the base of a leaf stalk (**petiole**). In cannabis, they are the lanceolate protrusions at the junction of the petiole and the stem.

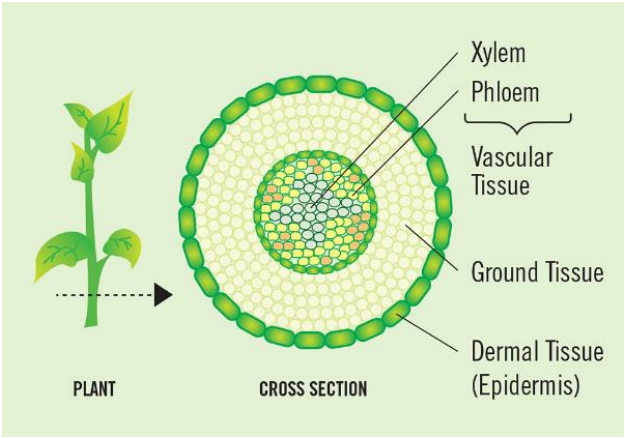

Female Floret
Calyx
Bract
1cm
Style
and
Stigma
Ovary

Tissues of Plants

Why You Need to Know: An understanding of all tissue types sets the stage for you to learn about leaf tissue. Leaf tissues are an important subset of dermal tissues, and are useful for you to be familiar with because of how they react to light. Plus, learning about leaf tissue is easy and fascinating.

There are three major types of tissue in a plant (and many more, specialized, sub-types with which we will mostly not concern ourselves); these are **dermal**, **ground** and **vascular** tissues. These three basic types make up the entire structural portion of the plant, from the green, aerial parts to the root systems to the interior tissues that carry water, **nutrients**, and products of**photosynthesis** to various parts of the plant.

The vascular tissue, which you may recall if you paid attention in high school biology, is comprised of **xylem** and **phloem**. Xylem carries water and **ionic** minerals (nutrients) up into the plant so that it may conduct photosynthesis; and phloem distributes the products of photosynthesis.



Cross Section of Stem at Grade Level

The outermost layer of a leaf is called the **cuticle**. It is a sometimes thick, but in the case of cannabis, it is a very thin, waxy layer that serves as a barrier to seal water into the leaf. It is

present on both the upper and lower leaf surfaces. Once water is in the plant, its primary means of transport and loss is convective, meaning it diffuses through the leaves. The cuticle allows the plant to control water loss through specialized pores (called **stomata**) that are located on the bottoms of the leaves.

Just beneath the cuticle is the **epidermis**. Epidermal cells are usually transparent and are oftentimes convex, which allows them to focus light into the interior portion of the leaf. Just beneath the epidermis are the **palisade** cells, which are a layer (or more) of tall, vertically-oriented (hence the name) cells that sit between the epidermis and the **spongy mesophyll**. The palisade cells contain **chloroplasts** and have the effect of refracting and scattering light prior to its contacting these chloroplasts.[29]

Even more of this scattering occurs in the spongy mesophyll, which is characterized by numerous air pockets and watery (think: shiny) surfaces.

The scattering of light provides multiple opportunities for it to contact a chloroplast and become useful energy. As a matter of evolutionary design, this is a rather remarkable arrangement.

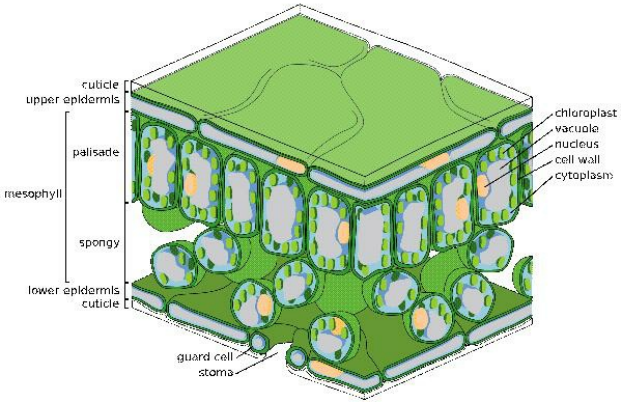
From a distance, you will notice that the plant orients its branches toward the source of light; upon closer inspection, you will see that each of the individual leaves also orients itself towards the light. This is possible because of special cells called**pulvini**, that are located in the petiole and that can inflate or deflate (with water) as needed to change the leaves' orientation.[30]

To recap: the outermost layer of leaf tissue focuses light into itself using convex epidermal cells, breaks it up with another layer of (palisade) cells, and then scatters it throughout the spongy mesophyll beneath. Reflecting the light around in this way maximizes the odds that some of it will make contact with a chloroplast and be used.

But it doesn't stop there. The chloroplasts themselves are also able to change their orientation as required by light intensity. In extremely intense-light situations, the chloroplasts will arrange themselves like coins set on their edges around the perimeter of the palisade cells in order to allow light to pass by. This avoids a potentially destructive situation called **photo-inhibition**(see Section Three, CO_2). In dim-light situations, the chloroplasts arrange themselves like dinner plates laid flat on a table, perpendicular to

the incident angle of the light, in order to capture more of it. (I mentioned that the light scatters once inside the leaf, so how much of a difference can the chloroplasts' orientation make in terms of light captured? 15-percent.[31] Not too shabby.)

We have drilled down now to the underside of the leaf-the next layer of epidermis and cuticle. On this side, though, are specialized structures called stomata and **guard cells**. The stomata are apertures in the leaf that allow gases to enter and water vapor to exit, and the guard cells are there to regulate the opening and closing of the stomata. Together, they keep CO_2 concentrations inside the leaf at high enough levels to permit photosynthesis. They also prevent excessive water loss.



By Zephyris (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0) or GFDL (http://www.gnu.org/copyleft/fdl.html)], via Wikimedia Commons

Hindering their work is a layer of exhausted gas and water vapor that collects under the leaf. This is called the **boundary layer**. It is one of three layers of resistance through which CO_2 must diffuse before it can enter a plant cell. The other two are the stomata cells themselves and the interior air spaces. This is why moving the air inside your grow room is so important. By stirring the boundary layer, you aid

the function of the plant.

In Summary: There are three basic kinds of plant tissue: dermal, ground and vascular, corresponding to the exterior of the plant, the root zone, and the interior parts of the plant, respectively. Leaf tissues are highly specialized areas where the plant produces its food (sugar) through photosynthesis. The plant, its leaves and the chloroplasts within the leaves are all able to change orientation with respect to light. Leaf tissues are very good at what they do; but, man, its hard work to be a plant!

Roots and Plant Hydraulics

Why You Need to Know: All manner of foolishness flourishes when growers fail to understand how roots take up water and nutrients, or how water and nutrients move throughout the plant. Don't be one of the fools.

It is worthwhile to know a few things about ground tissues. Understanding how they work will save you money when you shop for products that claim to sweeten your buds or when you sort through the advice offered indiscriminately on the Internet.

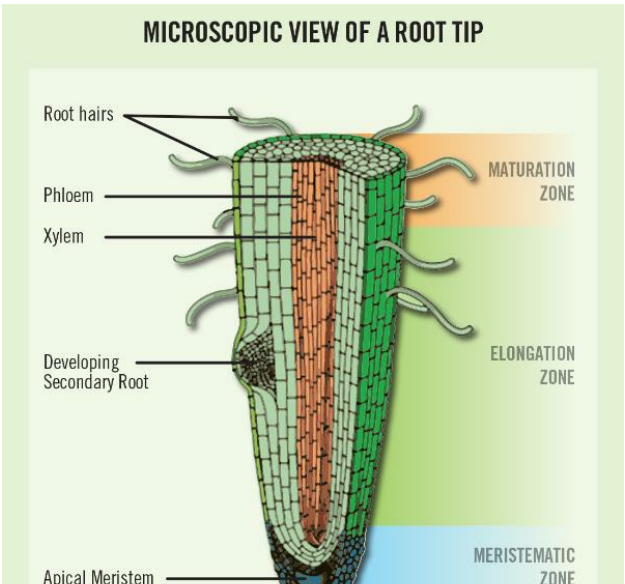
The root is comprised of four nested layers of tissue: the outermost layer is the **epidermis**; just inside that layer is the **cortex**; this is followed by the **endodermis**; and finally, at the core, is the **stele**. There are also **root hairs**, which are extensions of the epidermis

which serve to greatly increase the root's surface area. And, finally, at the growing tip of the root (the**meristematic region**) are specialized cells known as the **root cap**. Some truly amazing things go on in the root cap. None other than Charles Darwin understood the root cap of the plant to function "like the brain of one of the lower animals."[32] [33] [34]The root cap can detect:

- water
- gravity
- toxic chemicals
- nutrient
- light
- pressure
- bacteria

- fungus
- rock/inanimate objects
- other plants
- other members of its own species
- its own roots

In short, this is an amazing part of the plant.



Roots bring water and nutrients into the plant using **osmosis** to absorb water, and **active transport** to absorb nutrients. (Note the use of the word "absorb"--with a B--which connotes transport across a barrier and into another space. When we consider soil properties in a later section of this

book, we will discuss adsorption--with a D--which means to stick onto, rather than transport into.) This fact is worth emphasizing: **Roots use osmosis to absorb water, and active transport to absorb nutrients**.

Counterintuitively, water and nutrients do not enter together with the ions that are dissolved in water. That's an important point to remember. They enter separately. The second point to remember is that plants do not use nutrients in their **organic** form. They cannot use nutrients until they have been broken down into their **inorganic** form. We will get into that later in the book, just note it for now.

An additional mechanism is used within the plant to move water and other solutions around. That mechanism is called**convection**. So, that's three ways of moving water into

and through the plant: osmosis, active transport and convection (where the first two bring water into the plant and the third moves it around). Let's have a look at each.

Understanding osmosis is critical to your understanding of roots. Please take the time to comprehend osmosis because doing so will serve you in many ways as a gardener. To begin, it will help to become familiar with a few terms:

Solute: This is the stuff that gets dissolved. Here, we mean mineral solids (nutrients)

Solvent: This is the stuff that dissolves the solute. In this case, we mean water

Solution: A combination of solute and solvent

Dilute: Lacking in, or having a low

level of, solute

Concentrate: High in solute

Osmosis is the transportation of solvent through a semi-permeable membrane and into a concentration of higher solute in whichever direction will enable it to equalize concentration on either side of the membrane.

We always want osmosis to create pressure (which results in **turgor**, or the stiffening of pressurized tissue) in the plant **cell**. This causes the plant to stand upright.

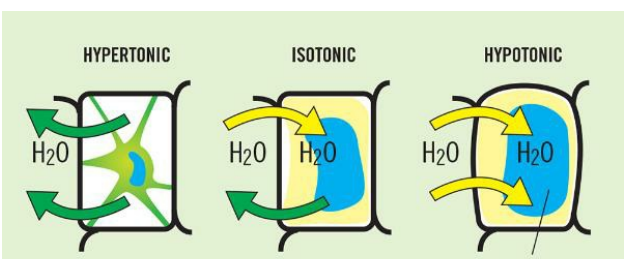
Osmosis becomes a factor when the dissolved chemicals on one side of a semi-permeable membrane cannot pass through the membrane in order to equalize concentrations. Instead, water moves through to achieve the same result. Hence:

If the plant cell has a high concentration of solute (think dissolved nutrient) and the water outside the cell has a low concentration of solvent (think pure water), we describe that cell as being in a **hypotonic** solution and the plant cell will absorb water, resulting in turgid plant tissue.

If, on the other hand, the plant cell has a high level of solvent and the material surrounding the cell has a high concentration of solute, we describe that cell as being in a **hypertonic** solution and the plant cell will lose water, resulting in flaccid plant tissue.

When a plant cell is in a solution equal in concentration to the fluid surrounding it, it is said to be in an **isotonic** solution. This does not mean that no transport is occurring; it means that "water in" is in balance with

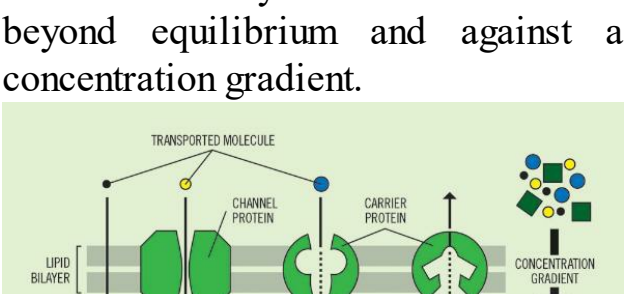
"water out."



Active transport costs the plant energy; that's why it's called "active." Active transport is the use of chemical energy (**ATP** in this case) in order to move solution *against* the concentration gradient. That means moving mineral nutrient ions from an area of low concentration into an area of high concentration, or, in other words, not equalizing the concentration but instead creating a greater concentration disparity--just in the opposite direction of osmosis.

Plants need to engage in active transport after they have exhausted

their ability to absorb nutrient through **diffusion**. (In contradistinction to osmosis, diffusion is simply the tendency of molecules to evenly distribute themselves; for example, in the way an odor can become detectable at a distance from where it originated.) Since the plant's need for ionic nutrient is greater than the supply available outside the plant in the soil, the plant must have a way to move that nutrient beyond equilibrium and against a concentration gradient.



Plants are able to do this by using ATP to change the shape of **proteins** in the cell membranes. When the proteins

change shape they are able to bind to ionic (charged) nutrients and deposit them on the opposite side of the membrane, which, in turn, causes another change in protein shape and results in another transport of ions, this time in the other direction. Simply put, there's a trade. After the trade has occurred, an additional ATP molecule is needed to repeat the process.

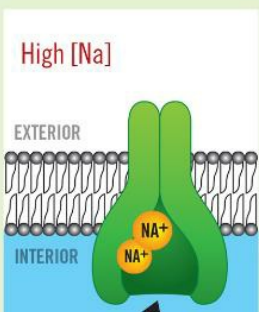


FIGURE 1
Three sodium ions (NA^+) enter the enzyme from within the cell.

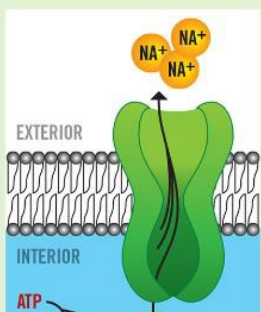


FIGURE 2
ATP phosphorylates the enzyme, which pumps three NA^+ out of the cell.

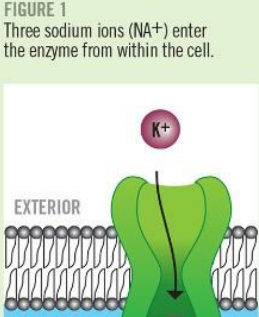


FIGURE 3
Two potassium ions (K^+) enter the enzyme from outside the cell.

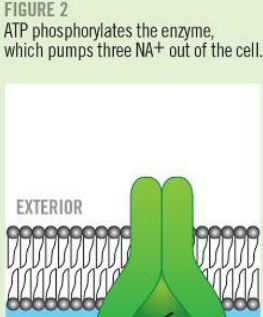


FIGURE 4
The now-unphosphorylated enzyme pumps the two K^+ into the cell.

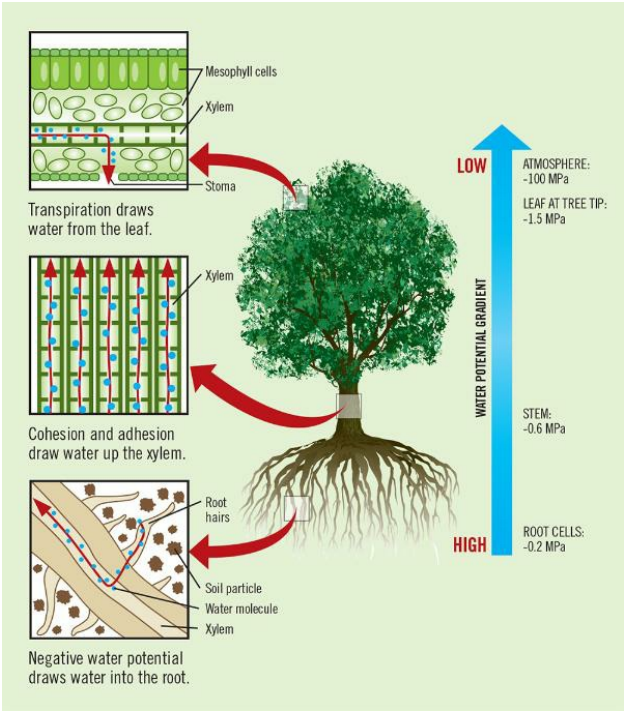
Plants use H^+ (hydrogen) and OH^- (hydroxyl) ions, which are products of

plant **metabolism**, to trade for mineral nutrient ions that adhere to soil particles, such as $NO3^-$ (nitrate) or K^+ (potassium). This mechanism is so effective that plants are able to move some nutrients against a gradient with a difference in concentration of 10,000 times![35] Plants do not secrete H^+ (hydrogen) and OH^- (hydroxyl) ions in equal measure; instead they tend to favor H^+, which means that the plant is actively acidifying its soil (this occurs in addition to decomposition and consequent carbonic acid accumulation.) We will get into this a little more later on because it has implications when you mix or buy potting soil.

Convection is the loss of water through the leaves of the plant. This loss creates a lower pressure gradient at the top of the plant which the water moves toward in order to fill. This

phenomenon of the plant pulling water upward is called the**Cohesion-Tension** (or C-T) **mechanism** and it is the primary mechanism for moving water through a plant.

Water sticks to itself because of its hydrogen bonds (cohesion). In the small tubes of the xylem, these bonds provide enough tension to enable the low pressure at the top of the plant to literally pull water great distances upward without ever breaking this tension.



In Summary: Roots are amazing, almost "smart" things. Osmosis, active transport and convection carry water and nutrients into and throughout the plant. Plants do not absorb nutrient broth the way a sponge soaks up water from a countertop; mineral nutrient ions and water enter separately.

Excessive concentrations of nutrient solution in the soil can reverse the direction of osmosis, killing your plant. Understanding how uptake and transport mechanisms work also resolves the question of whether or not you need to "flush" at the end of each growing cycle. Flushes are pure nonsense, as you now know. Only someone without an understanding of these transport mechanisms would claim differently.

Photosynthesis

Why You Need to Know: Photosynthesis is your plant's metabolism, and it is the one thing your plant does the most frequently during its life. The world's first and most efficient solar panels are the leaves on your plant. Dig it.

Let's have a look at how this miracle of nature works. You have probably read, and may even have memorized the famous chemical equation:

$6CO_2 + 6H_2O$ (+ light energy) $\rightarrow C_6H_{12}O_6 + 6O_2$

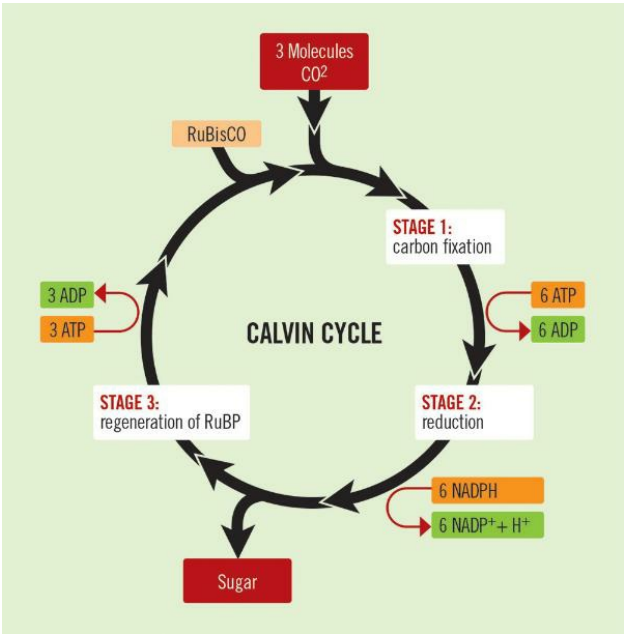
To translate that into terms most of us can understand, that's six molecules of carbon dioxide gas, plus six molecules of water, plus light (an input of energy) being transformed into one molecule of sugar (glucose), and six molecules of

oxygen gas.

Where I just wrote "transformed" in the previous sentence, two big things are going on: **light reactions** and **dark reactions**. In light reactions, **chlorophyll**, the plant's famous green **pigment**, is using light energy to produce ATP and **NADPH**. The byproduct of this reaction is oxygen. These are light-dependent reactions--meaning they cannot occur without the presence of light.

ATP and NADPH are chemicals used to power structures called **chloroplasts**, which, in turn, drive the **Calvin Cycle**. The Calvin Cycle is a rather complicated sequence of chemical reactions. It is not necessary to know how it works, but you should be aware that this process is commonly referred to as the dark reactions. These reactions are light-independent so they

can take place in the dark, but they can also occur during daylight hours. The dark reactions are what produce the ordered, storable form of energy we know as sugar (glucose).



The Calvin Cycle

In Summary: Your plant's primary activity, in its vegetative phase, is conducting photosynthesis. Photosynthesis requires the presence of light. Maximizing the supply of light during vegetative growth will give you the biggest plant in the shortest possible time.

Auxin and the Tropisms

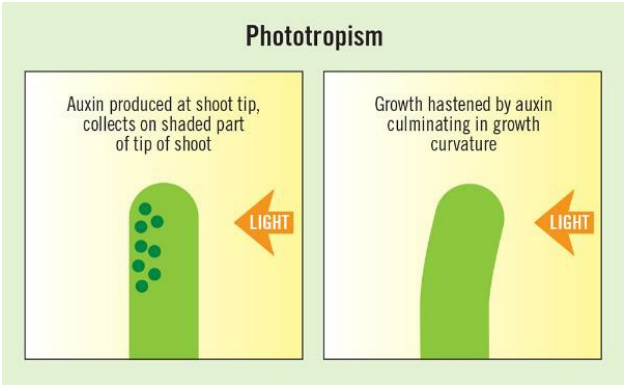
Why You Need to Know: This is how your plant responds to stimuli. You can use the plant's **tropisms** to great advantage. If you want to be a master at plant training you need to know this, no question about it.

Plants do some amazing things, including moving about and around things, orienting themselves toward light, lifting themselves up off the ground and seeking water and food. Most importantly, they move.

They move toward or away from certain stimuli. This ability to duck, dodge, dip, dive, and dodge is given different names according to the stimulus to which the plant is responding--collectively they are called tropisms. When a plant's leaf twists to face the light, we refer to that

as phototropism. When a plant's roots move toward water, we call that hydrotropism. When a plant is turned sideways and then rights its growing tip (even in the absence of light), that is called geotropism. There is also: thermotropism, your plant's response to temperature; thigmotropism its response to touch; chemotropism, its response to chemicals--you get the idea, lots of tropisms.

As a side note, thigmotropism refers to the way that vines wrap around poles and how roots move around rocks. But consider this: a vine responds by moving *toward* a pole while a root responds by moving *away* from a rock. One is positive thigmotropism, while the other is negative thigmotropism. Amazing.



So how does the plant make these moves? To make a long story short, the plant uses a hormone called **auxin** (which, in actuality, is a group of related hormones) plus light-sensitive cells to achieve its mobility.

Let's take phototropism as an example. When one side of a plant's stem is continually exposed to light while the other side is kept in relative darkness, the plant senses this and ramps up its production of auxin. It then transports the auxin to the darker side of the stem. When the auxin enters the dark-side's

cells, they respond by elongating. (At the same time the plant also decreases the pH levels of these cells in order to soften the tissue and make elongation easier.) This elongation causes the stem of the plant to bend toward the light. Once it has bent far enough to allow all sides to receive an equal amount of light, the auxin production will be inhibited and balance out, causing the stem to retain its new orientation.

In Summary: We can make plants do things by manipulating the release of auxins!

Cannabis Phyllotaxy

Why You Need to Know: You don't. It's just cool. Every now and then you see a seedling with whorled branches and it's nice to know what you're looking at.

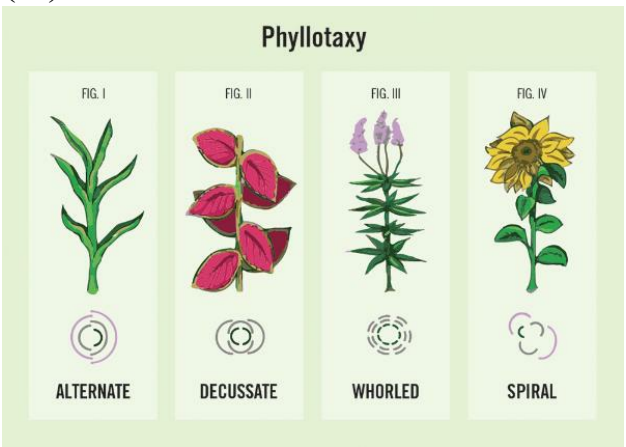
There are three ways in which cannabis arranges its branches on the meristem, the patterning of which is referred to as**phyllotaxy**. After your seed has sprouted and its two cotyledons have shriveled and fallen off, you will have two (or sometimes three) true leaves arranged opposite each other on the meristem and emerging from the same latitudinal position, called a **node**.

Subsequent leaves will branch off the meristem opposite each other at right angles to the pair below them. This is called decussate (or opposite

decussate) phyllotaxy (ii). When the plant ages and prepares to flower, the branches transition from appearing directly opposite each other to alternating positions (still on opposite sides), each above the last, growing from its own node. Unsurprisingly, this is called alternate phyllotaxy (i). After a plant has begun alternating, it remains that way for the rest of its life. Cuttings that have been taken from plants growing in alternating patterns, and placed under 24-hour lights, continue to exhibit this pattern.

Rarely, you may come across a plant that is growing three branches from the same elevation on the meristem. This is called whorled phyllotaxy (iii) and it may be the result of a either a genetic mutation or a physiological influence. Both can cause it and, though it is not a well-understood phenomenon, we do know that it is heritable in some

plants.[36] Plants exhibiting the whorled pattern will eventually alternate, too; except that instead of one branch appearing above and opposite the previous branch, they will rotate around the meristem at 120o phases, in a pattern known as spiral phyllotaxy (iv).



In Summary: Phyllotaxy is the name given to plant branching patterns. Cannabis can exhibit four of these patterns.

Trichomes

Why You Need to Know: Trichomes are the source of most essential plant oils and medicines and are, therefore, of great significance and human interest. For growers who wish to make hashish, knowledge about trichomes is indispensable.

The root of the word trichome is *trich* meaning "hair," and indeed, these outgrowths are the aerial analogue of root hairs. Both grow from epidermal cells and are exceedingly thin (in some plants, as small as one cell in diameter) hair-like appendages.[37] Esau defines trichomes as "epidermal appendages of diverse form, structure and functions... represented by protective, supporting, and glandular hairs, by scales, by various papillae, and by absorbing hairs of roots."[38] They take all manner of shape and size,

from simple spikes to branched things resembling plants upon plants to cannabis' familiar club-shaped ones.

Most plants grow trichomes. Plants that have trichomes are described as **pubescent**; plants that do not are described as**glabrous**. Not all trichomes exude essential oils. Cannabis is not special because of its trichome production; instead, its trichomes are special because of what they exude.

Have a look around the nursery next time you're in one. Check out the incredible diversity and prevalence of trichomes. Or, simply think of the last tomato plant you grew. Tomato plants are covered in them--even the tomato itself is covered in tiny trichomes. An old European bed-bug control strategy is to place bean leaves on the floor at wall bases and beneath beds. The bed

bugs climb over the leaves, impale their feet on the bean leaves' sharp trichomes and remain trapped until morning when they can be swept up and destroyed.[39]

Trichomes are thought to aid plants in arid environments by reducing the intensity of solar radiation,[40] thus enabling the plants to retain water;[41] for plants in humid environments, trichomes help by increasing the rate of water respiration,[42] providing a defense against herbivorous insect[43] and animal attacks, and by protecting the plant's epidermal tissue. Trichomes often produce chemicals that can be noxious smelling, attractive smelling, bitter, sweet, stinging, poisonous, sticky, or slippery, to name a few.

Why the marijuana plant produces trichomes that exude the sticky resin that contains THC and other

cannabinoids remains somewhat of a mystery. It is probably, in part, a defense against intense solar radiation and insects,[44] as anyone who has seen a plant glisten in the sun or has observed gnats trapped on buds can well imagine. That they produce a glistening, sticky exudate is not surprising; that they produce one that contains a chemical that fits into human anandamide receptors, however, is fairly astounding.

It is often said that once fertilized, female plants drastically slow down production of trichomes. I am not aware of any studies that have explored this theory, and I am equally unaware of any definitive explanations for the putative observation that seeded pot is weaker than unseeded pot. As I see it there are a few possible explanations for why this "trichome-growth-stops-after-fertilization"

heuristic may be what I call only functionally true.[45] All of my ideas follow upon the (rather banal and obvious) assumption that trichomes evolved to *serve the plant* in some way that assists it in its survival.

The first possibility is that trichome growth slows down as the plant itself matures and senesces. Plants that set seed die sooner than plants that do not; hence, plants that are frustrated in their attempts to set seed continue producing their trichomes, while plants that die young (having set seed) are cut short in their trichome-producing activity.

Another possibility is that the slowing of trichome production is secondary to relative age, which is indicated to the plant by the fertilization event. The distinction being that in the former suggestion, the production of trichomes occurs epiphenomenally to age,

whereas in the second, it is cued by age. The second idea suggests that, once fertilized, the need for plant defense (provided in part by trichome growth) diminishes as the time-to-success (fruit set) horizon is established. That, however, strikes me as counter-intuitive. If the purpose of producing trichomes is to fend off attacking insects, herbivores and solar radiation, would not seed set be the time to *increase* such defenses?

A third suggestion, proposed by Clarke some decades ago, follows along the lines of my first and second ideas (which I am not claiming are original). Clarke theorizes that hormonal changes, which are cued by the fertilization event, result in the cessation of trichome production[46] -- for whatever reason. It is well beyond my expertise to judge the merits or likeliness of such a mechanism, but

because this explanation is agnostic about evolutionary advantage, I find it unsatisfactory. It answers *how*, but evades the thornier questions of *why* (to what end) such hormonal changes might occur.

A fourth suggestion is that, perhaps in cannabis, the sticky trichomes serve--at least in part--to trap pollen. Holding pollen near the stigmas would be useful, and this would also explain the high concentration of trichomes on the seed calyx. Having completed the fertilization phase, the plant would no longer need to bother putting energy into trichome production. This idea is very similar to the plant-defense concept, but it follows more naturally upon the fertilization-event-as-cue idea. Sexual selection, rather than survival selection, in other words, may be the guiding paradigm. In any case, this is certainly an area that could use

further study.

By Indirectantagonist (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commonsght at en.wikipedia [Public domain], from Wikimedia Commons

Cannabis trichomes become brittle when dried or cooled, and the compounds they exude are hydrophobic; therefore, collecting them is a rather simple affair. Ice, or bubble hash, is made by separating the trichomes from the rest of the plant material by agitating whole plant tissue

in cold water and then filtering the broken trichomes through a fine mesh. (I have always found it ironic that fine-screened hashish commands a higher price than course-screened hashish. After all, when shopping for buds, big trichomes are favored. Why should this standard be turned on its head when shopping for hash?)

Cannabis has four kinds of trichomes, each differently shaped. These are stalked-capitate, sessile-captitate, bulbous and non-glandular trichomes.

The familiar mushroom-shaped trichomes that are often depicted in weed porn are known as stalked-capitate trichomes. These produce the magical, miracle molecules right up on top in the bulbous portion, right where our imaginations want them to be. The reason they are located up on stalks, away from the leaf, is because they

produce high levels of phytotoxic terpenes, which are poisonous to the plant itself. If they were produced on the leaf surface, the plant would succumb to its own toxins.[47]

There are also sessile-capitate and bulbous trichomes. **Sessile** simply means "fixed in place." When applied to trichomes or plants, it means "attached without a stalk." So sessile-capitate trichomes stick right to the leaf epidermis, while bulbous trichomes have only a few cells to act as a stalk. These trichomes also manufacture the cannabinoids, as well as lower levels of terpenes and more than 400 other chemicals.

The fourth kind of trichome that marijuana produces are non-glandular and do not manufacture chemicals. These are the**cystolith** hairs.

Note that while trichomes are the loci of THC production in the plant, this does not necessarily mean that lots of trichomes equates to lots of THC. Some plants use these structures to produce other compounds in varying degrees and THC production may be limited for a given strain, regardless of trichome production. You cannot determine, simply by observing high trichome density, whether you are dealing with a high-THC strain. However, without high-trichome density, it is unlikely that THC production will be high. Therefore, trichome density is not a dispositive guarantee of potency, but rather a limiting precondition for potential THC-content.

In Summary: Most plants have trichomes. Cannabis has four types of trichomes, three of which produce the miracle molecules we have all come to

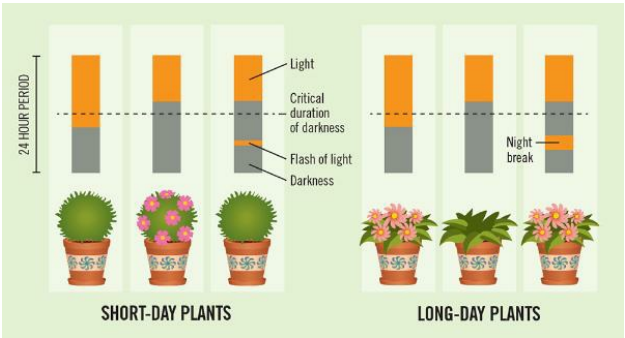
know and love. As important as they are, however, we do not know much about what function trichomes perform for cannabis nor how they are connected to its sexual machinery.

Light Response

Why You Need to Know: Length-of-night determines flower-set for cannabis. Unless you have a grasp of this fundamental aspect of marijuana physiology, you will fail, to some degree, in your endeavor to grow weed. While it is not necessary to fully understand all of this, it does make for interesting reading.

You were probably taught that when you reduce your plant's light period (**photoperiod**) to 12 hours or less, your marijuana will begin to flower. This is functionally, but not factually, correct. Cannabis is what is commonly called a **short-day** plant. However, this is a misnomer, because what cannabis (and all other plants that flower by day-length) responds to is not duration of light, but rather, duration of uninterrupted darkness.

Cannabis is a **long-night** plant, not a short-day plant. When the length of contiguous (uninterrupted) darkness equals or exceeds 12 hours (this varies somewhat by strain), then the plant begins to flower.



This is not just splitting hairs. The plant has two phases, the **photophile** phase, which is induced by the presence of light, and the **photophobe** (or **skotophile**) phase, which is induced by darkness.

This is an example of something you already knew, but perhaps didn't know you knew. Allow me to prove it to you:

You would not have a problem shutting lights down during the photophile phase if you needed to relocate a ballast or change a lamp, for example; but would you flip the lights on during the skotophile (dark) phase to show your plants off to your friends? No, you would not. You know not to do this, so you know that contiguous periods of uninterrupted darkness are critical to your plants' flowering mechanisms, whereas contiguous periods of uninterrupted light are not.

Interrupting the skotophile phase stops the plant from flowering. Interrupting the photophile phase does not stop flowering. Why?

To understand how this works it is useful to first know the history of how we came to recognize this mechanism. It's an exciting story (in that it has only recently been concluded), and an

interesting one (because of how the mechanism was first deduced to exist).

Imagine you are raising chrysanthemums for sale. Say you planted one plot of mums in April, another in May and still another in June. Late August rolls around and your plants all begin to flower in unison. What's going on here? They cannot all be using the same **endogenous** signal to flower. There must be an **exogenous** cue, meaning the plants are detecting something in the environment. What is the cue, though? Temperature? Light color? Daylength? Plant age? Perhaps all four? Well, it turns out it can be any combination of these cues, depending on the plant species. We are going to remain focused on the only factor that matters to cannabis husbandry: photoperiod.

Way back in 1920, a couple of USDA scientists by the names of Garner and Allard were playing around with a mutated strain of tobacco called Maryland Mammoth. Maryland Mammoth was different from all other tobaccos in that it would not flower during the summer, but instead waited all the way until December. The two scientists discovered that they could induce Maryland Mammoth to flower earlier by subjecting it to artificial light and reducing daylength. They hypothesized that the reduction in light signaled the release of a chemical compound that in turn induced flowering.[48]

Following up on this research in 1937, an American-Russian scientist named Mikhail Chailakhyan determined that this flower-inducing chemical--which he dubbed "**florigen**"--was located in the leaf, because he was able to induce

flowering in a non-flowering plant by using leaf graft.[49] A leaf graft from a flowering plant could be donated to a non-flowering plant and cause the non-flowering plant to commence flowering. Moreover, since flowering begins in the plant's meristem tips, he deduced that florigen must be transported through the leaf and through the stem, all the way to the growing tips of the plant.

If that's not complicated enough (and trust me, I am simplifying this as much as I can while still holding the scientific narrative together) there is a second half to the flowering mechanism story that is necessary for you to know. It has to do with light spectrum and the flowering response.

There is a group of five light-sensitve pigments in plants called **phytochromes**. They respond

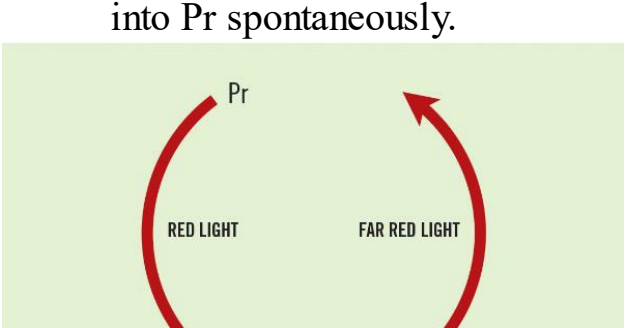
chemically to light. Two forms of phytochromes are used for growth regulation and signaling. One form is sensitive to red light (in the 660 nm wavelength) and another is sensitive to far-red light (in the 730 nm wavelength). They are known by shorthand: Pr and Pfr. The two forms or**isomers** convert rapidly from one to the other. Pr converts to Pfr when it is struck by red light. Pfr is converted to Pr when it is struck by far-red light. In the dark, Pfr converts back into Pr. Those three rules make for a simple but fascinating mechanism for regulating plant growth. This mechanism is what is referred to by plant scientists as the Hourglass Model.

To recapitulate the rules:

- Pr converts to Pfr when it is struck by red light.

- Pfr is converted to Pr when it is struck by far-red light.

- In the dark, Pfr converts back into Pr spontaneously.



Like much of the light in the green range of the spectrum, chlorophyll does not use far-red light, which is outside the range of light it can use. White light--sunlight, for example--contains ALL spectra. Thus: Plants are getting both red and far-red light during the daylight hours. Far-red light passes through leaves (but is detected by Pfr). Red light is absorbed by leaves and is

detected by Pr. Pr is being converted to Pfr and back again all day long. Therefore, Pr and Pfr are in a state of constant equilibrium during the day when the plant is exposed to sunlight.[50] When the sun sets, Pfr converts to Pr. When the sun rises, this situation returns to equilibrium.

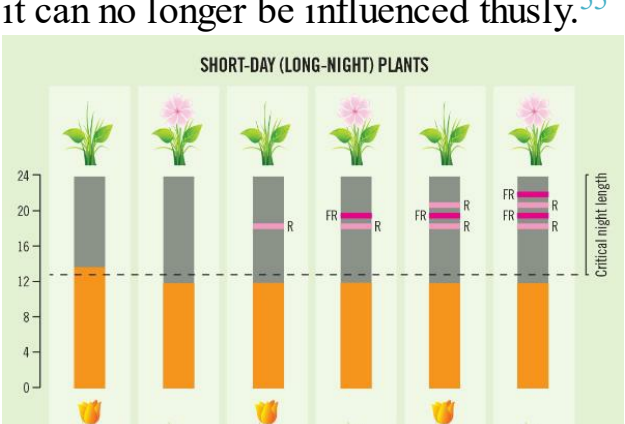
In the 1940's it was discovered that a flash of light during the skotophile phase prevented flowering in short-day plants.[51] [52]What this tells us is that the length of uninterrupted darkness is critical, not length of light. Thus, scientists deduced that florigen is created by long-night plants during the skotophile phase and that it degrades during the photophile phase, which explains why interrupting the photophile phase is not harmful but interrupting the photophobe phase is.

More experiments were conducted--

this time, using different light colors. It was then hypothesized that red light during the skotophile phase will convert the newly (and spontaneously) created Pr back into Pfr instantly, and prevent the plant from flowering.[53] But--and here's the kicker--a second flash of light (this time a far-red light so that the plants are exposed first to a flash of red and then to a flash of far-red during the dark period) will undo the damage! In other words, the far-red flash corrects the first interruption. (The lag time varies by species.)

In fact, you can do this as many times as you like. If you finish with a flash of red light, long-night plants will not flower (but short-night plants will). If you finish with a flash of far-red light, long-night plants will flower (despite the interruption), but short-night plants will not.[54] Called **photoreversibility**, this phenomenon does have its limits.

If too much time elapses between flashes, the plant is said to have "escaped from photoreversibility" and it can no longer be influenced thusly.[55]



While this certainly implicates phytochrome as germane to the induction of flowering, there's a fly in the ointment. The Hourglass Model fails to account for another bit of evidence that was discovered: At night Pfr converts back to Pr completely in about two hours. Think about that.

Why, if that conversion is completed in only two hours, does a long-night plant need, say, twelve hours of uninterrupted darkness in order to flower? It was a puzzle. Here are the clues we have so far:

1. Whatever is causing plants to flower is transmissible from leaf to plant tip (as was established by the grafting experiment).

2. Length of night is critical (as was proven by the light flash experiments).

3. These two phenomena are interrelated.

4. Because all Pfr converts to Pr in about two hours at night, and we can mess around with it and still have the plant "think" it is experiencing our choice of photoperiod, the phytochromes

are part of the mechanism, but not in-and-of themselves the entire flowering mechanism.

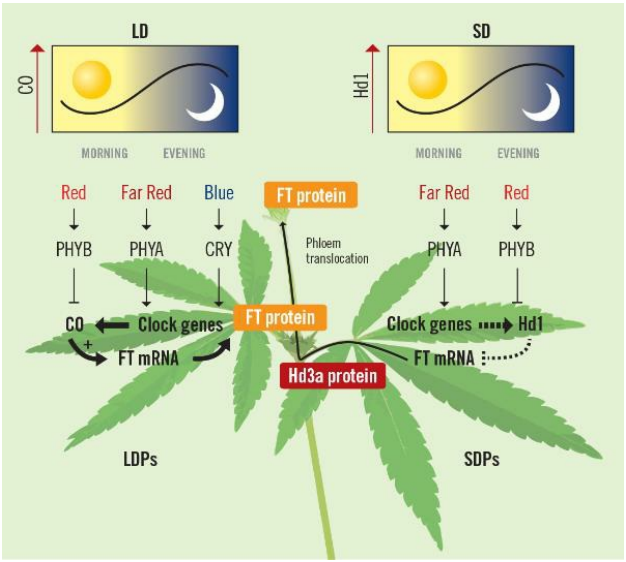
5. Lastly, we know that phytochromes do not move about the plant; instead, they are either setting off a reaction, or they are regulating one.

The Hourglass Model, in combination with the red and far-red light experiments, strongly suggests that the phytochromes set an endogenous chemical clock each photoperiod, to which the plant responds when the darkness-timer crosses a certain threshold.

What is happening is that the Pfr/Pr mechanism is setting a clock--called a **circadian** clock, or circadian rhythm ("circadian" meaning "circa diem"-of or pertaining to a 24-hour period).

This signals the plant to produce florigen when the clock hits a certain threshold (and in some plants, it is accurate to the minute), which, in turn induces flowering.

Now, when I finished that last sentence by writing "...in turn induces flowering," I was using shorthand for a series of events that you don't want to read about because you would be reading agonizing sentences like: "This long-day-dependent activation of FT requires CO, which is a zinc finger transcriptional regulator containing two B boxes and a CO, CO-LIKE and TOC1 (also known as APRR1) domain (CCT domain) CO probably activates FT transcription by directly interacting with the FT promoter."[56] The point is: It's a complicated mechanism, but scientists finally figured it out.



Note: Cannabis is a Long-Night Plant (SDP).

After almost 70 years of additional research, it turned out that Chailakhyan's hypothesis was correct. In 2005, the mysterious substance, florigen, was finally discovered to be the RNA component of a gene known as FT and this was declared to be*Science Magazine's* "Discovery of the Year"[57]...

and then that discovery was retracted in 2007[58]...

and then florigen was found to be a protein of the same FT gene later that same year![59] [60]

In Summary: Your plant flowers under conditions of uninterrupted darkness--12 hours is sufficient. A flash of light, even for just 30 seconds, will disrupt the flowering process. However, if you do accidentally flash your plants, a final flash using light with a 730nm wavelength will make things okay again.

SECTION 2: LET'S DO THIS ALREADY

The Grow Space

We are focusing on achieving a big yield in a small space, so space is a critical issue. Too little space and the plants won't thrive; too large a space and disease can take over unnoticed. I would prefer that you to grow in a 4'x8' tent, but will assume you only have space for a 4'x4' tent, or are growing in a closet space.

Please do not grow in a smaller space and expect to get the same results. If your space is a tent, you're pretty set; if it is a closet, you have some prep work to do. You should have about 6 feet of vertical space (height) and the room should be either sealed airtight (if you intend to supplement CO_2), or be well-ventilated with fresh air (if you do not). I strongly suggest you use CO_2. We will cover that a bit later on in the book.

If you are growing in a closet, first paint the walls white. It doesn't matter if you use flat or glossy paint; just use whatever is cheap. White paint is nearly as reflective as Mylar but it makes for a quieter room and does not conduct electricity like Mylar does. Furthermore, when the walls get dingy, you can simply treat them with a fresh coat of paint.

Once the paint is dry, you will need to seal the room as best you can if you intend to use CO_2 supplementation. (And I strongly recommend that you do.) Sealed means you can feel the air push back when you close the door. Be particularly careful not to leave any gaps at the bottom of the door, as CO_2 is heavy and will leak more from here than it will from a gap at the top of the door (though I am not forgiving gaps there either). Take your time and cut a piece of door-jamb weather stripping

that fits as closely and perfectly as you can manage.

Next, waterproof the floor. It should be able to handle the presence of big puddles--puddles are an inevitable part of the growing process.

Provide inflow and exhaust vents for your ducted light(s). In a tent, these are already built in. In a closet, you will have some minor construction-work on your hands. Try to avoid bending the duct-work too much, as bends are inefficient in terms of air flow. If you cannot avoid bends, then do what you have to do and move on. Six-inch ducts are ideal, but I have no problem with using 8" ducts for bigger setups.

Secure the room by making sure that entry to it is lockable.

Have lots of outlets or several power strips mounted up off the floor where

you can easily reach them. Take the time to calculate the proper amperage for the room. A good rule of thumb is five amps per 600-watt light, per plant. Leave yourself some overhead (10-percent is reasonable) and check your wire gauge (see below). If you have a 20-amp circuit, consider the maximum to be three 600-watt lamps/plants. That leaves room for running pumps, heaters, a small cloning operation, regulators, etc. If you have any doubts about this, consult an electrician. Seriously.

After I published the first edition of this book, an acquaintance of mine who is an electrician sent me an email that I think helps to clarify things. Take his advice; it can save your home and your life.

For the uninitiated: A = amp, AWG or G = American Wire Gauge/Gauge

(where smaller numbers equate to thicker wires) and W = watt. The names and their abbreviations are used interchangeably here.

Here's what my electrician friend wants you to know, in his words:

According to the 2011 NEC - AWG 14 is rated for 15 amps, AWG 12 is rated for 25 amps, and 10G is rated for 30 amps (solid copper).

A lot of houses aren't properly wired for whatever breaker it has, also we haven't taken into account the % of efficiency of the ballast/light fixture. I worry and I have seen it - a 20 amp breaker or 30 amp breaker on a strand of 14G wire. Then some numb-nuts tossing a whole operation on one circuit... Poised for failure.

I always, when doing wiring, give an appliance (the ballast in this case)

90% efficiency (even though I know some are better and some worse). What this means is for a 1000W device you'll be adding 10% to that number--or 100W, and for the 600W device add 60W (1100W/660W, respectively).

That makes a 600W device run at 5.5 amps and a 1000W @ 9.166 amps.

One of the other big deals is how long the wire run is. Also how many other things you have running on the wire-fans, water pumps, air pumps, ambient lighting, etc. All of these factors make it difficult to offer "one-size-fits-all" instructions for wiring situations.

The main problem I have with the wiring is the safety factor. Yes a 14AWG wire is technically rated at 20A - but you NEVER want to run a wire over 75% of its rated load. It can and will get hot and potentially burn

up.

Figure: I used to run 2 x 1000W ballasts and, for the argument, they equal about 18amps (technically under the 20A limit of 14G) - however, you can damn near melt the insulation off of them with the heat that they're making. 12G isn't much better. I run 10G on a 25-30A breaker to run 2 x 1000W's. (The wires stay nice and cool and I have no worries about burning my home down.) It is, however, a bit more expensive, but I feel it's worth the extra $20-$30 to make sure I'm not homeless.

Like I said before, when in doubt, call in a pro!

Temperatures in the room must be kept in check. You cannot have a room that is too cool or too hot. Both extremes will impede growth and yield. Ideally,

you will want to keep your grow-room between 70o F and 86o F (21o-30o C).

Also, do not add moisture. A common error amongst new growers is to put a humidifier in the room with the plants. Cannabis does not like to be wet. Adding moisture to your room will only result in your fighting powdery mildew and botrytis fungus (bud rot) before you know it. You will more than likely need to remove moisture with a dehumidifier--the plants add that much. Portable air conditioners are nice in that they also serve to remove moisture. In a garage or an uninsulated space, a small heater may be necessary. Do not skimp on thermostats. The cheap orange duct units sold at grow-stores are inadequate. You will need a more sensitive unit that can hold temperature within a 10o F range (+/- 5o).

In Summary: This book describes how to do a small home grow, in either a 4'x4' or a 4'x8' space. Choose an appropriate tent, closet or small room in your house. If using a small room or closet, paint the walls white, and then seal, waterproof it and secure the space. Provide for air flow and adequate electricity. Make sure that you can keep the temperature stable.

Equipment Lists for the Systems in this Book

Why You Need to Know: It is important to have the right materials on hand when you set up your space and begin growing your plants. Different grow methods will require different equipment.

While there are many ways of growing plants--and many of them are effective--there are three that I believe yield better result than all the others and which I will cover in detail in this book. They are: deep water culture, a style of hydroponics; growing in soil, also known as geoponics; and a hybrid technique I call duoponics. Each method has its own merits.

Deep water culture (or DWC) will allow you great freedom as you can leave the plants for several days and

still come back to healthy, happy plants. Growing in soil will be the easiest method for the beginners because it is harder to destabilize from a nutritional point of view--provided the plant has enough soil, that is. Duoponics combines the benefits of both hydroponics and geoponics. Once you understand each method better, you can choose which one you prefer. I hope you will try (and master) them all, because doing so will make you a better grower.

Below I will list first the equipment you will need regardless of which method you choose and then the equipment necessary for each individual method.

Common Items Equipment List

(4'x4' Room / One Plant)

- One 6- or 8-inch ducted

reflector. It doesn't matter which size you use, so long as it seals and is ducted. I personally do not like the ultra-wide reflectors, as I prefer a more focused pattern.

- Ten feet of 6- or 8-inch ducting. Use the good, insulated stuff.

- Aluminum-foil tape. You cannot use duct tape as it, ironically, will not stick to duct metal.

- One high-pressure sodium lamp

- One thermostat (to control your duct fan)

- One centrifugal duct fan. A 6" fan is much less expensive than an 8" fan; this should be a consideration when deciding between 6" or 8" reflectors.

- One pedestal fan
- Two power strips
- One big-ass bag of long zip-ties

Optional Common Equipment List

- One CO_2 cylinder. You would be best off going with a 50-pound aluminum cylinder. Twenty-pound cylinders empty too quickly, steel is too heavy, and there's usually economy in volume when refilling a 50-pound tank. Sorry, these cylinders aren't cheap. It is less-expensive to buy them at a soda wholesaler than at a grow store, though.
- One CO_2 controller ("sniffer")
- One CO_2 solenoid valve

- Standard blue air tubing

Growing in Soil Method Equipment List

- One #10 plastic nursery pot. See note below.
- Enough pumice/lava rock to fill three to four inches of the pot.
- Soil

Note: When is a gallon not a gallon? When you're buying nursery pots. For some reason, the nursery-pot industry continues to operate out-of-compliance with a 1971 law requiring uniform measures. As such, the term "gallon," when applied to the nursery pot trade, does not correspond to the volume of an English gallon. Further complicating the situation, the "#" notation does not seem to be based on any consistent reference point either. What I mean

when I refer to a #10 nursery pot is one that is roughly eight real gallons.

Deep Water Culture Equipment List

- Two 5-gallon black buckets
- One bucket lid
- Two 1-1/2-inch Uniseal(R) pipe-to-tank seals
- One 18-inch piece of black PVC pipe
- One 2-3/8" hole-saw. This should be multi-toothed, and not of the wood-saw variety.
- One 6-inch bucket-lid-style mesh pot
- One heavy-duty air stone
- One two-hose or four-hose air

pump

- Standard blue air tubing
- One 4- x 4-inch rock-wool cube, drilled. I prefer to use Cultilene(R) cubes because they do not require pH'ing before use. You are only dealing with one or two plants, so buy your plants started in rock wool.
- One PPM pen. A cheap one will do, just make sure it has temperature compensation.
- One pH pen. Again, a cheap one will do, just make sure it has temperature compensation.
- Plant nutrients

Duoponics Method Equipment List

- Two 31-gallon opaque

Rubbermaid(R) Roughneck(TM) tote bottoms (Item #2244). You do not need the lids. Off-brands are fine as long as the shape conforms to the Rubbermaid. Pictured later is Home Depot's(R) own brand.

- Two 4"-diameter PVC pipe T's
- One utility knife
- One 8-inch bucket-lid-style mesh pot
- One heavy-duty air stone
- One two-hose or four-hose air pump
- Standard blue air tubing
- Four 5-foot stakes--preferably metal U-fence stakes

- One 4' x 4' roll of turkey-wire fencing
- Bailing wire
- 4 cubic feet of great potting soil (4 cf = 30 US gal)

Pros and Cons...

Each of the different growing methods that I will be detailing in this book has its own pros and cons. These factors can play a large role in your decision about which you favor. The pros and cons as I see them are:

Deep Water Culture (DWC) Method of Growing

Pros:

- Easy cleanup involving little waste

- Elegant
- Once set up you can walk away from your plants for a week if necessary

Cons:

- More complicated setup
- Requires more tools and a longer, more costly equipment-list
- Supplies only the necessary nutrients to the plant, excluding all the things that go on in soil such as mycorrhizal fungus/root symbiosis and stuff we don't even understand yet
- Dumping nutrient down the drain is not a sustainable practice
- Warm weather can create

pythium problems

Soil Pots Method of Growing

Pros:

- Uncomplicated if buying a competently mixed product in a bag
- Simple set up
- Short equipment list
- Consumers perceive soil grown as "clean" and wholesome
- Soil is fascinating to study and learn to get right
- Natural, as plants evolved in this medium
- You can add spent soil to your vegetable garden

Cons:

- More prone to problems with fungus gnats
- Messy cleanup involving more waste (you have to do something with the spent soil)
- Requires more frequent watering
- You must keep an eye out for nutrient deficiencies and pH issues
- May require mid-flower potting up to correct nutrient problems

Duoponic Method of Growing

Pros:

- Less costly than DWC

- Short equipment list
- Consumers perceive soil grown as "clean" and wholesome
- You can add spent soil to your vegetable garden
- Low-maintenance

Cons:

- More costly than growing in regular soil pots
- More prone to fungus gnats
- Messy cleanup involving more waste (you have to do something with the spent soil)
- Must keep an eye out for nutrient deficiencies and pH issues

Which Lamp?

Countless hours (and dollars!) have been wasted discussing which is the best lamp and the perceived differences between the available technologies, wattages and brands available. I know because I myself have argued and tested the merits of many more than I care to admit. In this section, I will give you the skinny on lamps. For a detailed explanation of how light is measured, what all the terms mean (and maybe even how to win an argument about lighting) please see Section 3: Measuring Light.

Metal halides (MH) are good lamps, but in my opinion they are second to **High Pressure Sodium** (HPS).The overall color emitted by MH lamps is great--for people. For plants, they are okay, but when compared to HPS, the MH are lower in the critical orange

range, and the extra radiation in the blue does not compensate for this difference.[61] There is simply more**Photosynthetic Active Radiation** (PAR) to be had with a good HPS than with a good MH.[62] Likewise, switching between lamps from halides to sodiums (veg/flower) does not strike me as being efficient for the home grower. The gains, to the extent that they are even there, do not justify the added cost.

The secret here is that plants only need about 7-percent of their light to come from the blue end of the spectrum in order to prevent growth dysfunction.[63] HPS lamps provide at least this much. I also hasten to add that the mid-market lamps are every bit as effective as the high grade lamps. Don't be overly concerned about lamp spectrum and don't spend an arm and a leg for "the best." Above a certain level, all you

pay for is advertising.

In the previous edition of this book, I strongly recommended the use of 600-watt HPS lamps for their efficiency. I still prefer HPS lamps for this reason, but new evidence leads me to instead recommend 1000-watt HPS lamps. A small but well-constructed study was conducted to test levels of **Photosynthetic Photon Flux Density** (PPFD) and cannabis growth rates,[64] and the results have led me to the conclusion that an increase in light intensity is, in fact, warranted.

This study found that a PPFD of approximately 1500 µmol m^2s^1 is optimal.Though these results are from only one small study, I feel that you can benefit from knowing about the increase in net photosynthesis under stronger PPFD. Importantly, keeping temperature at or below 30o C (86o F)

at this light intensity is *crucial* because temperatures above this level will reduce net photosynthesis dramatically.

What is 1500 µmol m^2s^1 in terms you already understand? For HPS lamps, a conversion factor for PPFD to **lux** is 82.[65] So 1500 X 82 = 123,000 lux.

Lux is a measure of **illuminance** per unit of area, so we need to convert from **lumens**, which we all (for better or worse) use when shopping, to lux in order to see if our lamp matches our needs (see Section 3: Measuring Light.) To do this, understand that 1 lux is equal to 1 lumen *as it hits a surface area of 1 m^2*. Lumens are measured at the source and are the amount of light radiated (**luminance**). Lux is measured at the thing illuminated (irradiated by visible spectra) and is divided over area.

Immediately, you can see that holding your surface area to 1 m² will allow you to use the lumens rating as an exact lux equivalent for that area. Recall, also, that we are growing in an area only slightly larger than 1 m². How convenient! This is useful as a mental guide for on-the-fly math at the hydro shop.

A typical 1000-watt HPS lamp is rated at around 140,000 lumens--more than what is called for; but since we are growing in an area greater than 1 m, this is okay. If we adjust our area up to about 3'6" x 3'6" we get what we want: about 123,000 lux! Boo-yah!

I still advise the use of 600-watt high pressure sodium lamps for those who are on a budget, trying to keep a low profile or simply appreciate the moderation of using 600's.

LED's

Standard lamps, as you know if you have ever touched a lit incandescent light-bulb, do not produce light efficiently. Electrical efficiency is the percent of useful power output per power input. If what we put in is electricity and we want out is light, we do not want to also get a lot of heat. Lots of heat means that the electrical efficiency is low. A 1000-watt lamp, whether HPS or MH, emits about 3000 BTU's, which is indicative of its overall inefficiency. (However, these types of lamps are quite efficient relative to other conventional lamps, such as halogens, which are the least efficient choice.)

What has always been promising about LED's is their efficiency in producing only the band(s) of radiation that you need. Gone are the greens and other

wavelengths that plants cannot use effectively. Additionally, they cut down on heat output, though they do not run cool--not by a long shot. LED's still produce a lot of heat, but nowhere in the same neighborhood as a conventional lamp. A 1000-watt "equivalent" LED consumes approximately 600 watts, which saves you 40-percent in electricity usage. This is particularly helpful for those growing in stealth situations.

The newer LED lamps are of quite good quality, and, if you can afford them, may be worth considering. I have grown to believe that a well-made LED lamp can be a worthwhile investment for some growers. If you are a commercial grower, I strongly advise that you take a hard look at phasing in LED's. I have provided Total Cost of Ownership and Time-to-Payback calculations in Appendix III:

Useful Information. A $1000 investment in a quality LED lighting-unit (to replace a conventional 1000-watt HPS lamp) has the potential to pay you back in full though electricity savings within approximately three years,*assuming you run contiguous grows* for that period of time. I use a 90-day cycle as one grow period (on 24-hours a day for 30 days; on 12-hours a day for the next 60 days), which is one quarter of a year, so adjust accordingly. If you only grow once a year, this quadruples your payback period to 12 years, and in such a case, the high initial costs are not worth the end results.

Another consideration when it comes to LED's is quality of radiation. Recent tests show that HPS-grown plants produce greater overall biomass than those grown under LED's.[66] The difference is small, however, and I feel

that the grower's savings in energy more than make up for this difference. Also, I am willing to accept manufacturers' reports that there have been significant advances in LED technology since the early 2000's when NASA scientists studied their effects on plant growth.

Interestingly, these scientists also discovered something rather surprising: adding green LED's to the array of diodes actually improves plant growth. (Insert perplexed pause here.) Yes, that's right. Green increases growth.[67] [68] How can this be? Don't we *know* that green light is rejected and reflected by plants? The researchers explain:

Although the chances of green wavelengths being absorbed into the photosynthetic apparatus is small, the wavelengths not absorbed are

repeatedly reflected from chloroplast to chloroplast in the complex network of photosynthetic cells. With each reflection, a small percentage of those wavelengths is absorbed, until finally half or more are absorbed by most leaves and are used in photosynthesis.[69]

When scientists first studied the wavelength-absorbing properties of plant pigments, they did so in-vitro, not in-vivo. In a flask, this bouncing around (and ultimate utilization) of wavelengths does not take place. In leaves, however, it does. Did you know that? Neither did I. I bet the LED designers don't know this either.

If you choose to purchase LED lighting, you should look for high-quality internals and a company that has been around a while and is willing to stand by its product. Often,

individual diodes go out, so look for a unit in which these are replaceable. Also, ask for laboratory radiation bandwidth tests. You know what to look for: graph peaks at 390-500 nm and at 600-700 nm. Plus a few diodes tuned to the UV-B; and, yes, green ranges may help with potency.[70] [71]

Of course, as good as lighting technology is getting, the sun is still the gold standard!

600 Watt HPS: The Efficient Lamp

For some reason, lamp choice is one of the most contentious issues among growers. My advice: buy a good lamp--not a bottom-of-the-barrel brand--but don't break the bank. You just don't need to. As for the 600-watt vs 1000-watt debate, look at this real world comparison: 600-watt lamps come in

at around 90,000 lumens whereas 1000-watt lamps usually emit about 135,000 lumens.

3 x 90,000 = 270,000 lumens at 1800 watts

2 x 135,000 = 270,000 lumens at 2000 watts

By using 600-watt lamps, you are saving 10-percent on electricity!

Not so relevant for a home-grow, but a big deal in a commercial grow. We are going to SCROG these plants, so light penetration depth is even less important, meaning that the 600-watt lamp is still your best budget choice.

Ceramic Metal Halides (CMH)

Simply put, I'm excited about this technology. These new bulbs are available in 315 watts (Philips Elite

Agro(TM)) and the growers I know who have tested them like the results they are getting. From what I have seen, their efficiency is excellent and their spectrum is quite good. I think that the total PPFD is low, but a boost to in wattage would fix that problem. Watch for this technology to eclipse HPS in the near future as your best all-around choice.

CO_2 Sniffers

You can buy one for as little as $150, or spend as much as $600. The only advantage I see to the more expensive ones (and I have used nearly every brand) is that they typically allow you to turn the ppm to a desired limit, whereas the cheaper ones are often preset at around 1400-1500 ppm--which is much higher than it needs to be.

The more expensive units can save you gas-money and hassle when it comes to refills, but it will take you a long time to pay off the added expense of buying them. I use the cheap ones in small spaces, and the more expensive ones in large spaces for that very reason.

Your CO_2 sniffer should have a photo-switch that turns the unit on when the lights are on, and off when they are not.

That way, you will not be enriching during the skotophile phase--which is a waste of CO_2.

For in-depth detail about CO_2, please see Section 3: CO_2.

Soil Selection

Have I mentioned that I own Scientific Soils? Well, I do. Yet I grow in both soil and hydro because I think that each has its place. When I was in the medicinal-marijuana business, I was growing thousands of plants. I wanted to take the labor out of soil mixing, so I refined my recipe over many, many generations and had a professional mixer blend it for me.

The result is my Scientific Soils Professional Growers' Mix, a just-add-water product that is mixed under computer control to tight tolerances and is--I can say without hesitation--the highest quality, most nutritionally dense mix available on the market. This product is the only one of its kind that is truly designed for cannabis cultivation by cannabis growers. Use your favorite mix, use my mix, or mix

your own. I am including a great recipe for mixing your own soil at home later on in the book. Whatever you use, just be sure to use enough.

Nutrient Selection

Don't sweat this. I like General Hydroponics(R) original 3-part in the pink, green and brown bottles (you need them all.) When deciding which to purchase, remember: plants do not care if the nutrients are synthetic or organic, only people care.

If you are a commercial grower, keep in mind that people want to buy soil-grown more than hydro-grown. They see soil as clean and hydro as "chemical." There is no scientific or horticultural basis for this, but that's how it is. They will even tell you that they can taste the difference (which is nonsense).

Since with a small grow, you are likely growing for yourself and your close friends, marketplace considerations are less important and shouldn't matter

much. Just do whatever makes you most comfortable.

In Summary: Make the decision between soil and hydro, and then get shopping!

The Environmental Variables

Why You Need to Know: I don't want to alarm you, but it is possible to mess this up in a lot of different ways. The way to avoid messing up is to first have a solid grasp on what it is you are doing. Your task is to maximize the growth of your plant(s). That means you must be able to identify and control the variables.

This seems obvious to some, but a surprising number of growers I talk to don't have this down. There's no shame in not knowing this, and you shouldn't get too concerned about knowing them all by memory, but there is power in knowing what the variables are. The six variables you should be concerned with are: nutrition, media pH, air, temperature, water and light. So let's review each of them in detail.

Variable One - Nutrition

There are 19 nutrients that are necessary to the growth of a plant. They can be divided up into non-mineral macronutrients, primary macronutrients, secondary macronutrients and micronutrients.

Nutrients from Air and Water (non-mineral macros):

Hydrogen (H)

Carbon (C)

Oxygen (O)

Primary Macronutrients:

Nitrogen (N)

Phosphorus (P)

Potassium (K)

Secondary Macronutrients:

Calcium (Ca)

Sulphur (S)

Magnesium (Mg)

Silicon (Si)

Micronutrients:

Chlorine (Cl)

Iron (Fe)

Boron (B)

Manganese (Mn)

Sodium (Na)

Zinc (Zn)

Copper (Cu)

Nickel (Ni)

Molybdenum (Mo)

You are not going to be able to control each one of these nutrients individually (and it's usually not wise to try), but you will be able to supplement them en masse if the need arises. In hydro setups, this is a non-issue because the nutrient manufacturer will have already balanced this for you. In soil setups, although you might expect the same to be true, as a soil-mixing-industry insider I can assure you that that is not always the case.

Soil growers need to pay far more attention to avoid the presence of nutrient deficiencies than do hydro growers. I will cover the most common nutrient deficiencies and nutrient problems in a later chapter. For now, be aware that there are 19 essential

elements, 16 of which can be provided and supplemented by you.

Variable Two - Media pH

Related to the previous variable, pH functions as a mechanism for releasing or sequestering various nutritional elements. So, you can modify these nutrients simply by adjusting the pH. Plants take up nutrients by way of ion exchange. The biggest concern in this regard is water and media pH. A pH between 6 to 7 is ideal. A little more in either direction isn't a crisis.

Whether you are a hydro or soil grower, this is something to you should be aware of, but not something you should spend a lot of time worrying about. Many growers waste too much time playing around too much with pH!

Test your tap water for ppm and pH a few times over the course of the year.

If it's below 50 ppm and the pH is around 7, you can relax. Do not worry about R/O, and do not add "up" or "down" chemicals; just forget about it.

In soil, what you need to watch for is a drop in pH around the middle to end of the flowering period. This can be corrected by watering in a little dolomitic lime. If you use rock wool, be aware that some brands, such as Grodan(R), require an acidification soak before use. For this reason, I prefer Cultilene(R) because it does not require pretreatment of any kind.

Make Slow Adjustments in Soil

Soil growers: Soil pH is a tricky business. It is hard to test accurately and it is a moving target, so take your test results with a grain of salt. The plant itself is constantly changing the pH of your soil--as are bacteria, fungi,

decomposing manure and a hundred other things we are only recently beginning to discover and understand.

You could send three samples from the same bag to three different labs (or the same lab, for that matter) and get three different results back. Maybe one sample had a bigger chunk of peat while another got a little more lime. You can do the same experiment at home. In fact, you should do this experiment and average the results--every time you test for pH. Doing so helps to eliminate some of the error.

How to Check pH

Using distilled water, bring your soil up to field capacity (the point at which it saturates and water begins to run out of it). You can do this by using a metal strainer (stainless steel) and slowly adding water until it begins to drip.

Then dip your testing device into the water/soil paste and take a reading. Record your reading, rinse your container and repeat with a fresh sample. More often than not, if you have a nutrient problem, soil pH is the cause. Adding nutrients to soil that is at the wrong pH will only compound your problem. Be sure to always test your soil pH before you add what you think the plant needs.

Once you have made an adjustment to your soil pH, give it some time. You should notice a subtle improvement in about four days, with noticeable correction beginning at about day seven.

Variable Three - Air

Air is as much a plant-growth variable as it is a mechanical issue. Keep it moving. Add CO_2 if you can afford to;

introduce fresh air if you cannot. Do not humidify and do not allow for temperature extremes. Pot performs best when air temperatures are between 77o - 86o F (25o - 30o C), depending on the strain. By "performs best," I mean achieves its maximum rate of photosynthesis. [72]

Carbon dioxide supplementation is a great, if expensive, addition to your grow. I realize that the initial costs are high, but the increase in plant performance is spectacular. As with nearly everything related to growing, there is a performance curve associated with CO_2. You want to hit the peak of the curve. Overshoot and you waste gas; undershoot and you miss growth potential. When a plant drops below ambient CO_2 of about 400 ppm, its growth slows down. This means that it is critically important to introduce fresh air if you are not

supplementing CO_2. It also means that even a little bit of CO_2 added to the room can ensure against dramatic performance declines--even if you aren't aiming to hit the top of the growth-performance curve.

The conventional wisdom is that you should set a target of 1500 ppm. I realize that I am stabbing a sacred cow here, but I think that this is wasteful. Furthermore, it is unsupported by the scientific literature. (Please see Section 3: CO_2) In my experience, you hit peak performance gains at around 900-1100 ppm. After that, the gains are incremental at best, and the waste of CO_2 begins to exceed the performance value. Can I support this argument with evidence from scientific journals? Unfortunately, plants differ greatly in their use of CO_2 and ours is not a commonly studied one. I have been able to find one study that supports the

use of CO_2 and gives us a glimpse at the performance curve, but it never tests at concentrations above 700 ppm.[73] (That study is covered in detail in Section 3: CO_2.) What I *can* tell you, having written checks to the gas dealer and weighed yields at harvest time, is that my peak was at about 900-1100 ppm. Take that for what it's worth: my (definitely unscientific) personal observation.

Variable Four - Temperature

Air temperatures should be between 70o and 86o F (21o to 30o C) for enriched rooms, and between 70o and 80o F (21o to 27o) for fresh-air rooms. Don't worry too much about temperature unless it gets above 90oF (32o C) or below 60o F (16o C) for prolonged periods of time. These temperatures cause stress to the plants and result in slowed growth, but a few

hours in either extreme isn't going to do much harm. The presence of CO_2 allows plants to tolerate somewhat higher temperatures without undue stress.

Hydro growers: keep water temperatures around 60o to 70o F (16o to 21o C). High water temperatures invite the presence of pythium, and this will set you back to zero in a New York minute. If your buckets are on a concrete floor, this is probably not going to be a problem, but if they are suspended or up on a platform, you are asking for trouble. You can buy a chiller if your setup is warming your water to too high of a temperature; but this guide is all about keeping things simple, so if possible, set your buckets on a concrete slab and you'll be golden. Also, if at all possible, position your air pump outside your room or tent. This will reduce the

temperature of air that you are sending to your roots and, if you have an enriched room, it will improve the level of oxygen going to the roots.

Purple Bud Made Easy

No section on temperatures would be complete without the mention of purple bud. For a while, purple bud was quite popular in Colorado, so we learned how to turn green pot purple. This can be done by removing chlorophyll through temperature manipulation. You can turn any pot plant purple simply by exposing it to cold temperatures (45o to 50o F, or 7o to 10o C) for a week or two during the last weeks of flowering. Doing so breaks down chlorophyll (the green pigment) and allows purple anthocyanidins to appear.

Variable Five - Water

I covered most of this earlier, but it

bears repeating. I have witnessed far too much hand-wringing over water. All you really need to do is test your tap water for ppm and pH a few times over the course of the year. If it's below 50 ppm and the pH is around 7, you can relax. Do not worry about R/O. Do not add "up" or "down chems." Just forget about it.

City tap water is almost always low-ppm and close to a pH of 7. Where I live in Colorado, the tap water is dead on at pH 7 and the ppm is always between 5 and 15! Water that isn't at pH 7 tastes funny and hurts plumbing. Similarly, water with a high ppm fouls pipes and causes a lot of commotion among the general population. Your local water treatment professionals are doing a good job so if you are using city water you should be fine (unless, of course, you have something unusual going on in your house.)

On the other hand, if you are using well-water, you probably will need to watch and treat your water. Well-water tends to have high ppm readings and the pH is inclined to fluctuate a bit, too (though even a pH of 6.5 is not a big concern). Using well-water for your plants will almost always require you to buy a reverse osmosis (R/O) filter. Another option for people with well-water is to collect rain water. If you can do that, fantastic, but it too should be tested before you use it. Don't just assume it's perfect. Rain water is *always* a little bit acidic.

Finally, a word on chlorination, because growers often worry about too much chlorine. Water can have too much chlorine, there's no question about it. But if you turn on your hose full-power and spray or splash the water into your bucket, the chlorine will gas-off right then and there. Put

your nose down in the bucket next time you fill it--you can actually smell it come off. Another alternative is to just let your water sit for a day before using it.

Chloramine

Chloramine, however, is a bit harder to deal with. Chloramine (bound chlorine) is increasingly being used by municipal water treatment plants as a secondary, or even primary, means of treating water. You can call your local water treatment plant to ask which method they are using. Another way to tell if your town is using chloramination instead of (or in addition to) chlorination is to fill two white buckets, one with your tap water and the other with clean (distilled) water, and then compare the two. If you notice a greenish tinge to the tap water, chances are strong that your town is

using chloramination in its water treatment. The greenish color is caused by the monochloramine isotope found in cloraminated water.

There is probably not enough chloramine left in the water that comes out of your tap to cause concern, however, this chemical does have a much longer half-life than chlorine. According to the EPA, reverse osmosis systems will not rid your water of monochloramine.[74] Ironically (because, Alanis, the objective is to eliminate chlorine), one way to get rid of monochloramine is by adding chlorine bleach (which strips the ammonia from the monochloramine), and then agitating to remove the chlorine. Another solution is to just wait it out. The half-life in water for monochloramine (according to various anecdotal reports) is around 160 hours--or roughly a week. My advice

is to not worry too much about this except in extreme cases, such as if the water looks exceptionally greenish. In such a situation, you should buy distilled water to use instead.

Chlorine as a Nutrient

It took years to discover that chlorine is actually one of the essential nutrients needed by plants. The reason it took so long is because the essential elements for plant growth were revealed through a process of deprivation. An element, say magnesium, would be withheld, and if the plant got sick and died, that element was determined to be necessary to the plant's vitality.

But in the case of chlorine, the need for it is so low that the plants being tested were actually getting an adequate amount through the perspiration on the scientists' fingertips! It wasn't until the

chlorine-deprived plants were handled with gloved hands during testing that they were truly deprived, at which point they got sick and died. One touch from a bare finger can supply a plant with all the chlorine it needs. A fascinating implication of this is that we still may not know the whole story when it comes to essential plant nutrients!

Variable Six - Light

I prefer to use high-pressure sodium lamps. With the exception of LED's, HPS lamps are the most efficient source of light you can buy, both in terms of light output and light spectrum.

Having read nearly every book on the subject of growing pot, I feel that their authors tend to overemphasize the importance of light spectrum. You do

not need to alternate between metal halides (for growth) and sodiums (for flowering). That is an oversimplification of the plant's light requirements. You may do this if you like--it certainly won't hurt--but I firmly believe that the gains are just not great enough to justify the cost of the extra MH lamp.

An HPS lamp provides an adequate amount of blue light to prevent growth dysfunction.[75] If you are cloning under fluorescents, there is no reason not to use mixed color tubes, or even all blue tubes; but if you happen to be rooting clones in the same room in which you are vegging your plants under HPS, there is no need to go to great expense to add more blue. I ran my veg room under sodiums, and the plants were happy and healthy. I have also flowered under halides, and the plants were happy and healthy.

In regard to the 1000-watt vs 600-watt choice, I discussed the efficiency question in a previous section. For the record, this argument is not a mountain I want to die defending. 1000-watt lamps penetrate deeper into the canopy (assuming the height above canopy is held the same--see Section 3: Measuring Light). For some people, this is worth the added expense. If you want to go the extra mile, or if you are not SCROGing, go for it! Likewise, if you want to swap bulbs between growth phases, by all means go for it!

In Summary:

The more well-versed you are in your understanding of the six variables of plant growth, the better you will be at assessing problems when they arise. The variables work like a chain; if one of the links is weak, the chain is going to break. With respect to nutrients,

remember Leibig's Law of the Minimum: Growth is controlled by the limiting nutrient. Pick a hydro nutrient brand you like and stick with it. Or, if you grow in soil, pick a high quality mix or mix your own and watch for deficiencies and pH problems. Control your air, maintain a constant temperature, and don't fret too much over water or light.

Setting up the Grow Room

If the tent (or room) you are using is going to be enriched with CO_2, it must be properly sealed from outside air. Cooling air enters one side of the tent through ducting, passes through the reflectors, and is then exhausted out the other side of the tent. The only new air coming into the tent is CO_2.

The air within the tent or room, however, must be kept moving 24/7. Do not skip this feature of the grow room. A 12" fan on the medium to high setting will provide plenty of circulation. This circulation is critical because moving air will accomplish three things:

- it will jostle the plants, thereby strengthening their stems and helping them to stand upright without the need for **staking**;

- it will help to remove the byproducts of respiration from underneath the leaves (a film of exhausted H_2O and O^2 molecules collects there and slows down **transpiration**, a phenomenon known as **boundary layer resistance**), thereby enabling greater **stomatal conductance** and faster photosynthesis;

- and it will help to remove water vapor, thereby preventing fungal infestations.

Air circulation is important, but be careful that you do not wind-whip your plants. You will know you are doing this if their leaves begin to twist or corkscrew. If this happens, back it down a notch. Set up your fan below the canopy, aimed upwards at about 20o and let it oscillate, or aim it in

such a manner as to create a vortex around the perimeter of the room. Setting your fan to blow at an upward angle will help to alleviate transpiration, which occurs mostly on the bottoms of the leaves, and it will redirect heavy CO_2 to where it is more useful.

Consider setting up your CO_2 tank outside of your grow-space because you will have to unbolt it from the regulator and change it out every so often, and it is easier to handle when it is outside the room or tent.

A few words about these tanks is in order for those who have never dealt with them. They come in aluminum and steel. Steel is a lot cheaper--and a lot heavier. This doesn't matter much if you are buying 20-pound tanks, but makes a significant difference when you buy 50-pound tanks (the pounds

refer to the weight of the gas the tank can hold; the tank itself is much heavier). You can usually find good deals on used tanks at soda service companies and welding supply companies. Ask around. Also, check Craigslist. A price of $100 for a steel 50#, and $150 for an aluminum 50# is about right.

You exchange these tanks when they are empty. If you buy a brand-new aluminum tank that is still buffed all nice and smooth and you take it to be refilled, do not be surprised if you never see it again. What you are paying for is a kind of CO_2 tank membership, so you're better off just buying a used one. Do, however, make sure that the tank has been recently pressure tested. By recently, I mean within the last five years. If you are within five, you're good because you'll be done with it and it will be in circulation (and the

filler's problem) after it has been exchanged.

The tank will be stamped on the shoulder with the most recent test date. Here's what all those numbers mean and which ones matter.

First row, Canadian and metric measures:

TC or CTC = Transport Canada

3AL = aluminum

MXXX (where X is a number) = pressure in bars

TXXX = tare weight in kilos

Second row, US and English measures:

DOT = Department of Transportation

3AL = aluminum

XXXX = working pressure in PSI

xxxx (where x is alphanumeric) = model number

xxxx = manufacturer name or code

xxxx = tank serial number

Third row, the important stuff:

Month and year of latest hydrostatic test with inspector code, for example

"02A13" = February 2013, independent inspector

CO_2 capacity, for example 50#CO_2

TW = tare weight in pounds

There may be a + on a steel tank indicating it can be overfilled by 10%

TP = test pressure

The setup of the CO_2 in the room is that of a feedback loop. The sniffer or detector should be positioned inside the room at canopy level. You should already have a fan in one corner blowing along the length of the tent in such a manner as to keep the air turbulent. If you aim the fan upward, you will get more out of your CO_2 because it is heavy and falls fast. Your sniffer should have a photocell that turns it off when the room is dark and back on when the room is light. If it

does not, you should install a timer that is set to coincide with your light cycle. Running CO_2 in the dark is complete waste. In fact, because of cellular respiration, CO_2 is actually given off by your plants when it is dark.

The regulator is a simple solenoid switch (electromagnet) that the sniffer turns on and off. When the solenoid is powered, the valve opens and gas flows into the room. There are two things you need to know about this. First, if you run out of gas the sniffer is going to continue to hold the solenoid open until it senses enough gas to trip the sensor. When the solenoid is held open, it heats up. This can shorten its life and it may even burn your fingers when you finally discover it. Which leads me to my second recommendation: make sure you have good seals between the regulator and the tank and between the regulator and

the pressure gauge. Otherwise, you will waste gas quickly and might even ruin some expensive gear. Use a soapy water spray to check for leaks. Keep an eye on the pressure gauge and avoid allowing the solenoid to stay open for days on end.

The sniffer should ship to you factory-calibrated. If you notice that the solenoid is frequently flipping on and off, check to make sure that the sniffer photo-cell is not being intermittently blocked by plant material and that it is situated several feet away from the drip-line that supplies the CO_2. You want your sniffer to be detecting the average CO_2 level; if it's too close to the drip line, it's going to get beaten up by the unblended CO_2. If you need to recalibrate the instrument, be sure to follow the manufacturer's instructions. Calibrate it outside in the fresh air where the CO_2 is at a natural level of

about 400 ppm, not in your room or house, where it is likely a little higher.

My final word on CO_2 is that it can kill you. This is not a joke. It takes a LOT of CO_2 to do it, but it can happen. If you are paying attention, you will know by your headache, muscle twitches and deep breathing that you're getting too much. A popular way to kill pests in a sealed room or tent is to gas the little bastards. Don't gas yourself, too! Also, keep in mind that this gas is under pressure, which means that it comes out COLD. You can get frostbitten if you release it too quickly. These are extremely rare and unlikely events; but let's face it, stoners can do stupid things.

Set your light reflectors so that the bulbs are over the center of the room. In a 4- by 8-foot room, square them on the 2-foot and 6-foot points along the

8-foot axis. The light should initially be about 36-inches from the top of the plants. You can then move it to about 24-inches once the plants have gotten used to it (a process called "hardening off"). If you're unsure, remember, too close is worse than too far away.

In a tent or a typical residential house with 8-foot ceilings, you can't get your light too far away anyway--there would be enough light even if you mounted your reflector directly to the ceiling. For the purists, point-source light drops off by inverse square, so distance does matter, but I have seen more people over-lighting than under-lighting their plants. My caution is against the former. (Believe it or not, you can have too much light. This is called **photoinhibition**; see Section 3: CO_2.)

My lamps are attached right to the tent

crossbar as shown in the photo. Be sure that you are not going to burn anything directly above the lamp. The surface of the lamp will exceed 700oF (371o C), so it is not to be treated casually. Hang the reflector so that the hinge is on the distal side from where you will be entering the space so that you can easily open the housing if you need to change out a lamp.

Also, you may want to have a spare lamp on hand in case you have one burn out on you. Trust me, if this

happens to you mid-flower on a Sunday you'll wish you had taken my advice and spent the $60 ahead of time.

In short, don't be overly concerned about distance from canopy. A 600-watt HPS in 4'x4' room will provide plenty of light--wherever it's hung.

HPS and MH Ballasts

The only difference between a magnetic HPS ballast and a magnetic MH ballast is the ignitor. HPS lamps require an initial surge of electricity to get them going while MH lamps do not. A switchable ballast simply turns the ignitor on or off--that's it. If you have an HPS ballast that won't start your HPS lamp, try it on an MH lamp; you may find it works just fine. In this case, you can fix it by simply replacing the ignitor. They usually cost only about $5

to $10.

A word of caution: Be careful when working on magnetic ballasts. All magnetic ballasts contain capacitors which, even when unplugged, hold a charge--a pretty good wallop of a charge, at that! Make sure you always ground out the capacitor before you touch it.

Also, since you'll eventually wonder about this, you can safely under-power a lamp, but should never over-power one. If you get stuck with a toasted 600 watt HPS lamp and all you have lying around is a 1000 watt HPS lamp, you're good to go until you can get a correctly-rated replacement. I repeat, however, you should never over-power a lamp.

Electrical Items

In a sealed grow room or in a tent, you

will have water pooling on the floor from time to time. There is no avoiding this. Mop it up when you see it, and never put your electrical gear directly on the floor. Never. Not even for a moment. In fact, let me stress this point in bold capital letters.

ALL ELECTRICAL GEAR MUST BE MOUNTED SECURELY ON A WALL OR TENT POLE.

Calculate the amount of amperage you will be using, and make sure it does not exceed the total amperage to the room. Leave yourself some headroom. When an HPS lamp starts up, it requires an initial burst of power to ignite the gases inside it. So, you will need that extra electrical headroom. Staggering the start times of your lamps may be helpful if you know that you are close to maxing out your amps and you

are tripping breakers. Think you can ignore the electrical calculations and just wing it? You're wrong. And if you're unlucky, you'll be dead wrong.

Use zip-ties and Velcro strips to tie up all of your extension cords neatly, mount your ballasts on the wall, and elevate your air-pump so that it is above the level of water in your DWC pots or use a check-valve to prevent back-flow. Do this stuff. Sure, it takes time; but it is well worth it in terms of safety, appearance, ease of assembly and disassembly, and pride in a job well-done. Step back and ask yourself if the electrical cords and components are arranged in such a way that an ordinary person would be able sort out what's what. If it's that tidy, good job! If it's not, fix it.

Ventilation, Ducting, Temperature Control

If you plan on enriching your room, you will need to seal your ducts. You will be setting up two air systems, one for cooling the lamps and the other for plant life. Cool air must enter the duct system from somewhere outside the room, pass through the reflectors, and then exit, all without ever mixing with the enriched air inside.

It will not do you much good if you set up a tent inside a small room, exhaust hot air from the tent into the room and then try to use that air to cool your lamps. In such a setup, you will have to cool the air at some point in the loop. Running an air conditioner in the room solves the problem.

I got into a situation once where I set up two enriched 4'x8' tents in a cold garage, but did not have sufficient amperage to power them both at the same time. I also had a temperature

problem. So, I set up the ballasts on a flip/flop switch and when one tent was running, the heated air exhausted into the dark (cold) tent, and vice versa. It worked out great.

If you are not planning to enrich your room, then you only need one air system. You need a way for fresh air to enter and mix in the room continually during light hours. This means you need a place for the displaced air to exit. This air will carry an odor. You can filter it, mask it with a scent such as Ona(R), neutralize it with an ozone generator, or tolerate it if detection poses neither a legal nor a social hazard. None of these methods is perfect, but often a combination of two or more does the trick.

I like using filters the best. They work pretty well, but they are admittedly expensive and also require the

purchase of an additional centrifugal fan. They can also be quite noisy, so you may find you have to buy a muffler, which adds to the expense. Ozone and Ona work well in combination. This method isn't too expensive and the air smells like dryer exhaust to the neighbors. In both situations you will be using a wall-mounted centrifugal fan. The 6" models are the least expensive.

Let's talk a bit about sealing and air pressure. Sealing is nearly impossible to do perfectly. I think the Centers for Disease Control and NASA have managed to do it, but I don't know of anyone else who has, myself included. Imperfectly manufactured lamp reflector hoods will have small openings even if they are "sealed" units. Radiator style clamps that screw metal bands down also lose a little bit of air. I like to use aluminum tape.

Unlike duct tape, it sticks to both the ducting and hood flange, gives a great seal and is inexpensive to keep on hand. (Caution: it's super easy to cut yourself with it.) If you are pushing the air through your lamps, the little openings in the hood seal will leak air, positively pressurizing your room. This can happen amazingly fast. If your tent is blowing up like a balloon and bulging out, that's what's happening. The thing about the tents--and almost any converted room--is that they are not perfectly sealed, no matter how good of a job you did. Tents have zippers that leak and rooms have door jambs and hinges that leak. It's unavoidable.

Why am I going into all this detail? To explain the difference between pushing and pulling air in your grow space. Remember, CO_2 is heavy. If you push air through your reflectors, you will go

through your CO_2 very quickly. This is because when the CO_2 leaves the drip line above the canopy, it will get pushed out by air that has been inadvertently introduced into the top of the room through leaks in your reflector hoods. Conversely, if you pull air, you will negatively pressurize the room; and since CO_2 tends to sink and your leaks are in the hoods which are up high, you'll save a little CO_2 (since it will be mostly in the bottom of the tent).

Set up your centrifugal fan to push air and watch your tent puff out like a parade float, then turn the fan around and pull air, you'll see the tent draw in. Your CO_2 tank will last significantly longer if you pull air rather than push it. Odor control in a negatively pressurized room is easier to manage, too. It sounds nitpicky, yes; but try it.

In either case, if the expansion or contraction is extreme, you need to slow down the air flow! Turning down the volume by installing a dimmer switch will help with the rate of leakage, but you must be mindful of interior temperature. As a general statement, the air's heat capacity is not great; if you find that slowing down the volume of your flow causes an increase in temperature, then turn it back up and consider adding a supplemental fan.

If you don't mind the extra expense, pushing and pulling the air using two fans (one at either end), will reduce the severity of the leaks from both push (into the room) and pull (out of the room) pressure gradients. This is your best bet, though it is a bit more expensive. Two lower CFM fans strategically positioned at each end of your ducting beats one high CFM fan at

only one end.

In Summary:

Take the time to set your room or tent up right. Is your air under control? Is your CO_2 system set up correctly? Have you paid sufficient attention to your electrical components? Have you gone the extra mile to ensure your safety? Now is your chance to get the whole operation set up properly. Review it. Do it right, or don't do it at all!

Hydroponics: Deep Water Culture Bucket System

Building DWC buckets that don't suck--this is my time-tested and hard-earned contribution to the hydroponic pot-growing community. My DWC system is simple, cheap, elegant, low maintenance and moves plants along, if I do say so myself.

Gather the items you need (identified in the list in Chapter 2: Equipment Lists) Do not make substitutions. You need Uniseals(R). You need a multi-toothed hole-saw, not one that will tear and rip at your bucket. You need black buckets, not orange or white. You need a lid and you need black PVC pipe. You will also need a hacksaw to cut the PVC pipe into an 18-inch piece, a power drill, a wood file (bastard file), and some soap and water. You're also going to need some muscle. Sorry, no

way around that, but I promise it's worth the effort. Got your stuff?

This is how the hole should be positioned on the bucket.

Measure up 2.25 inches from the bottom of the black bucket, positioning the guide bit on your hole-saw so that it is in line with the axis of the bucket's handle. Now drill your hole. Try to maintain control of your drill. You want the hole saw to cut, not tear.

The reason why we use a 2-3/8" hole-saw is because the exterior dimension of the Uniseal(R) is 2-1/2" and the extra 1/8" of tightness provides the compression needed to prevent leaks.

Now clean the plastic flashing from around the hole.

And pop in your Uniseal(R).

View of the Uniseal(R) from the inside. Note how the plastic debris has been cleaned away.

This sloppy job will probably leak.

Cut a piece of black PVC to 18". You will have a sharp edge on the PVC.

Very important: sand or file those edges round or they will bite into the Uniseal(R) and you'll never get the PVC pipe through it.

Put some dish soap and water on the PVC and inside the Uniseal(R) to make the insertion easier.

Now, insert the PVC into your second bucket so that the finished product looks like this.

Two buckets properly conjoined.

Insert blue tubing through the net pot like this:

Why two buckets for one plant?

Your plants are going to get big and heavy, and they are going to be pushing against your SCROG screen, creating

even more downward pressure. You don't want to have to lift the net pot off to the side every time you need to add nutrient or water. The root ball is also going to fill the bucket and displace most of the water in it. With the two bucket system, you just lift the lid off the non-plant bucket and make your additions and adjustments there.

The additional reservoir will also ensure that you can leave for a few days without harming the plants. I have found that it is possible to leave for up to seven days during full bloom and still expect to find healthy, happy plants when you return. (If you do this, remember that your ppm is going to increase over the time that you are gone as the plant takes up water faster than food. You should therefore start with around 800 ppm if you want to come back to 1200 ppm, otherwise you might end up with some leaf-burn.)

Now it's time to put your plants in and watch them grow. Simply remove the plastic wrap from around your cube, drop your plant into the net pot and fill in the gaps with loose rock wool. The objective here is not to pack the roots in, but just to close the gap around the top with enough rock wool to block any light that would otherwise fall on the roots. Roots exposed to light will develop chloroplasts, which is a waste of plant energy and a waste of good root area.

Next, fill your DWC bucket system up with nutrient to just below the net pot. You don't want the net pot in the nutrient, you want it just above. Make a mark on the lidded bucket at this level to make future refilling easier. Thread the blue hose through the net pot and out the top so you can get a good seal between the net pot and the bucket. Put your air stone on the end of the blue

tubing. The air stone should rest on the bottom of the bucket (see photos). Now when you send air through the air stone and the tiny bubbles pop at the surface, droplets of nutrient will land on the root ball. In a few days the roots will begin to grow down into the nutrient. Soon the root ball will become impressively voluminous.

Because the two buckets are connected only by a small pipe, when adding nutrient, you need to be careful with ppm measurements. The two buckets will balance, but it will take several hours for the concentration gradient to equalize. (I let it equalize overnight before taking my final reading.) You are always averaging what you add with what is already there, and there are two variables you need to be concerned with: concentration and volume. I add 1000 to 1100 ppm once they are up and running (having

increased concentration incrementally over a period of 3 to 4 days) and then I keep an eye on ppm changes. I have never exceeded 1200 ppm. Recall that the plant will use water faster than nutrient, so there will be times when you need to only add water.

In Summary:

Take your time when building this inexpensive, leak-proof, high-capacity, two-bucket deep water culture system. You will be rewarded with a system that is easy to use and that will support the healthy growth of your plants for many days without your input or attention.

Geoponics: Potting Your Plant in Soil

Why You Need to Know: There is so much happening in soil that we are continually discovering more about it. Soil growers are capable of producing the finest cannabis products of all growing methods, but only if they have a solid grasp on what the soil is doing for their plants. Growing in soil without understanding it is like driving with a blindfold on; you might keep your car pointed down the road for a while, but it will eventually result in disaster. For a more detailed explanation of soil chemistry and its structural components, please refer to Section 3: Soils Primer after reading this introductory chapter.

Potting soil needs to accomplish four things for the plant. It must:

1. Provide substrate for the plant's roots so that the plant may stand upright

2. Allow for oxygen to get to the roots, i.e., the soil structure must be good

3. Remain moist while allowing excess water to drain

4. Provide nutritional support for the plant

Let's look at each of these four items separately. Item #1 is fairly straightforward--this is the purpose served in hydroponic applications by rock wool, net pots, expanded clay pellets, etc. The roots need something to grip.

Items #2 and #3 go together. Soil structure is perhaps the most commonly overlooked component of soil. It is

something that beginners often get wrong or disregard entirely, but it is critical. Soil that is too fine will hold too much water and muck, thereby choking off oxygen and allowing the proliferation of anaerobic bacteria. This will quickly make a plant sick and eventually kill it. Conversely, soil that is too coarse will not retain enough water or nutrient nor will it provide much of an anchor for roots. Plants in soil that is too coarse will starve, tip over or dry out. It is important to note that the act of watering soil--that is, flooding the surface so the water sinks down into the soil--draws air and oxygen down into the root zone, which is highly desirable.

A vigorously growing plant in soil that is just right will require watering 2 to 3 times a week, an act that will replenish the oxygen each time the water falls through the soil to the

bottom of the pot. This is why it is especially important to have a layer of rock at the bottom of the pot to create a plenum, or air space. You never want your soil to be sitting in a saucer full of water; with a few inches of rocks at the bottom, this cannot happen. I like lava rock the best for this application.

The final item, nutritional support, is the most complex of the four. It is also the area that most commonly frustrates new growers. There are 19 essential nutrients that a plant needs to have in order to reach its genetic potential. These 19 nutrients, which I covered earlier in the book, include the primary macronutrients: nitrogen (N), phosphorus (P), and potassium (K); the secondary macronutrients: calcium (Ca), magnesium (Mg), sulfur (S), and silicon (Si); the micronutrients: chlorine (Cl), iron (Fe), boron (B), manganese (Mn), sodium (Na), zinc

(Zn), copper (Cu), nickel (Ni), and molybdenum (Mo); and the nutrients the plant gets from the air or water: hydrogen (H), carbon (C), and oxygen (O). It is yet to be determined whether or not selenium (Se) and aluminum (Al) are essential so I have not included them in my list.

Access to these nutrients is determined by the soil's pH and structure. For example, the critical nutrient nitrogen is present as dinitrogen (N_2) in the atmosphere but is not available to plants in that form (though this is the source of all soil nitrogen). Organic nitrogen (C-NHN_2, where C is a larger organic molecule) gets broken down in soil by the nitrogen cycle into the three forms: NH_4N^+ (ammonium nitrogen), NON_2^- (nitrite), and NO_3^- (nitrate)--all of which are useable by the plant. Soil that is not getting enough atmospheric oxygen is problematic because the

aerobic bacteria in your soil will take the oxygen they need from nitrate (NO_3-), creating NO and N_2, both of which are gasses that will escape from the pot and not be utilized by the plant. Proper potting procedure and well-structured soil is critical to your success.

Finding or creating a high-quality soil that is properly structured and has sufficient nutrition is the first hurdle; then, you must be sure to plant in a container that is large enough to meet your objectives. The right pot size depends on the size of the plant you intend to grow and how long you intend for its life-cycle to be. I advise using a #10 size nursery pot (about eight English gallons) for this system.

Add to the bottom of the pot three inches of larger lava rock (pumice), and then add your soil up to an inch

from the rim of the pot. You want to plant your plant so that the soil comes just above where the roots and the green stem meet. Neither more nor less depth is desirable, but it is better to err by going a bit deeper rather than not deep enough. Soil pH is optimal in the 5.5 to 6.5 range. Fungi enjoy this range of pH, but bacteria proliferate in higher pH soil; therefore the addition of beneficial bacteria is not a bad idea. Adding a high compost component to your mix will acidify the soil, so use compost sparingly.

The Soil pH Flowering Decrease

Why does soil pH drop during flowering? The plant is doing it! Here's how it works. Nitrogen is

available to the plant in three forms: ammonium nitrogen, nitrite and nitrate. As the soil decomposes, the ammonium nitrogen is transformed by bacteria into nitrate, changing the ratio from "high-ammonium to low-nitrate" to "low-ammonium to high-nitrate" (stopping along the way as nitrite).

Chemically, ammonium is expressed as NH_4^+ and nitrate as NO_3^-. You can see that ammonium is a cation (positively charged) and nitrate is an anion (negatively charged). Lots of diagrams on the Internet get this wrong, confusing ammonia with ammonium. Ammonia is not ionic and is a gas; it is not available to the plant.

What happens in the pot is that the plant roots secrete another cation, H^+, into the soil which it exchanges for the ammonium (+ ex-changes for +), or an anion, hydroxy, OH^-, for nitrate (- ex-

changes for -). H^+ is acidic (in fact "pH" is the measure of the activity of solvated H) and OH^- is basic. The process of ammonium uptake will acidify the soil over time, while nitrate uptake will have the opposite effect.

The acidifying effect is exacerbated during flowering because during this time, the plant increases its uptake of K and Mg, which also trade an H^+ for their absorption (P uptake has the reverse effect). This is why soil, depending upon its composition, can be rapidly acidified during peak flowering. The fix for this is to add dolomitic lime to the soil. Just water some in and give it time. It will correct.

Dolomitic Lime vs Gypsum

Dolomitic lime is calcium carbonate. It will raise pH. Gypsum is calcium

sulfate. It will not raise pH. Dolomitic lime will add calcium; gypsum adds calcium and sulfur, and can help restore soil that has a high sodium content.

Be careful when you substitute one for the other (know your objectives). More peat requires more lime.

A Damn Good Soil Formula

Structural mix:

- 35% coir
- 25% chunky perlite
- 25% peat
- 10% compost

Nutrient admixture:

- 40% composted manure

- 25% topsoil (the real stuff--black, not the tan garbage that is all-too-often offered for sale)
- 10% dolomitic lime
- 10% gypsum
- 5% bone meal
- 5% blood meal
- 5% azomite or other source of trace minerals

Stop with the structural mix if you wish to grow in "soilless" media. Using only the structural formula, you will find it necessary to add your own nutrients. Be aware that the peat will tend to acidify the mix. If you wish to blend in all or most of your plant's nutrition at the outset, combine the two mixes. A good approximate structural mix to nutrient admixture ratio is around 2:1.

My own product (www.ScientificSoils.com) is more sophisticated than the formula presented here, but that's because I have access to computer controlled mixing machinery, highly advanced admixtures and the ability to run enormous volumes. This formula, comprised of ingredients you can find locally, will definitely get you to the finish line with your plants in good health. I promise.

In Summary: Soil is a wonderful, albeit complex, growth medium. By choosing to grow in soil, you will enable your plant to enjoy the benefits of fungal and bacterial symbiosis, but you will have to do a little more work at the outset if you choose to mix your own. You will also have to be sure to use enough soil to ensure that you don't run into nutrient deficiencies. Also, when potting, you must be sure to leave

a plenum in the bottom of the pot. These hurdles are easily cleared, though, and plants grown in soil are often the healthiest you will find anywhere!

Introducing Duoponics

Half hydroponics, half geoponics, this technique takes a piece from each method and marries them into one. The concept is to grow your plant in soil, yet water it continuously without over-watering. I want to give credit where credit is due. I know there is a company that has designed something similar for growing tomatoes, and I've used their devices before; but what I will be describing is a scaled-up version intended specifically for growing marijuana. I didn't develop it; I just think that it's slick, economical and effective.

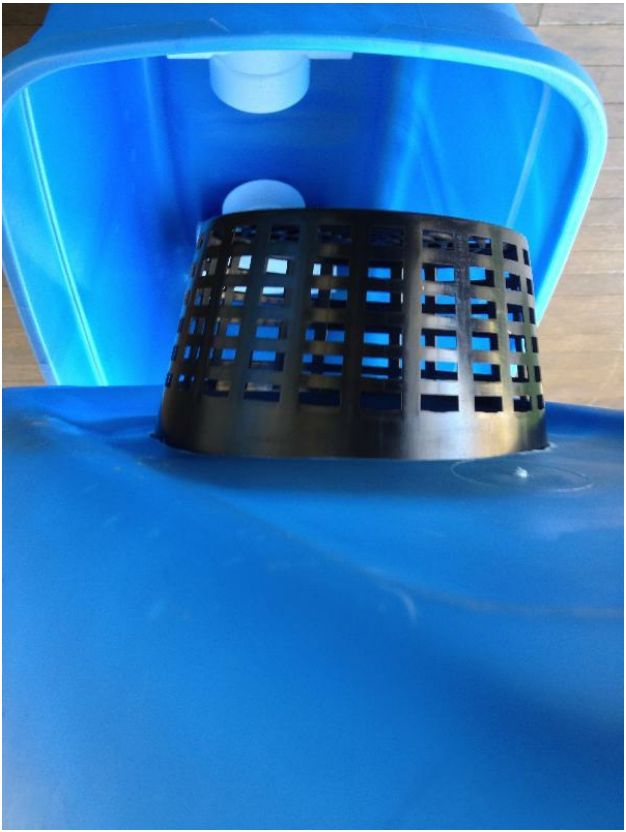
A big thank-you is due to the guys who showed me this method: Farmer Lars, Jesse, Jack, and Dealin' Sam. Thanks for the work you put into refining this system! Some of these guys prefer to call this method "soil-ponics." Others

refer to the system as "Jack pots"--because Jack is the one who introduced the idea to them. Whatever you want to call it, these guys are knocking out pound-plus monster plants in a 60-day timeframe with ease--which is *exactly* what this book is about. Enjoy!

Materials List

- Two 30-gallon opaque Rubbermaid(R) Roughneck(TM) tote bottoms (Item #2244). You do not need the lids.
- Two 4"-diameter PVC pipe T's
- One utility knife or scissors
- One 8-inch bucket-lid-style mesh pot
- One heavy-duty air stone

- One two-hose or four-hose air pump
- One 3' x 3' piece of fiberglass window screen
- Standard blue air tubing
- Four 5-foot stakes--preferably metal U-fence stakes
- One 4- by 4-foot roll of turkey-wire fencing
- Bailing wire
- 4 cubic feet of great potting soil (4 cf = 30 US gal)



1. Place the PVC T's lying side down in the bottom of one of the 31-gallon totes. This is your reservoir tote.

2. Connect your air stone to your blue tubing and drop that in.

3. Using your utility knife or scissors, cut an 8-inch hole in the center of the bottom of your other tote so that the bucket lid mesh pot can be seated and the

mesh portion protrudes out the bottom. It doesn't have to be perfect; the lip on the mesh pot allows for some error.

4. Drill 1-inch holes in each of the four corners of the same tote. (Optional: Cover them with pieces of the screen.)

5. Now nest the tote with the installed net pot into the reservoir tote so that the PVC pipes support each side of the top tote. There will be enough space between the nested totes for you to add water.

6. (Optional: Line the mesh pot with the window screen) and fill it with soil so that it is firmly packed. Alternatively, pack it with rockwool all the way to the top. The point is to

create a wick while minimizing the amount of soil that can enter the reservoir-tote; either way works.

7. Fill the reservoir tote with water to a 6-inch depth so that it just reaches the top of the PVC pipes. Your wick should be soaked. Ensure that it is.

8. Finish filling the top tote with soil and moisten the soil.

9. Plant your marijuana over the center above the net pot wick.

10. Insert your stakes into each corner of the system and, using the bailing wire, connect your turkey wire fence to the stakes, creating a horizontal SCROG mesh.

11. Hook up your air tubing to your

pump and you are ready to plant!

Note that the PVC pipes allow for the water to flow around and through them. This is better than cutting 4-inch sections and placing them vertically because that would create pockets of standing water. One system per 4' x 4' area, per light is used. The reservoir will typically run dry in about a week.

The reason why this works so well is that the top portion of the plant's roots spread horizontally for nutrient while the central roots grow downward in search of water. The supply of water and nutrient is continuous, yet the drainage is also ideal. With this system, plants receive water from the bottom and occasionally from the top, as required.

In Summary

If you cannot decide between hydroponic and soil growing, duoponics is a great way to have things both ways. The guys who showed me this use it on a commercial scale; so you can be sure it's going to produce.

Other Techniques

Why You Need to Know: It is easy to become entrenched in certain ways of doing things, but I urge you to avoid the temptation to become a technique snob. Testing out different systems and combining elements you like from different systems into new ones is an enjoyable pastime. Realizing that there is always room for improvement keeps you alert to new ways of growing excellent cannabis. I hope you will join me in the spirit of innovation and exploration and develop (and then share!) your own ways of doing things. In this chapter we will review the remaining established techniques used by cannabis growers.

There are six basic ways you can set up a hydroponic system. I write that with a little apprehension but also with some respect. Are they like simple

machines in that we have discovered them all or are there more ways to do it that are just waiting to be discovered? It may be arrogant to think the former, and I prefer to think the latter, but I am agnostic about the question. It may be a matter of hair-splitting anyway. If you found a way to train your dog to jump into a vat of nutrient and then shake it onto the root zone of your plant six times a day, would you have invented a new system? A critic might argue that you have only developed a variation on aeroponics. Either way, you should probably stop dipping your dog in nutrient. On a more serious note, I have noticed that some dogs do enjoy the flavor of certain nutrients. Keep it out of their reach because it probably is not all that good for them!

We have already covered geoponics (which is soil, not hydroponics), deep

water culture and the hybrid duoponics (soil with passive wick watering) system. That leaves us with drip, flood-and-drain, aeroponic (spray) and nutrient film technique (NFT) systems. As far as hydroponic systems go, this is an exhaustive list at the time of printing. You can see that what varies between the different systems is the manner in which the nutrient is delivered to the root zone. There are undoubtedly going to be new variations on these systems, but it may be a while before a method is significantly innovative enough to be declared a new system.

All hydroponics systems--except for wick systems--deal with post-application nutrient in one of two ways: they either recycle it or it runs to waste. For me, run-to-waste is not an option. I do not like the added expense, nor do I like the hit to the environment

that waste entails. For me, recycling is the only way to go. Any system can be run as either recycling or run-to-waste.

I have used all of the systems mentioned in this book and have liked various elements of each. I present them to you so you can analyze, dissect, and recombine them into new methods. Each of these systems combines the two critical elements that are the key to growing huge, healthy plants in a short period of time. These elements are:

1. Continuous or frequent contact with nutrient

2. Continuous aeration of the root environment

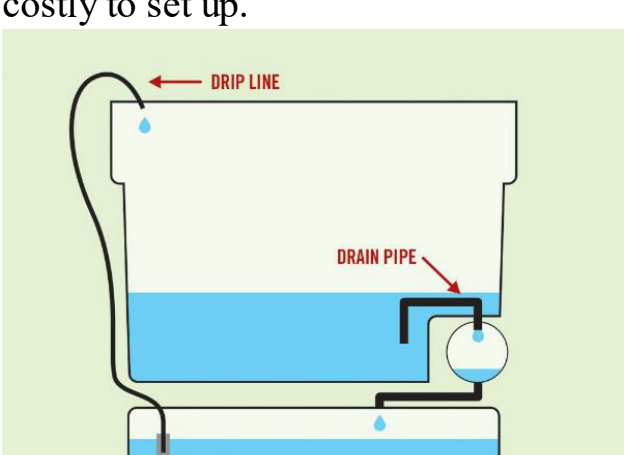
Drip Systems

Drip systems, as you may have guessed by their name, slowly drip nutrients

into the root zone of the plant. Dutch-pot systems are my favorite style of drip system. I find them to be great for medium-scale production (up to 100 plants). They satisfy the two rules of continual nutrient contact and continual root zone aeration. They also rectify the only problem I have with ebb-and-flood bucket systems, which is that the nutrient ebbs as well.

The idea here is that a continuous supply of nutrient is delivered to the top of the medium, trickles down over the roots, and is collected in a small reservoir within the container. This reservoir then fills up and overflows through a drain into the main reservoir where it is then recycled. I have grown huge, healthy plants fast using this system--no question about that at all. The hassles I experienced were that the spaghetti tubing and the drains clog, and the flow-rate is hard to get just

right. These systems also tend to leak and are a bit time-consuming and costly to set up.



Drip System

Other ways of setting up a drip system are limited only by your imagination. All you are doing with this system is slowly pumping nutrient to the top of your root zone, catching it at the bottom and recycling it. Also, not all drip systems leak--that's just a complaint when using a Dutch pot. For $25 and a

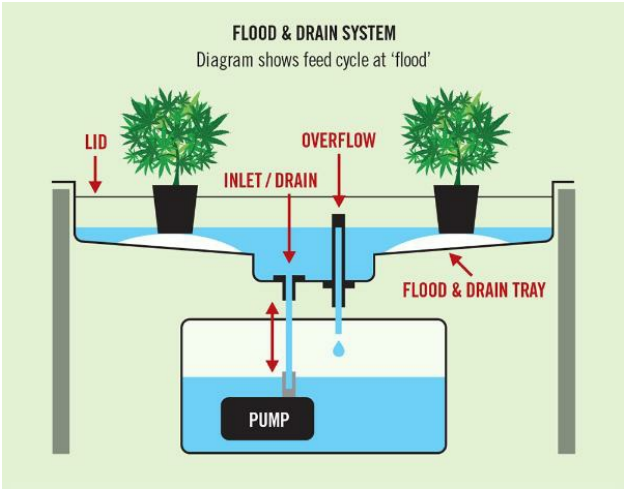
trip to Target(TM) or Home Depot(TM) you can have a drip system up and running later today.

Flood-and-Drain

With a flood-and-drain (also called ebb-and-flood) system, a timer actuates a pump at preset intervals--typically set for one to four times a day--to flood the root-zone container with nutrient. There is an overflow preventer (like what you would find in a bathroom sink) that allows the flooded container to level off for a while before the pump shuts down and gravity drains the nutrient back into the reservoir.

I use a table system and love it for how it fits my schedule. I am continuously growing and I find that the pace of growth from a flood-and-drain table is just right for me to veg new plants

between flowering cycles. I use 4-inch Cultilene brand rock wool cubes to grow my babies into 24- to 30-inch teens. A 3 x 3-foot table fits well inside a 4 x 4-foot tent leaving enough space for you to offset the reservoir beneath it and to mount a shelf for clone rooting (as well have sufficient space to work in). Forty-nine planted, 4-inch cubes can fit into the table, which is way more than a personal grower needs.



Flood and Drain System

The plants are continuously exposed to nutrient because the rock wool holds plenty of it and the roots get aeration with every flood-and-drain cycle. The plants do slow down and "wait" for me once their roots have filled the rock wool cubes, and they begin to air-prune as they protrude from the bottoms of the cubes. This problem could be remedied by filling the tray with clay balls, but that would add a cleaning element that I am not eager to deal with.

Unless you are growing Sea of Green (SOG), I don't recommend using flood-and-drain for the entire life-cycle of the plant. From rooted clone to teen size, however, this system works great. The expense is a bit high--about $300--but once it is set up, it is nearly foolproof and only needs attention about once every 60 days for a cleaning and nutrient change.

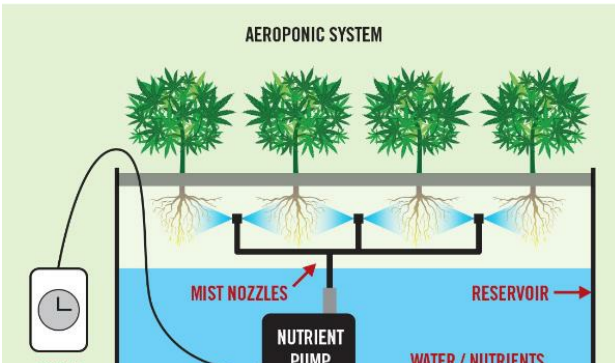
Flood-and-Drain Buckets

This system uses the same principle as the table setup, but utilizes buckets arranged in series to contain the plants, and a pump and float-valve to flood/stop-flood and reclaim. I have seen truly great results from this system, but I think it is a huge pain-in-the-ass to clean between uses, and I have dealt with enough broken timers, pumps, clogged vacuum breakers and spaghetti tubing in my life that I must say no thanks to this one. It's just far too complicated for my taste.

Aeroponics

The concept here is fabulous: spray the nutrient onto the root zone because in doing so, you aerate the roots as well. In reality, that ideal world lasts about 20 minutes, at which point your spray jet clogs.

I can't say I'm a fan of these systems, though I would really like to be. The problem is that they NEVER. STOP. CLOGGING! Aeroponic systems rely on sprayers to mist the roots with nutrient, but roots are living things that age and shed debris which the pump then passes up to the inside of the spray nozzle. Because of this, the system is set up to clog eventually. Putting your pump inside a filter-housing does help--for a while. But then the filter clogs, and you have to clean the filter. Also, the pump can overheat your nutrient, which means that if you want to avoid rot, you need a chiller... The solutions to the problems just seem to compound into new problems.



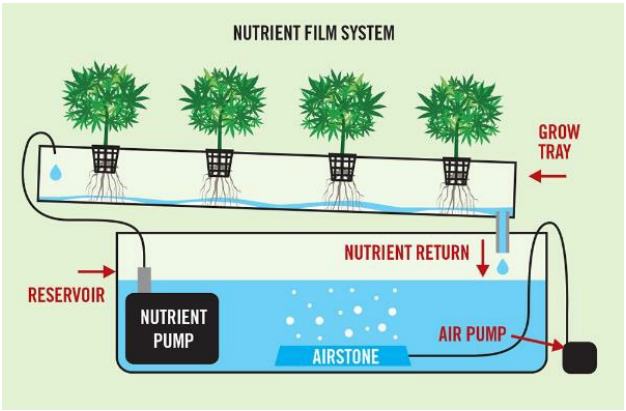
Aeroponics System

I wish someone could figure out an economical solution to this, because aeroponics simply cannot be beat as far as aeration is concerned. Maybe the nutrient could be delivered at high speed (through a wide enough hose that it wouldn't clog) onto a deflecting surface that splashed the nutrient onto the roots? Or perhaps a root fogger with a non-recycled nutrient supply in a uni-directional flow with drain-to-waste is what we need? That would be ideal. But costly. And I hate waste.

You see the problem here...

Nutrient Film Technique (NFT)

Here, the concept is that a film of nutrient flows across an inclined table past the plant roots and is then either recycled or drained to waste. It is essentially a horizontal drip system. This system has the same air pruning limitation inherent to using rock wool on a flood table. You can get past that by filling the table with clay pellets; but be aware that cleaning the clay is no picnic. You could periodically discard and buy new clay pellets but I find this to be wasteful, cumbersome and expensive. Combining this system with rock wool cubes may be just the ticket for someone who wants to build their own inexpensive SOG or clone-to-teen veg table.



Nutrient Film Technique

In Summary: Assess your needs. Do you want to fiddle with your system daily? Some people enjoy doing that. Or are you the type of person who likes to "set it and forget it?" Will it be used as your only means of growing, or will it be used only for vegging or flowering? Once you have that worked out, get on out to there and build something new. Keep it cheap and effective, and share your ideas!

Growing and Training

Why You Need to Know: We have covered the nuts-and-bolts; now it's time to put your tools to use. This is the applied-technique portion of the manual. A good mechanic has an intuitive understanding of his materials and machinery. He knows that metals have elasticity, so he does not over-tighten and sheer bolts. He can hear when an engine is running optimally, and feel all the parts fall into place as he makes adjustments. You will become a mechanic of growing plants as you develop a green thumb and learn to listen to your plants. Develop a relationship with your plants and you will know when things are right and when they are off. There is only so much you can learn from a book; experience will be your teacher after that.

You probably already know that SCROG is an acronym meaning SCReen Of Green, which is a single-plant variation of the Dutch high-production method called Sea of Green. Sea of Green is a cannabis husbandry technique in which a multitude of small individual clones are forced into flowering early (no veg time) so as to produce a large flood-tray full of only "top buds." This is desirable because it reduces plant waste by virtually eliminating smaller "popcorn" buds, which have little bag appeal and therefore little commercial value, and it gives an excellent flower-to-lux ratio. While it is labor intensive, in that it requires lots of cloning, it is also high-production because it eliminates the vegetation phase thereby enabling its practitioners to move quickly to the next round of plants. A good Sea of Green grower can fit as many as six sequential crop turns into a

year's time.

SCReen of Green, of the other hand, is better thought of as a training method than as cannabis husbandry. It is efficient in that, like SOG, the finished product is lots of top colas per unit of illuminate surface area; but it addresses none of the timing benefits associated with SOG and is mute as far as how many total plants are grown. A SCROGged plant will still have to be vegged for about 30 days before being put into flower, and a good SCROG grower is still limited to about four crop turns per year. In short, SOG is a production method, whereas SCROG is a training method.

Because of the legal implications of growing many plants (the Feds get involved in cases of more than 99 plants; and fewer plants generally means less severe consequences),

growers here in the US developed the SCROG method, through which one plant is trained so that its flower buds grow into a (usually wire) matrix positioned above the plant, resulting in a "table top" of buds. The bottom popcorn buds are trimmed off so the plant puts its energy only into the larger top buds. This way, you can enjoy some of the benefits of the SOG method while keeping your plant-count low--and your ass out of jail.

A lot of your success will be owed to the SCROG training method. Most of your work will take place during the vegetative period, because it is the point when you are most able to force the plant into the martini-glass shape that you want when heading into flowering.

The way you achieve this shape is by manipulating hormones in the plant

called auxins. Auxin (indole-3-acetic acid) is, among other things, a branch-growth-inhibiting hormone that resides in greater concentrations in the growing tips of plants (called the meristematic apices). Look at a pine tree for a good example of how this hormone works. Note how the top branches are much smaller than the bottom branches. The branches at the bottom are longer because they are less inhibited by auxin. They are less inhibited because they are further away from the source of the auxin--the top of the tree. Auxin also explains how phototropism works. The auxin collects on the shady side of the stem and causes the cells to elongate, bending the plant toward the light. Auxin is also responsible for gravitropism--how the plant knows which way is up.

By decapitating the meristematic apex,

you reduce the quantity of auxin and allow the branches beneath to grow. Another way to achieve the same effect is by pinching the meristematic apex just above the branch(es) you wish to grow longer. The difference is that when you cut the top, you end up with two leads, whereas if you only pinch, you retain a single lead. You can do this anywhere on the plant. Just remember that the lower down on the meristem ("trunk") you go, the less pronounced of an effect the pinch will have. Have a look at the meristem of one of your plants and you will notice that a cross-section of the stem is similar to the shape of a cloverleaf, except that one of the axes is less protuberant than the other. It is the less protuberant axis that you want to pinch because, in my experience, this direction is least likely to break the stem. When pinching, you want to gently crush, not break, the stem.

Whether you decapitate or pinch is up to you. Both methods work. I pinch. I even have a pair of pliers specifically for the purpose of crushing when the stem gets tough and I want some extra length out of branches lower down on the plant. You must be careful with the mechanical advantage given by pliers because an open stem is an invitation to molds and bugs. I wrap the jaws of my pliers with electrical tape to prevent serious injury to the plant. You just want to give it a series of squeezes until your branch length is where you want it to be.

The main reason I prefer to pinch instead of cut is because by pinching you can bend the meristem to a horizontal position, and thanks to phototropism, the meristem will then turn into one long chain of top buds. Again, I'm not sure it matters which method you choose; this is just my

personal preference. I have done it both ways and I'm not convinced that either one is decidedly better than the other.

Remember: A pinch increases growth on the branches beneath the pinched branch; a topping results in not only increased growth of the branches beneath the cut branch, but also adds two new leads--in other words, the cut creates a node from which two leads will grow.

Just a quick word on FIM, which in a demonstration of stoner humor is an acronym for "Fuck, I Missed." As the story goes, as a grower was once topping his seedling at an early age, he had difficulty cutting between the first and second nodes of the seedling and cut a little low--about 20% into the lower node. Because the new side branches of the lower node were left

somewhat intact, the result was that the plant ultimately grew four leads instead of the expected two. The difference between FIMming and topping, which has not to my knowledge been pointed out in any growers' forums, is only one of timing. The plant was going to grow two branches from the node anyway. It was also going to divide its meristem into two leads as a result of the cut. Now, all four will appear to grow from the same node instead of having an internode between them.

How Long To Vegetate

Vegetate your plants until they are about 30-inches in height (aerial parts, excluding the bucket or pot), about 30-inches in diameter (across the top of the canopy), and have been trained into the desired martini glass shape. "Top" (cut) or bend the plants in order to

achieve this shape. It is not a problem to have a few long branches snaking around the netting. Alternately, you could simply decapitate the meristem and top branch tips to achieve the same result.

After your first or second grow you, will have gotten the knack of training. Plants will increase in volume by about two to three times during the flowering phase (though strains vary). Your objective is for your plants' canopy to fill an entire 4'x4' space by harvest.

Because there is a variation between strains and your ability will improve with time, adjust your expectations down the first time through. Subsequent grows will allow you to determine if you can flip from veg to flower at, say, 24-inches in diameter instead of 30. For this reason, I advise running the

same strain several times. Doing so will allow you to focus on your ability.

Pruning

Pruning accomplishes the twofold goal of thinning the plant for improved airflow and better light exposure while directing the plant's energy to the biggest, most dominant budding sites. If there is an art to growing, it is to be found in pruning. This is because while you are manipulating the growth pattern of the plant, you are also predicting which budding sites will end up in a position to gain weight. There is not much point in allowing the plant to put energy into flowering sites low down on the plant that will only give you small buds. The same logic applies to branches. There are going to be branches that are better off removed than permitted to finish. You will know both the budding sites and branches to

remove by their small size and low position on the plant.

Pruning should take place once the plant has achieved sufficient leaf surface area that pruning it will not stunt its growth. Once a plant has filled out to about 24- to 30-inches (61-76 cm) there should be enough leaf surface area that you can begin pruning. It is not uncommon for me to remove 30- to 40-percent of the plant material in the weeks right before and right after initiating the flowering photoperiod. By taking notes over the course of a year, observing which branch sizes yield worthwhile buds, and comparing plants flowered at the same time, you will develop a knack for knowing how much and where to prune to get the greatest benefit.

Netting (The SCReen in SCROG)

The netting that is placed across the top of the plant during flowering is there to hold the plant in its martini glass shape. Because of phototropism, the plant is going to try to close up; you are going to fight to keep it spread open.

I have seen several creative solutions for netting material. I have seen chicken wire, turkey wire, paper clips and twine, and plant "yo-yos;" but my favorite of all is the orange construction fencing you can buy in rolls at hardware stores. It can be stretched between tent poles or hooks screwed into the wall and then pulled taut with zip-ties. The material is rigid enough to hold the plant open, but flexible enough to let you work with it. Finally, it is inexpensive enough that if you need to cut some of it away to save a branch or a bud you can do so without worry or great cost.

When To Harvest

Here we are. You've flowered the plant for about 8 weeks and you're ready to chop her down and dry your weed for use or sale. How do you know if it's ready? Err on the side of waiting longer. Many an ounce has been sacrificed to over-eager growers who cut too early.

Remember that the plant is gaining weight quickly at the end. A good quick visual rule of thumb is that you want the stigmas (the little white "hairs") to have almost all turned red--about 75-percent red is good. If you are growing the plant for sativa qualities, pay attention to the trichomes. A little on the early side gives a zippier high, so cloudy (rather than amber) trichomes are preferable for sativas. A little on the late side gives a more relaxing high, so amber

(rather than cloudy) trichomes are preferable for indicas. If clear trichomes and white-green stigmas are still growing, that indicates that it's too early. Too many stigmas on a bud give it poor bag appeal and reveal a grower in a hurry.

In Summary: Vegetate until the plants are about 30-inches high and trained into a martini glass shape about 30-inches across, and then initiate flowering. Use a screen of your choice to resist the plant's phototropic pressure and spread it out across your 4'x4' space. Prune away the numerous lower buds and branches that are shaded or exceptionally small. Resist the urge to harvest early, waiting until about 75-percent of the stigmas have reddened and shriveled.

Sweeteners, Lore and Other Ideas

Why You Need to Know: One of the most fascinating things about plant physiology is that, because of plants' incredibly high level of complexity, there is still a lot left to discover and many more experiments left to conduct. You can contribute to the knowledge-base if you are willing to do the research and take some risks with your own plants.

That said, there is a handful of principles and ideas that are worth knowing. They will enable you to conduct worthwhile experiments instead of foolhardy ones. The people studying plants are incredibly smart and are currently working on some esoteric problems because most of the easy ones have already been solved. Like what? Well, here is a list of things

that are fairly settled (and that you can save time, money and face by not bothering to pursue), as well as a few things that need more exploration.

Sweeteners

Adding sugars or Country Time(R) lemonade (I once met someone who swore by this addition to his lemon skunk) to the nutrient or soil does not add sugar to the plant. It is a misnomer when we say that we "feed" our plants. Plants make their own food (sugar). We merely supply the necessary mineral nutrient ions to enable them to do so. Plants cannot absorb sugar. This is because the sugar molecule is too big to be absorbed by the plant through osmosis or effectively through active transport.

Osmosis is the transportation of solvent through a semipermeable

membrane to a concentration of higher solute in the direction that equalizes concentration on either side of the membrane. Osmosis creates pressure (turgor) in the plant cell and causes the plant to stand upright. That means that if the plant cell has a high concentration of solute (think nutrient salt) and the water outside the cell has a low concentration of solvent (think pure water), the plant will absorb water, resulting in turgid plant tissue. If, on the other hand, the plant cell has a high level of solvent and the material surrounding the cell has a high concentration of solute, the plant cell will lose water, resulting in flaccid plant tissue.

Therefore, if you add enough sugar to your nutrient solution or soil, you will reverse the normal osmotic direction and kill the plant. Sugar does feed bacteria in your soil, though it is

probably overkill to bother with this if you have compost in your mix or you have inoculated your soil. Furthermore, sugar attracts insects and bacterial and fungal pests, so if you do use it to feed your soil, do so sparingly (see molasses, below).

Do manufacturers know that these products are useless? Yes, they do. Are they ripping you off with sweeteners? Yes, they are. If you look at the labels you will see that they always contain elemental nutrients such as magnesium, sulfur and potassium--that way, they do something, but they don't sweeten. Plant sweeteners serve only to transport money from a greater concentration in your bank account to a greater concentration in the sweetener company's bank account.

Molasses

Here's one that works! Molasses contains iron, magnesium, calcium and potassium--all of which can be used by the plant. It is these compounds, not the sugar content, that makes molasses valuable. Molasses will also feed your soil microbes. Play with molasses if you like.

Note: Too much sugar creates an environment that is conducive not only to beneficial microorganisms but to lots of nasty ones, as well. Use it sparingly.

Compost Teas

This is an area of great interest and one that has both detractors and advocates. I am becoming an advocate; but it is still an emerging area of study. There are some things to note about compost teas. There are two general types: aerated and non-aerated. The teas

introduce bacterial populations that can be either desirable or undesirable. Some bacterial populations suppress unwanted fungi, such as damping off,[76] [77] while others, such as E-coli, salmonella and coliform bacteria, are bad for human health and food safety.[78] Some research indicates that the sole benefit arises from the inclusion of nitrogen in the tea.[79]

I suspect that what is developing here is the science of the use of specific bacteria in horticulture and that the use of compost tea is meaningful only insofar as it is known which microbial populations are being introduced. In short, the research is all over the map on compost teas. Use them with this understanding, but by all means explore their use. (For an updated and more in-depth look at compost teas, please see Section 3: Compost Teas.)

Flushing

Here I am referring not to soil flushing, but to plant flushing. Given what you now know about osmosis, do you think finishing flushes could possibly work? No? You're right. Basic plant physiology tells us that "flushing" is meaningless, unless by "flushing" you mean "making the plant wilt or starve." So! Let's talk about starving and how that might factor into the quality of your final product...

Drying and Curing

Smooth smoke--not harsh, biting smoke--is the objective. I once met a guy who told me that his buddy (it's always a "friend of a friend!") buries his weed in glass jars for a year before digging it up and smoking it. Is this necessary? Can it possibly help to produce a smooth smoke?

Here's the skinny: Chlorophyll and other pigments are what make the smoke harsh. If you dry your plant slowly, you will give the chlorophyll time to degrade and the result will be a smoother smoke that doesn't burn your throat or taste grassy. How slowly? Sorry to say, you have a bit of a balancing act to perform here.

Chlorophyll is not water-soluble,[80] so slow is best (to give the pigment time to break down), but if you move too slowly you will invite molds. Air circulation will help, but if you move the air too rapidly you will dry your bud too fast. Starving removes chlorophyll. This is a key step in the drying and curing of tobacco, too.[81] [82] Degrading chlorophyll, I submit, is how "flushing" really works.[83] [84]

A friend of mine has a knack for this. Here's what he does: He cuts branches

off the freshly harvested plant and immediately plucks the fan leaves. This removes most of the stomata and therefore slows down the transpiration of water vapor from the stem. He then hangs the branches (still rather large) from wire coat hangers in the bathroom where he periodically runs a hot shower (because he needs to shower). The branches take about 7 to 10 days to dry completely. You will know when they are finished drying because they will snap rather than bend. Once they are dry, he trims. (I prefer to trim wet. This is one of those things that does not readily submit to easy answers and that potheads can discuss at length. I do not have a strong opinion on it.)

This seems to me to be a good pace--not three days and not one year underground. The last thing I will note is that the faster you dry, the more

color your bud will retain, So keep that in mind if purple bud is your goal.

Plants Don't Care About "Organics"

When I went to high school we had to learn the hard sciences--physics, chemistry and biology (and hike to school barefoot through freezing fields of broken glass uphill both ways). In those days, organic meant that a compound had a carbon ring attached to it and that was the end of it. All life on Earth is carbon-based (or so scientists thought at the time), so the word "organic" connoted life. Today, there are more than 40 definitions of the word in the United States, and they vary depending on where you are standing. Literally. Nearly every state has its own definition, and there are as many different certifying organizations as there are definitions. This is unfortunate. It has had the effect of

introducing a great deal of confusion where none should have existed.

Most consumers think they know what organic means; but if you press them, they can't actually define it. "It means 'grown without chemicals'" they might say; but everything is made up of chemicals, including the vegetables they want grown without them. All biology is chemistry. (And all chemistry is physics.) What is a carrot if not sugars ($C_6H_{12}O_6$) and beta carotene ($C_{40}H_{56}$) in a cellulose ($C_6H_{10}O_5$) chemical matrix? "Oh you know what I mean--*harmful* chemicals." Well, that doesn't cut it, either. Gasoline is chemically organic, but most people would not want to wash their vegetables in it. Water is inorganic, but we know it is necessary to life. The difference between a poison and a medicine is usually just a matter of amount, so what

is*intrinsically* harmful? Even too much water can be a poison. Water can kill you by osmotically depleting you of electrolytes and thus stopping your heart--but nobody thinks of water as a harmful poison.

What consumers are telling industry is that they do not support the poisoning of land and surrounding ecosystems by the overuse of chemical fertilizers, pest controls and growth-enhancing compounds by farmers and food producers. These have the additional unintended effect of harming soil microbial populations that would otherwise allow natural fertilizers to break down and become available to the plant, damaging related or surrounding ecosystems, sickening animals and persisting in food in great enough concentrations to harm consumers. "Organic" has become shorthand for this belief, or something

like that. I think we should all support sustainable agribusiness. Furthermore, these concerns are valid and urgent, but the abuse of the word "organic" has made things harder to sort out.

Returning to my point (and why I'm bothering with all this), your plants do not care where their 19 elemental nutrients come from. They cannot use these nutrients until they have been broken down into their ionic--that is, inorganic--forms. You can supply them with nutrients sourced from chemicals synthesized in a factory, or you can provide them in the form of manures, compost, soil, etc. Either way the plant gets the same chemical compound!

This fact offends some people. I know this because they have told me so. They do not like to hear it and will do everything they can to believe it is incorrect, but a fact it remains. These

people want to believe there are "organic" (good, from nature) nutrients and "chemical" (evil, from cancer-billowing factories) nutrients, and that each has different properties. This is simply false. The nutrient itself is the same; the method of producing it and the effects on the environment of using it are what is different.

Now before I am slandered or misquoted, I want to make it clear that I am absolutely not saying that I oppose the organic farming movement. I think it is a necessary counterweight to all the bad actors hell-bent on destroying our farmland. What I *am*suggesting is that the organic farming movement is scientifically confused and that it paints a false picture of both nature and large-scale farming. There are lots of deadly poisons occurring in nature. Large-scale farming is feeding a lot of people who might otherwise starve. A

topic this complex does not allow us the luxury of sweeping generalizations.

I bring this up because I want you to be fully informed when you make your nutrient decisions. Whether you use hydro or soil, you get the same end product. If, on the other hand, you are growing for medicinal purposes in a business setting, the word "organic" has power and the patients who buy your product will respond to it--for good reason. Many of them may have become sick because of the environmental damage caused by the unenlightened practices of unscrupulous people. They want you, the owner, to respect and employ healthy, sustainable practices--and that is warranted.

For the record, my own product is all-natural. I am mixing on a much, much larger scale than you are, and I feel that

my scale has a significant environmental impact. If my product gets dumped onto your garden when you are done with it, I want it to be helpful, not harmful, to the microbial health of your soil.

Stressing

Stressing--the right kind--works. It also harms. There's room here for experimentation and I'd love to see more of it. Here are a few aspects of plant physiology that may guide you in the right direction.

We know that bending and breaking are related to hormone transport. We can use this fact to train and morph our plants into useful shapes. Splitting stems will have a similar effect on hormone transport but it will also introduce a wound where pests and fungi can enter the plant. Splitting is

not a good way to stress the plant. Water stress, likewise, does not seem to me to be a profitable avenue for exploring the effects of stress. Plants perform better when they are hydrated, not when they are deprived of water. Light stress is also a bad idea unless you are trying to induce intersexed flowers.

There is one area that is worth playing around with, though. Like insects, plants use pheromones to communicate with one another.[85] They even use pheromones to communicate with each other about insects.[86] One of the things plants can do in response to insect attack is to ramp up production of secondary metabolites, which include terpenes, phenolics and nitrogen-containing compounds, most of which are repellent to attacking pests in some way.[87] One of the ways that plants know an insect has attacked is through

the detection of insect saliva,[88] which usually has a proteinaceous component. Plants can, and do, communicate to neighboring plants that an insect attack is underway, thus giving their genetic relatives a leg up on the impending attack--a few extra days or hours to ramp up secondary metabolite production to fight off the insects.

Here in the West, we see the pines secreting sap to try to fight off pine beetles. Eventually a stand of genetically related pines will succeed. Those trees will reproduce, the others will not. Evolution, baby, evolution. I think you can see where I am going with this. What if someone in our community could discover a way to trick pot plants into thinking an attack was underway (or even allow a small, controlled attack) and not only ramp up secondary metabolite (e.g., THC)

production in that plant, but also in nearby, untouched plants?

18/6 or 24/0?

Another question that frequently comes up in grower discussions is whether to use an "18-hours-on, 6-hours-off" or a "24-hours-on, 0-hours-off" light timing for vegetative growth. (For some reason, probably our affinity for round numbers, such combinations as "21.25-on, 2.75-off" never come up.)

I use 24/0. I've tried it both ways and don't have a conclusive answer about which is preferable. My thinking is that the maximum amount of photosynthesis is my goal, so I leave the lights on 24/0 during vegetative growth--an idea that was promoted in the 80's and 90's.[89] (However, a good argument regarding energy savings can be made here in favor of 18/6.) Though I have not

noticed any ill effects, I may be wrong about this.

When a plant is left under constant light, it's circadian rhythm flatlines. When it is put back under a regular photoperiod, the rhythm entrains to that photoperiod. Recent studies indicate that plants entrained with a light cycle that *matches* their genetic circadian oscillators will outperform mismatched plants.[90] The question is, what is the genetic circadian rhythm of cannabis? As far as I can find, this has not yet been elucidated for cannabis. Plants' circadian oscillators are seldom exactly 24 hours. I would also bet that there's more than one oscillator, depending on the sativa/indica/ruderalis genetic percentages.

Another point to consider is that under natural conditions, the photoperiod is

gradually changing from day to day, based on the time of year (lengthening in the spring and shortening in the fall). Plants, as we know, anticipate the change in seasons based on these changes in daylength (really, night length) and respond accordingly. Cannabis will flower under 13/11 or even 14/10 light/dark cycles, depending on their genetic predisposition. What this implies is that a pat 12/12 light cycle may waste valuable time during which the plant could be conducting photosynthesis, especially during the early flower initiation period as the plant transistions out of vegetative growth. I am hopeful that with the end of prohibition, more research into cannabis will follow and we can answer these questions.

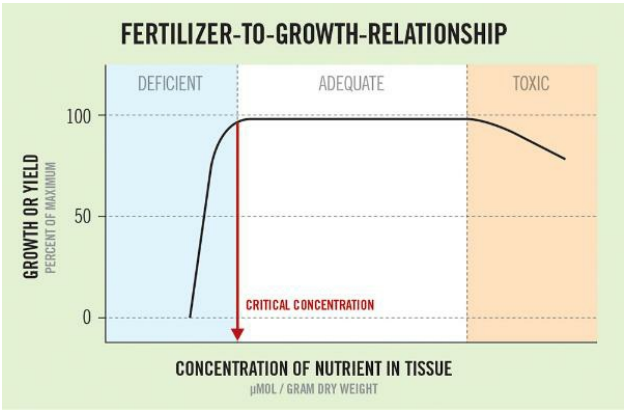
One thing that probably will not yield good outcomes is extending the

photoperiod much beyond 24 hours (for example, lights on 20 hours, off 12). The plant did not evolve that way, so the odds that the genetic oscillation will be compatible with such a schedule are probably low. That said, plants with 25- to 27-hour circadian oscillators are not uncommon, so if any of my readers decide to test this orthodoxy (for example: 14 on, 12 off), please do reach out to me with your results.

You Cannot "Push" a Plant

Here's a question that comes up a lot: Can I give my plant some Awesome Product to make them flower bigger, better, faster, stronger, or more? The answer is: Not unless they are in need of something that product provides. The simple fact about nutrients is that there is a deficiency range, an adequate range and a toxic range. If you are

within the adequate range, there is nothing left for you to do. Adding more will not help. In fact, it may hurt.



Effect of Sound

The practice of playing music for one's plants in order to improve growth is an interesting one. It certainly strikes scientifically-minded growers squarely in the bullshit receptors at first pass. But dig a little deeper and it may not be as stoned-silly as it seems at first. There are some fascinating new studies that support this idea or *something like it*.

Dr. Monica Gagliano, a researcher in Australia is provoking lots of attention[91] (not all of it positive) in the plant physiology community with her research. Recently, she demonstrated that that corn-plant roots make clicking sounds at a specific frequency. Moreover, *other* plants respond to these same sounds. When sounds in the same frequency range are introduced to the plants, the corn grows toward them.[92] As Gagliano points out, 20,000 or more flower species only release pollen when they encounter the frequency of bees' buzzing wings.[93] Some frequencies cause zucchini seeds to germinate more rapidly than seeds not so stimulated.[94]

This response to sound makes sense. We know--and nobody disputes--that plants respond to touch, light, gravity, water and so forth; so why should

mechanical vibrations in the air or ground be any different? What we are only now beginning to understand is how these vibrations may affect growth--that is, how the plant responds to such stimuli. What seems to be an incontrovertible fact is that plants respond to stimuli we call sound. Whether the plant "hears" is a matter to be determined.

That question, which is really one of whether or not plants are sentient, may pivot on the reductionist question of whether or not the plant has a *specialized apparatus that evolved* to detect these impulses. In other words, they detect sound waves, but do they mean to? It's a question of evolutionary adaptation. Or at least, that is how many researchers see it.[95] [96] (Though I understand why it would be attractive to believe otherwise, I'm lumping myself in with the skeptics out of a

respect for scientific parsimony.) Think of it this way: Dogs hear a range of air-conducted vibrations in a frequency range that we cannot. They hear those vibrations as sound because it served some useful purpose along their evolutionary journey. Plants may do something like that as well... minus the ears.

Can plants detect sound? Yes, that much seems settled. Is communication taking place? That's a different question altogether. As I imagine Dr. Gagliano would, I urge the reader to consider the paradigm of growing-as-communicating. Traditional plant husbandry tells us that human-plant relationships are a one-way street: The right inputs at the right times produce a desired and measurable output. If the plant is thought of as being responsive (if not completely sentient), however, our orientation toward this project

changes.

With this way of looking at gardening, our plants are not seen as docile, purely receptive objects, but rather as interactive communicators that respond to our inputs with what we should instead think of as *replies*. Thus growing becomes a kind of dialogue between plant and grower. It is possible to consider the consequences of changing one's paradigm without committing to the truth of such consequences. This could make for another "functional truth" which we would then have to examine for inconsistencies. After all, committing to a paradigm then examining it for inconsistencies is what we've been doing all along anyway.[97]

I have deliberately included a number of footnoted sources in this section for the curious reader to peruse. For those

who have a philosophical bent, I highly recommend reading the provocative book, *Plants as Persons, a Philosophical Botany*, by Matthew Hall, who gives the topic a much more thorough treatment than I am able to give it here. Also, a link to the essay, *Persons as Plants: Ecopsychology and the Return to the Dream of Nature*, by Monica Gagliano, is given in this footnote right here.[98]

Biodynamic Gardening

Biodynamic gardening is a technique that was developed by Rudolph Steiner in the 1920's. It blends organic practices with esoteric, mystical and spiritual ideas. It is often presented as holistic gardening, although it has never been shown that gardeners' private (or public, for that matter) thoughts about the zodiac have ever affected the growth of a turnip. As you

may have guessed, biodynamic gardening definitely sets my bullshit receptors off.[99] There is just something about putting a quartz crystal in a cow's horn and then burying it on a full moon[100] that crosses the line for me. Call me uptight.

If I haven't persuaded you yet, consider the biodynamic method for pest control: burn the offending pest, then scatter its ashes over your field at the appropriate position of selected celestial bodies.[101] How this works as a practical matter is not clear. I imagine that a person would need more than a few aphids in order to have the ashes necessary to scatter them over a field. Perhaps it's the way in which the *other* aphids begin to see you after you've begun to ritually set fire to their friends. You can only turn a blind eye to so many before you realize that, eventually, they come for *you*.

Much like the playing of Pink Floyd to improve plant growth, biodynamic garden practices are an interesting mix of fantasy and proven technology. In short, the practices of biodynamic gardening that have been shown to work are practices it has in common with organic gardening.[102] Organic gardening, by the way, while definitely better for soil health, generally does not yield as much as conventional farming.[103] [104] [105]

High Brix Gardening

This term was popularized by a guy named Dr. Carey Reams, a bullshit artist par-excellence and one that germ-deniers love to hold up as held-down by The Man--or whatever mysterious force it is that holds down such revolutionary ideas as the Biological Theory of Ionization from those of us who most need ionizing.

What of his grasp on human physiology and health? Would it surprise you to learn that his insights came to him after a long period of fasting and prayer? This man had a better grasp on his dick when he peed than he did on science when he theorized on the human disease process.[106] I beg you to do a few searches on the Interwebs and see if you can find a bigger shyster. I like to contribute to the corpus of human knowledge when I can, and since it is not clear that he was ever a doctor, I'll go out on a limb here and settle the matter. He wasn't a doctor.[107] But he *was* busted for impersonating one.

Now, I'm nothing if not a fair thinker, so let's separate the idea from the man. Here is Reams' Big Idea, according to his acolytes:[108]

Ream's contribution to agriculture was just as significant as his contribution to

human health. Reams taught that the functional foundation of nature is electromagnetic and that the chemistry of nature is secondary.[109] Reams applied this concept to plant growth. He maintained that plants grow through the process of ionization-similar to an electroplating machine. Likewise soil fertilization is done from an electromagnetic perspective as well. This is done by balancing the positive and negative charges.[110] Fertilizers are viewed as energy packages used to build and balance the electromagnetic field of the soil.[111] The minerals in the fertilizers carry specific energy forms. These energy packages (fertilizers) react with opposing charges in the soil during the process of synchronization.[112] This synchronization of opposite charges provides a release of energy, which drives plant growth.[113]

No. No, no, no!

Even if we give this pablum a charitable rendition and read it to mean "grown properly, fruits and vegetables can have a high mineral content," we would still have to accept the idea that high mineral content equals good nutrition. Well, what if that mineral is cadmium, lead or mercury?[114]

Most pot growers spend the last few days of the grow cycle trying to "flush" their plants or otherwise deprive them of excess mineral ions anyway, so how this caught on as desirable in marijuana plants is a mystery to me.

Lest you think I am being unfair, most High-Brix gardening practitioners use the method for growing nutritionally-rich fruits and vegetables. Well, okay. You got me. I agree that growing nutritionally-rich fruits and vegetables

is a good thing.

Brix is a measure of sugar content developed by a much more sensible person named Karl Balling, who wanted to measure residual sugar in beer. So high-Brix vegetables have a high sugar content. Brix is often used in tomato-strain taste evaluations. So how do we increase plants' sugar content? By pouring Country Time(R) lemonade on the soil, of course.

Sentinel Plants

I was recently shooting the breeze with one of the best growers I know and we were lamenting about the two biggest pest problems growers face: mites and powdery mildew (PM). We were talking about how, for many growers, these two particular pests go undetected for so long that when they are finally noticed, it's already a huge

management problem. The discussion progressed to talking about how, in vegetable gardens, cucurbitas (squash family plants) seem to always come down with PM, and how, of all the vegetables in the garden, they always do it first. The idea dawned on us to try using cucurbitas as sentinel plants in professional grows. There is no reason why home growers cannot do this as well.

The principle is simple: Plant a susceptible plant in with your cannabis plants. If the pathogen to which it is sensitive is in the air, that plant will be affected first. You can then bag the diseased plant and take preventative measures immediately, thus saving yourself a lot of hassle while also saving your garden.

For detecting PM, cucurbitas are an obvious choice--as anyone who has

ever grown them knows. (Also, one zucchini plant is so prolific you could feed your extended family zucchini for a month.) We were thinking that English ivy would be a good choice for detecting the mites...

In Summary: Sweeteners only sweeten the bank accounts of those selling them. Molasses contributes useful nutritional elements and can feed soil microbes, but use it sparingly. Compost teas are a mixed bag, probably literally so, and "flushing" the plant accomplishes nothing other than a depletion of chlorophyll. Dry slowly to accomplish the same goal and avoid harsh smoke; dry quickly to preserve color. Plants perceive no difference between organic nutrients and ones synthesized in a factory, but people and soil-dwelling organisms do. Plant stressors, particularly those that signal plants to ramp up secondary

metabolite production, are a worthy avenue for experimentation, as is light cycling. Don't try to push a plant; that almost always ends in tears. Plants respond to sounds, but not to cow horns stuffed with their own manure--that's just weird. Carey Reams was a fool, fruits and vegetables are good for you and sentinel plants might be worth having in your garden. Jump in and let me know what you find!

Plant Selection and Performance

Why You Need to Know: Your pot can only be as good as your plant's genetic potential will allow it to be. The goal is to squeeze the most out of your plant--in other words, to help it live up to its full genetic potential. Therefore, picking a great plant at the outset is your single-best opportunity to control your outcome.

You need to obtain the best genetics you can. I do not recommend buying seeds online. I have purchased well over two thousand dollars' worth of seeds that way and have found that about half of what you get, even when buying from famous breeders, are just not worth the effort to obtain. The other half, however, are pretty good. (One breeder I have found to be exceptional is Flying Dutchmen. They've been selling the same line-bred strains for

many years, and some of them are fantastic. And, no, they are not paying me to say this.)

When you obtain your genetics from someone who has already vetted the plant, you can save yourself a lot of time and hassle. Buying seeds through the Internet can be fun, and so can the excitement of seeing a plant grow from seed to harvest; but do not be surprised if your results are less spectacular than you'd expected.

The bottom line is that seeds in this industry are more inconsistent than they ought to be. The most frequent problem is intersexing. It is my experience that you will be much better off starting with a rooted clone from a trusted local grower who can tell you exactly what to expect from that plant. Performance characteristics are vital pieces of information. Other growers

have this information and are usually willing to share. That said, when you have your first harvest or two in the freezer, and you can withstand a possibly-substandard run, it's your turn to go out on a limb and evaluate a new strain--and then pass it around!

When you choose your plant, you will almost certainly be choosing one that is a good mix of sativa and indica. Please do not start with an all-indica or an all-sativa variety. Since the development of the famous Skunk #1, some serious breeders have been hard-at-work developing strains that combine the best of both subspecies, and you ought to be taking advantage of this work. Pure sativas (equatorial region plants that evolved under long grow seasons) will take eons to finish--120-day flowering periods are not uncommon. Pure indicas (temperate region plants that evolved with more

pronounced seasons) are often overly-leafy and won't have great bag-appeal. Note that I am not judging psychological effects, just the plants' growth characteristics. You can find hybridized plants that lean one way or the other in terms of resultant-high but retain a blend of the two plants' growth characteristics. (Later on in your growing career, you can, and should, try pure landrace strains; but that's just for fun, not for maximum production.) At any rate, you will almost always find plants that are indica/sativa blends; pure indicas and pure sativas are rare.

You should only pick plants that are offered by growers who have already flowered them, and who can assure you that they have done so. They should be able to provide you with a reasonable level of certainty that the plants will not intersex; are not

carrying disease; are vibrant, healthy and well-rooted; and have only one or two main leads (preferring one over two).

Do not buy leggy plants in unclean soil, or plants that have spotty or pale, burnt leaves, overly-purple stems, or that have dark or soft, rotting roots. This is all common sense, of course, but many people who are in a hurry to get started will buy substandard plants or grow out bag seed (bag seed can be fun, but it's high risk), and will then be disappointed when they finish with only one or two ounces per plant or end up battling mites for three months.

How Seed Breeders Are Fouling the Gene Pool

In order to compete, many breeders take the approach of offering novel strains--usually the recombination of

existing strains. This in itself is what breeders do, and it poses no problem. Novelty is exciting for the consumer and engaging for the breeder. The problem arises when the breeder either fails to stabilize the strain or offers feminized seed. It takes 6 to 7 generations to stabilize a new hybrid strain. At 90 days per generation, that's at least a year and a half without pausing.

Very few seed companies are bothering to stabilize beyond one generation. I know this because I have planted many hundreds of seeds and have spotted the 9:3:3:1 Punnett ratios come up--from breeders' packs! This is just fine if you are a large scale grower because you can afford to throw away the majority of a new strain and keep the occasional sport to clone and run into production. But for a home grower, this eats up lots of time and money.

The second problem comes from the production of feminized seed. The breeders use special chemicals (silver compounds) to force a genetically female plant to produce male (staminate) flowers for pollen, which is then used to pollinate female (pistillate) flowers on the same plant. This process is called "selfing." The purported result is seed that is genetically all female. The problem with seed from this technique (besides the fact that it takes only one generation to do this) is that the sexual expression of cannabis is not clear-cut like it is in humans.[115] [116]

In cannabis the sexual expression of a plant may not be determined by genes alone, but by as-yet unidentified conditions during germination.[117] Furthermore, the sex chromosomes themselves are not easily distinguished from one another.[118]Individual plants

are able to become male, female, or a combination of the two. Stress alone can cause a normally dioecious plant to produce both pistillate and staminate flowers, so the potential for such a problem is always looming.

The upshot? You will almost certainly have some staminate flowers in among your valued pistillate flowers if you choose feminized seeds. Even if you get lucky and this trait is minimal or not expressed, it is my experience that the predisposition is now "switched on," making the plant more sensitive to environmental stress. On the other hand, with a stabilized dioecious strain, the plant is much less susceptible to stress-induced flowering dysfunction. My advice is to find a source of clean clones that are known-performers and start there. You'll save yourself lots of time, lots of headache and lots of money that way.

Germinating Seeds

There are a lot of ways to germinate seeds, and all of the good ways to do it include moisture and a little warmth. If you went to a lot of trouble to get prize seeds and want to ensure that you germinate as many as possible, it is worth your time and attention to give them the best shot possible. If you are not worried about getting top germination rates, just put them in the medium you want to use (soil or rock wool), wet the medium and let nature do its thing.

To get top germination rates, I like to use the 50-percent water/50-percent drugstore-peroxide and paper towel method. Simply fold a paper towel in half twice, place it on a clean plate and moisten it thoroughly with a mixture of half water, half hydrogen peroxide (use the 5% drugstore strength, not the 28%

horticultural strength). Drain off any excess solution and place the seeds under one layer of the paper towel. Cover it all with plastic wrap and put it in a warm (not hot) place.

The peroxide sterilizes the paper towel and seeds and also provides oxygen, which will help prevent the seeds from drowning. As soon as the seeds sprout, put them in your destination medium with the radicle (little white root) pointing down. Be gentle. If you break the radicle, it will die. One more word of caution: You should act quickly once they have sprouted, as they will soon need moderate amounts of food and light.

Note: It is a good idea to sterilize your soil when starting seeds. This helps to prevent damping off (botrytis). In most other situations, I do not recommend sterilizing soil first. For people with the inclination to do so, pasteurizing soil--especially if you have added compost to it--is a fine idea. This means heating it to between 140o and 180o F (60o and 82o C) for 30

minutes. This is not hard to do. You can do it on a hot, sunny day on your driveway by simply enclosing your soil in some black plastic. At a temperature of 212o F (100o C), you will have killed everything--including beneficials. Therefore, if you overheat the soil, it is best to introduce new beneficial cultures before using the product. A sterile medium is an open invitation to bad pathogens.

It is often parroted by imperious politicians with too much time on their hands (is there any other kind?) that marijuana should not be legal because "today's marijuana is much more potent than the marijuana we grew up smoking in the 70's." I remember sorting seeds from the bud on an open double LP album cover, too (Sgt. Pepper's was great for this). I also remember getting ripped. This claim is half nonsense, half true.

You cannot make a species express what is not already in its gene pool. You can rearrange, exclude or include genes in individual specimens through breeding, and you can force expression of recessive genes, but you cannot *invent* genes through breeding. Selective breeding has increased the expression of potency, but the marijuana gene pool has not gotten magically stronger. What you need to know for your own grow is that you can't exceed the genetic potential of your plant. All you can do is maximize it.

There is some indication that exposure to UV-B wavelengths can increase (bring about the genetic expression of) potency.[119] [120] Of all the available light sources, MH's are the ones with the greatest UV-B, so a dose of MH at the end is something I have seen several commercial clients of mine doing. I

have no idea what the real gains are in terms of percentage-increase, I just wanted to let you know.

In Summary: Your plant can only be as good as its genes will allow. Take your time finding a good plant. Buy healthy clones from another grower who can vouch for their quality and tell you about their performance characteristics. Ask a lot of questions. Do not be shy about walking away from a sick plant or a seller who can't answer your questions. Do not bother importing seeds which is both legally risky and botanically uncertain. Pick a strain that is "middle of the road" in terms of sativa and indica blending.

Developing Protocols

Why You Need to Know: This is the most important chapter in the book. It is what good growers thrive on. Stoners who grow will quickly find themselves in trouble with their plants unless they adopt the grower's attitude toward protocol. Everything that you do in your grow room is able to be fit into a routine. That routine should follow the same steps every time. That is the essence of protocol.

Plants love predictability and consistency. Approach protocol as if it is sacrosanct; the day you do something out of order because you are tired, or in a hurry, or want to get on to other things, is the day you are likely to make a fatal mistake.

Do not violate protocol. You are better off postponing your routine for a day

than rushing through it. If you think this sounds didactic or preachy, you're right. It is; and I'm sorry for that. I realize that you're a grown-up. However, if by being preachy I have convinced you of the importance of protocol, I will have made you a better grower. Let's look at an example.

Preparing nutrient: Here is my hydro nutrient protocol. Because I have done it the same way every time, I know it by rote.

Step 1: Gather equipment (which is always in the same place because of protocol): graduated white bucket for nutrient mixing, three bottles of nutrient, measuring shot glass, ppm pen.

Step 2: Open valve-cock on my water tank; open spigot; put about a half gallon of water in the bucket to prevent

nutrient lock out; close spigot.

Step 3: Add grow nutrient: open spigot; rinse shot glass; close spigot; put grow back on shelf.

Step 4: Add bloom nutrient: open spigot; rinse shot glass; put bloom back on shelf.

Step 5: Add micro nutrient: open spigot; rinse shot glass; close spigot; put micro back on shelf.

Step 6: Add water; using pen to monitor, take nutrient to desired ppm.

Step 7: Close valve-cock; close spigot.

Step 8: Put tools and instruments back in their designated place.

That's it. Anal retentive? You bet it is. Is there any other way to be? Nope--not if your goal is to avoid doubling

one nutrient and forgetting another. Notice how I put the just-used bottle back on the shelf when I'm done with it? Doubling one and forgetting the other cannot happen if you follow protocol. No matter what happens, I cannot mess this up. A phone call can come in; a person might walk in and ask a question; the dog could flip out because someone came to the door--whatever. It makes no difference because I will know where I am in the sequence, and will be able to return to my task when the interruption has passed, all because of a known, established, inviolate protocol.

In Summary: It is worth your while to establish protocols. Protocols are useless unless they are always adhered to strictly. Please consider using them as they have the potential to save you from grievous mistakes.

Troubleshooting: What the Hell Just Happened?

Hardly a week goes by that I do not get the following distressed text message: "Read, what's wrong with this plant?" in conjunction with a picture of one leaf showing yellowing or spotting or something scary looking.

My reply is always the same: "What is the history of this plant? And may I see the whole plant, please, in white light?" These two dimensions of context: history and holistic view of the plant, as you will soon discover, are critical.

Problems Evolve Over Time

Let's talk a little about how we get into these problems, because knowing is the key to avoiding 90-percent of the problems you will encounter. Plants do

not suddenly become covered with spots, half-yellowed, wilted or covered in spider mite webbing. They get there gradually.

However, it is important to resist the "obsessed stoner" approach of endlessly tweaking your plants because you think you've seen the first signs of something going horribly wrong. Instead, it is better to observe--without panic--what changes your plant is going through, and wait for confirmation of your hypothesis (which, trust me, will come). Relax, but pay attention. The way you can avoid nearly all problems is to:

1. Know and understand the plant's life-cycle as well as the possible pitfalls that could occur and how to recognize them;

2. Watch for changes in the life-

cycle and possible pitfalls with detached patience long enough to make a positive differential diagnosis--or at least an educated guess, and then;

3. Act thoughtfully.

If you approach things this way you will succeed more often than not. The astute reader may wonder a bit about point number 1. How can you recognize something you have not seen before in person or (more importantly) in context? That is a good point. The Internet has a lot of close-up photos of diseased leaves, but provides few whole-plant photos paired with those close-ups, and even less information regarding context. Knowing what spider mite damage looks like at a glance is something that you will learn over time, I'm afraid, by dealing with spider mites (hopefully on a friend's

plants!).

Point number 2 is expounded on below. It, mercifully, has a tripartite framework for you to use as you watch for possible diseases to arise. Point number 3 is the easy part, but only if you do not rush straight into it. The potential for iatrogenic problems is high if you act hastily.

CSI: Cannabis Sickness Investigation

When you encounter a problem, you need to take a deep breath and do everything you can to beat back the urge to start spraying, plucking, rinsing, or otherwise manipulating your plant in an effort to fix things as fast as humanly possible. Instead, you will be better served by taking a crime--scene approach to assessing what went wrong. Take fifteen minutes to an hour

(overnight, if you have to) to mentally rope it off and assess the situation (sixty minutes is not going to make a difference anyway).

Stand there and look at the whole room in context to your historical and recent behavior. Ask yourself what you have been doing regularly, what you may have recently changed in your routine, and whether any novel opportunities for pathogen introduction have occurred--that sort of thing. You will probably have an Aha! moment that will illuminate the whole thing. Maybe you have been using pH-adjusted water for too long, or your dog or cat got in and brought mites, or perhaps you have been steadily increasing your ppm and that has finally snowballed, causing a burn. Whatever it is, you stand a good chance of figuring out the source of your problem. And, if you do, you will have learned a valuable lesson!

Don't beat yourself up over mistakes you or others have made, and never brag about how you have never made such-and-such mistake. Hopefully, you will be on the lucky end and learn from others' mistakes and photos; but, if it happens to you, so what? It's just a plant! Let's learn from it, humble ourselves, share it with other growers and move on. It's not the end of the world if you lose a plant, or even an entire grow. This is especially true if your experience enables you or others to avoid the same problem the next time around. You're a grower; you are in this for life, after all!

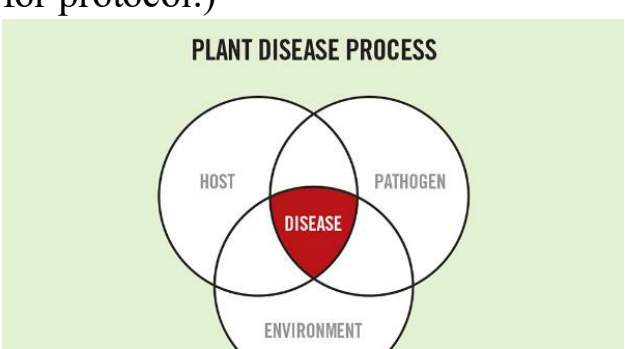
Disease Process Triad

Speaking of crime-scene style assessments, we are fortunate in that there is already a conceptual framework for making such assessments. When something goes

wrong and a plant gets sick or diseased, there are really only three factors you must consider. (Makes you feel better already, doesn't it?) Every student of horticulture knows this, and you should too.

The three components to any plant disease process are: a virulent pathogen or pest, a susceptible host, and an environment that is conducive to disease development. All three legs of this triad must be present before a pathogen can flourish and a disease can take hold. *If one leg is missing, the probability for disease is zero*. Assiduous maintenance of these three components is required to prevent disease from affecting your plants. (Note: The pathogen leg requires a vector, which is considered by some to be a fourth leg. I disagree because I feel it confuses original value with existential value. Still, it is an

important point and a strong argument for protocol.)



General maintenance of the integrity of the growing environment will prevent most outside contaminants from entering (vector). Regular inspection of both the grow room (environment) and the plants (host) is required to raise the alarm when disease (pest) does show up.

If contamination by pathogen does occur, the affected plants should be removed from the grow area and quarantined for treatment. If all plants

are affected (and in a small space this is highly likely), simply treat in-situ. Careful review of plant**edaphic** and aerial (environmental) conditions should be conducted to help avoid any future issues that may be caused by plant stress.

That leaves the pests themselves. Just as plants must live within certain conditions in order to flourish, so too must pathogens. The key to pest management is finding the ways in which the conditions differ, and then making conditions increasingly intolerable for the pest without making the plant too uncomfortable.

Sterile Technique

The sterile technique can be a valuable tool in your efforts to minimize the possibility of disease; but in a grow room environment, "sterile" must be

understood as a relative term. If you do not know the sterile technique, read on for a quick overview.

A sterile field (area of operation) is established and maintained as close to its time of intended use as possible. Introduction of new items into the sterile field may contaminate the field unless they too have been sterilized. Edges of everything--tables, containers, doorknobs, sleeves--are considered not sterile.

Sterile personnel should work only with sterile items; unsterile personnel only with unsterile items. Opening a sterile package renders its contents not sterile. The handling of items within the sterile field is to be kept to a minimum. Positively pressured areas should be pressurized with a sterile source of air (as in HEPA filtration). Upwind areas are more sterile than

downwind areas; therefore, contaminated items are not to be placed upstream of sterile items. The idea is that contamination is everywhere outside of your sterile field, and your mindset should be one of continual vigilance.

Of course, grow rooms are not operating theaters, so much of this has to be taken in relative terms; but there are good lessons and practices to be taken from sterile technique. For example, a regular cleaning routine is indispensable. Regularly wash all your tools. Hose ends, pots and cloning devices should also be on the cleaning list. Not dipping cuttings directly into your source of cloning hormone, but rather pouring a bit of it out to be used and then discarding it when done, is a good example of how sterile technique can inform how you work in your grow room. It's all about awareness of your

activities.

The Most Common Problems

You will probably run into one of two main categories of problems: nutritional or pathogen-related. Here I will list the ones you are most likely to encounter as well as their solutions. It is possible that you will encounter some of the more unusual problems, like viruses; but honestly, if that happens, you're going to have to start fresh anyway.

The #1 problem I see growers experiencing is caused by "loving their plants to death." (The #2 problem is lacking, or failing to follow, an established protocol.) It could be a virus, yes, but it's probably just a nutrient burn or a pH maladjustment. I have made this identification guide easy and short because identifying

problems is easy and should not take you a lot of time. In fact 99-percent of the problems that most growers encounter are listed here and are easily identified! The fixes, like the problems, often take time. Don't rush. Relax. If you want to spend time with your plants, just be with the plants. Don't fine-tune or fondle them. There is a lot of wisdom in the saying "If it ain't broke, don't fix it."

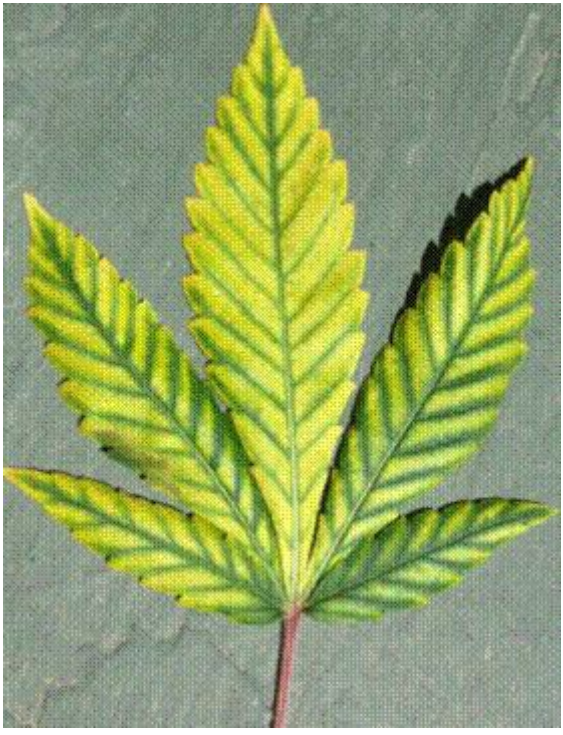
A brief word on mobile and immobile nutrients: some nutrients can be translocated in the plant; some cannot. Here's the breakdown in order of their prevalence in the plant. I have placed the ones where deficiencies are rare in parenthesis. (By rare, I mean look elsewhere for the source of your problem.)

Mobile: N, K, Mg, P, (Cl, Na, Mo, Ni). These can be moved around, so

your plants will translocate them to newer leaves and shoots where they are most needed. Therefore, if a deficiency exists, the older leaves will yellow first.

Immobile: Ca, (S), Fe, B, Mn, Zn, (Cu). Plants cannot translocate these nutrients; rather, they must remain where they are. Therefore, if a deficiency exists, the newer leaves and shoots will yellow first.

Note: The macros (N, P, K) are all included among the mobile group. This means that if you have discoloration at the growing shoots, you can almost always rely on a good micronutrient product to fix it.



Of the remaining nutrients:

- You simply will not see deficiencies of silicon (Si), chlorine (Cl), selenium (Se) or sodium (Na).

- Sulfur (S) deficiency is almost

as rare, occurring only in very sandy soils with extremely low amounts of composted matter. It affects the younger leaves.

- Iron (Fe) deficiency is a fairly common, but easily identified, problem that can be corrected quickly. Iron deficiency appears as a well-defined striping of the leaves. After you have seen it once, you will never miss it again.

- Copper (Cu), molybdenum (Mo), and nickel (Ni) deficiencies have been known to happen, but are rare. If I saw one of these deficiencies in my grow op, I would call friends in to have a look; that's how rare they are.

Common Leaf Changes Due To

A Deficiency Of Nutrient

Chlorotic leaves, green veins

In order of likelihood, these symptoms could be caused by a deficiency in boron (B), iron (Fe), magnesium (Mg), manganese (Mn), nickel (Ni), or zinc (Zn).

- Boron is a fairly common deficiency. It can be identified by the black necrosis of younger leaves, starting at the proximal end of the leaf. A little boric acid or borax in the water is all you need. This can be purchased at a hardware store.

- Iron, magnesium and manganese deficiencies are difficult to distinguish from one another until late into the problem. Your best bet is to treat for all of

them by adding a bit of commercial micronutrient to the water you are using.

- Zinc deficiency is easily recognized by deformed, puckered leaves that are eventually accompanied by necrotic spots.

- Manganese deficiency is often accompanied by necrotic spots. Manganese deficiency is typically an indicator of high pH levels. Perhaps you over-limed? Drop the pH a bit.

- Nickel deficiency will appear as leaf tip (distal, in contradistinction to boron) necrosis and can be fixed by adding a commercial micronutrient product. As mentioned above, however, it is

highly unlikely that you have a nickel deficiency.

Uniformly pale leaves (no green veins)

In order of likelihood, this could be caused by a deficiency in either nitrogen (N) or sulfur (S). *Hint: It's not sulfur*. Add some manure or other grow formula.

Leaf color changes that *may* be due to nutrient deficiency:

Spots on leaves, no green veins:

There are really only two likely causes of this symptom. In order of likelihood, it may be caused because:

- Your ppm is too high. If this is the case, you need to pull the ppm back a bit. You're burning because your ppm is too high,

buddy!

- If you are in soil, your pH is too low (especially if the problem occurs when the plants are flowering).

If your pH is between 5.5 and 6.7, *and* your TDS is between 800-1100 ppm, you need to add phosphorus (P) or molybdenum (Mo). Which? If your leaves are dark green (maybe even

purple) and spotting, add phosphorus (P); if they are pale and spotting, add molybdenum (Mo)--in other words, a micro product.

Note: a molybdenum deficiency can bring about a nitrogen deficiency in soils that are old and fully cycled. It is best not to reuse soil when growing pot. Add it to your vegetable garden instead.

Leaves curling, spotting, then necrosing:

- If in hydro, check the ppm to ensure that it is not too high.
- If in soil, a common cause of this problem is nitrogen toxicity. If your young leaves are curling inward and downward like eagles' claws, you have over-fed. This is more common in soil than in hydro because soil

growers often cannot resist adding bottled nutrient to their soil (which already contains nutrients). I'm not sure why this is; after all, the point of growing in soil is so you do not have to do this, but I see it happening frequently.

- Check that your pH is in a healthy range (5.5-6.7).

- If all of the above check out okay, then add calcium, because that's probably what is causing your problem.

Note: At this point the odds of your nutrient problem having not been fixed are slim to none. As a rule, and as you may have noticed, always: 1) check your ppm; 2) check your pH; 3) add nutrient as indicated above. Make all adjustments slowly and with patience.

Observe carefully for subtle improvements. An attempt to correct these problems quickly will only cause more problems. Take it slowly.

Soil flush

Now is a good time to discuss soil flushes. This should be done when you are certain you have over-fertilized; the leaves are burning and there is no question that you've overdone it with feeding. The soil flush will enable you to wash excess soluble interstitial fertilizer out of the soil so that the plant can recover.

Use lots of water. Measure out, and then rinse through the pot, water in the amount of three or four times the volume of soil. If you have an eight gallon pot, you are going to rinse the soil with 24 to 32 gallons of water. This is important.

If you use too little water you will only make the problem worse. Why? Because when soil is not saturated with water, some of the nutrient will not be in solution. If you add only enough water to dissolve that nutrient, you will have merely succeeded in exacerbating the problem you set out to correct. Rinse your soil thoroughly.

Now that you know how to flush properly, you should be made aware that as a result of the flush, you will have hurt your nitrogen stores. In my opinion, it's better to repot your plants than to flush.

My Shortcut Method for Non-Pathogen-Related Disease

Look at the whole plant. If it has spotted leaves (and there are no bugs or molds), it is probably either over-fed or the pH is too low. If it

has chlorotic leaves at the top of the plant, add micro nutrients. If it has chlorotic leaves at the bottom of the plant and the chlorosis is progressing upward, add macro nutrients (N especially). It's that simple most of the time.

What do these treatments all have in common? They're all related to nutrition: too much, too little, or the wrong pH is preventing access to it. *Three sources, four fixes*. There is simply no need to learn the deficiency and toxicity symptoms of all 16 nutrients (32 factors!) when there are only four fixes: flush/repot, adjust pH, add micros or add macros!

Pathogens

There are seven big ones in this category; four are bugs and three are fungi. The bugs are spider mites,

thrips, fungus gnats and root aphids. The fungi are powdery mildew, pythium and botrytis. There are other pathogens, of course, but these are the ones you are most likely to run into. You will learn to identify them soon enough. Here's how to control them.

THE BUGS

Spider Mites

Spider mites keep me awake at night. These evil little bastards can float in on a puff of air, a piece of clothing, your dog, your girlfriend, or a bad idea. I hate them, and they hate me back. They are nearly impossible to eradicate. I take that back; they are impossible to eradicate. The only way to beat them is to stop all production and go get the 10-percent bleach solution. Then get all new plants and hope for the best.

Spider mites doing what they do best: ruining your crop and peace of mind.

By J. Holopainen (From my camera) [GFDL (http://www.gnu.org/copyleft/fdl.html) or CC-BY-SA-3.0-2.5-2.0-1.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

You may not be able to eradicate them, but you can control them. And,

depending on how serious you are about it, you can do a fairly okay job of it. In Colorado, there are two kinds of professional grow ops: those that are fighting spider mites and those that are lying about fighting spider mites.

My home-grow, peace be upon it, still has no spider mites as of this writing. (Still! In 2014!) That is probably because I refuse to enter my grow space unless I have recently showered, shampooed and changed my clothing and my girlfriend. The dogs are not allowed in, nor are bad ideas. (I was kidding about my GF, by the way!) I also never introduce a new strain unless it has been quarantined in a separate space for at least a week.

When it comes to controlling spider mite infestations, I should start by saying what does not work--at all. No matter how many good vibes and

rainbows you put in the jar, home remedies involving garlic, oils, dish detergents, tobacco, or anything else in this category are simply not effective. Whenever I read posts touting these remedies on the forums, I think, "Here's someone who is offering advice that has not been tried on a spider mite infestation that existed within the scope of reality." Believe me; I have fought a lot of mite infestations. These critters are Tough with a capital T.

So, what does work? It's a short list. If the plants are not flowering, and they are still very small, destroy them, bleach and start fresh. If the plants are not flowering, but they are big, you will have to go for the evil stuff--the newest horror-show-in-a-bottle--and hammer those little vampires every 48 hours, because they have a short life-cycle (about three days).

A product I have used with good success, especially during flowering, is Hot Shot(R) No-Pest(R) Strips. This product is sold in most hardware stores, and its active ingredient is the chemical dichlorvos. This chemical is also used in the treatment of livestock feed to prevent insect infestation. The No-Pest Strips are not very effective in commercial situations--it's just not possible to use enough of them in such a large space--but for a 4' x 4' or 4' x 8' tent or closet, two of them will set your mites back without you having to apply anything directly to your plants. Their toxicity is high; they cause cancer; they are officially Not Good; but they work. We're all adults here; you make the call.

Also, please try to avoid using neonicotinoids. Yes, they work; however, these compounds kill bees. If you are growing inside, you should

consider using them if, and only if, you can dispose of the toxified plant material safely and without exposing bees to it. If you are growing outside, you should not use neonicotinoids. If you are uncertain about a particular chemical's toxicity, you can check online at http://www.pesticideinfo.org.

Another method of controlling spider mites is to tent them up and gas them with CO_2 at 15,000 ppm for a few hours. Be aware that you can kill plants, pets and people this way too, so be careful. Do this every three days until you have given the infested area four gassings. Then, once you have knocked the spider mites back, you can attempt to control them until flowering using more tame stuff like Beethoven(R) or AzaMax(R) and vacuum cleaner nozzles. Once the plants start flowering, you do not want this stuff on your bud. At all.

This bears repeating: Once the plants are flowering, no chemical, no matter how "safe," should ever be used. Never forget that you will be inhaling this plant eventually. Predators should not be used either, because this method simply trades one insect problem for another. I have seen modest success on modest infestations with some of the live mite predators that are available. The problem is, the mites always come roaring back; and if you are flowering, you will then find yourself with mites*and* predators sticking to your bud.

Plants infested with spider mites in late flowering must be harvested for use in extraction products. This effectively separates the pest from the useful components. No other use for a plant so infested is acceptable in professional settings; use your own judgment when growing pot for your

own personal use. Spider mites often crackle and pop when you smoke them, which is not pleasant.

If you are in late flowering, I do have one trick to offer you. You can outsmart the little shits. Firmly attach your plant to a stake. If the stake is the highest point, many of the mites will climb up to the top of the stake within a few hours. Once there, they can be wiped off with a wet paper towel. I noticed this by accident one day while working in a badly-infested medicinal grow. Note: this is not a cure; rather, it is a way to reduce their numbers before harvesting for extraction. Good luck--because you're never done with spider mites.

Thrips

Thrips are leaf-miners that infest the soft leaf tissue. These insects are hard

to spot, but thankfully easy to deal with. I recommend using Spinosad insecticide. Spinosad is a product derived from a strain of bacteria that was discovered in a rum still in 1975 by a scientist vacationing in the Virgin Islands--or so the story goes.

It works. Better still, it is harmless to animals. Mix it according to instructions, and spray it thoroughly onto all surfaces. Because thrips are miners, it is important that you also spray the soil. Spray again in three days. Put down some blue sticky traps to monitor for more insects. Once they're dusted, you are done!

Appearance of thrip damage to the naked eye.

Nymph (left) and adult (right) thrip. By --M.J. 16:36, 7. Jun 2006 (CEST) (eigene Aufnahme) [CC-BY-SA-2.0-de (http://creativecommons.org/licenses/by-sa/2.0/de/deed.en)], via Wikimedia Commons

Fungus Gnats

Another common pest, regardless of what growing technique you use, are fungus gnats. These gnats are seldom more than a nuisance and are easily controlled. They pose little threat to a plant--unless they are allowed to

proliferate. Do not ignore them, because fungus gnats are not going to go away.

You can, with little cost or effort, get their numbers down to a few a day; and you may even manage to eliminate them for long periods of time. The sooner you act after spotting them, the better. Note that their numbers will balloon, even after you have begun treatment, because they have two subterranean instars and a slow life-cycle (about 28 days). Just stick with the plan outlined below and you *will* win this battle. I promise.

By EBKauai [CC-BY-2.0 (http://creativecommons.org/licenses/by/2.0)], via Wikimedia Commons

Here's what you do. It's a simple two-step plan:

First, buy some mosquito dunks or another source of *Bacillus thuringiensis israelensis* bacteria (Bti). Toss the dunks in your watering can, reservoir or DWC buckets. If you are growing in soil, water your plants using Bti-treated water from the watering can. Doing this will kill the fungus gnats' larvae. (By the way, do

not worry about using Bti. It is safe. In fact, you could drink a glass of Bti with no ill effects.)

Next, put four to six yellow sticky traps around your grow to kill the adults. Horizontally positioned ones work better than vertically positioned ones. I have no idea why, but they do--it probably has something to do with reflectivity. Monitor the traps and replace them as needed.

Root Aphids

Root aphids are not terribly common in indoor grows unless you have brought in soil from outside. You probably will discover these pests by accident while cleaning up between grow cycles. If you spot root aphids, toss the infected soil, and clean your pots and surfaces thoroughly.

If you somehow discover them while

your plant is growing *and they are hurting your plant*, dunking in pyrethrins for a couple of minutes provides a good measure of control until you can finish flowering and clean your grow space with bleach.

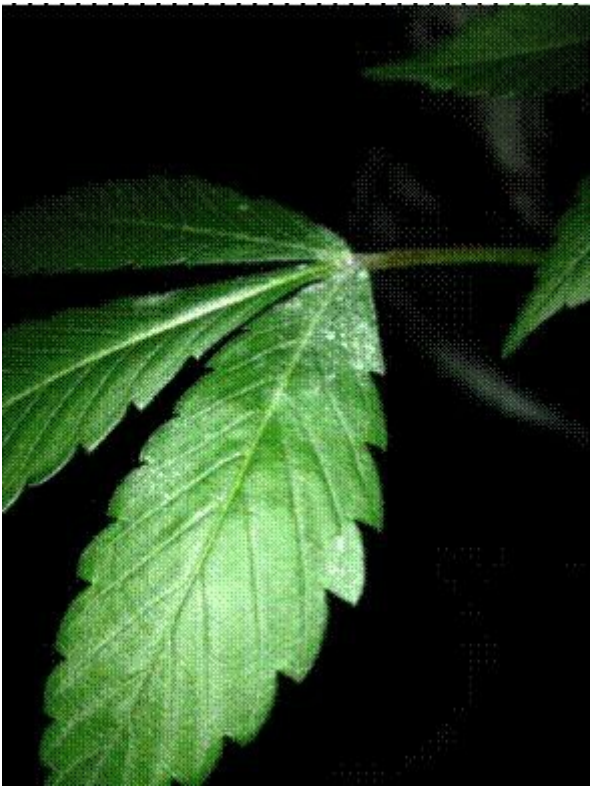
Root aphids. "Pemphigus bursarius, Wollige slawortelluis" by Rasbak - Eigen werk. Licensed under Creative Commons Attribution-Share Alike 3.0-2.5-2.0-1.0 via Wikimedia Commons - https://commons.wikimedia.org/wiki/File:Pemphig

THE FUNGI

Powdery Mildew (PM)

I wish I could say that powdery mildew isn't the spider mite of fungi; but once you have it, that's precisely what it is. This fungus is apparent on the surface of the leaves, but sends hyphal taps (haustoria) into the plant cell to obtain nutrient.[121] It is hard to eradicate. Cloning an apparently clean part of an infected plant, and then discarding the remainder of the plant is not a guaranteed way to eliminate PM from your grow room.

Fortunately, avoiding PM in the first place is easy enough. Simply keep the air in your grow space moving and keep the humidity low (below 40-percent). PM thrives in humid environments, as you might expect. Low humidity favors spore dispersal, high humidity favors growth. Unfortunately, this complements typical day/night conditions.



Powdery Mildew

Temperature is also an important factor when dealing with powdery mildew. PM is most active between 60o and 80oF (16o to 27o C). It is inactive at temperatures greater than 90o F (32o

C).[122]

So how do you deal with it? You can manage it by keeping your relative humidity (RH) low and your temperature high; but keep in mind that plants tend to slow down around 90o (32o C), so this is a balancing act. Doing this in combination with the use of an oil product such as JMS Stylet Oil(R) is a fairly effective way to control PM.

Water, counterintuitively, inhibits spore germination,[123] so rinsing leaves with water can also help; but doing this can also germinate other fungi and raise the humidity, therefore such rinses must be isolated and used sparingly.

Sulfur burners are a good bet and can also be used. Sulfur kills the fungus and is easily washed off the plant. I do not, however, recommend using sulfur

during the flowering stage.

Another product I have found to be highly effective against powdery mildew is Ferti-Lome(TM) Liquid Systemic Fungicide II (Propiconizole). Propiconizole is a systemic fungicide and therefore should not--I repeat NOT--be used during the late stages of flowering. As these things go, Propiconizole is fairly innocuous to plants and animals (except fish--it is deadly to fish). It requires two treatments and works amazingly well. As always, follow label instructions and don't be irresponsible with the disposal of unused material.

If you find you have a PM infection during flowering, drop the RH by running a dehumidifier, raise the temperature, and manage the infestation by using water rinses, excising badly infected material, and using botanical

oils until harvest. At that point, you can remove your plants, treat them with sulfur and then rinse. Next, clean everything again with a 10-percent bleach solution. It's a lot of work, so try to stay ahead of the infection by watching your grow-room's air conditions from the outset.

Pythium

Pythium is also known as root rot, though it can infect stems as well. It is actually one of a group of related oomycete parasites, but it is often treated like a fungi as it behaves in much the same way. It is a real sonofabitch to get rid of, but it is easily prevented.

You will know you have encountered it when your roots turn to mush and your stems soften and wilt. Pythium often hits cloning apparatus because of all

the small parts where it can hide and because electrical circulating pumps tend to heat water to a temperature that is conducive to the flourishing of this parasite. Pythium will also appear in standing water or even in regularly-used water tanks. It is spread during its "swimming" stage through infected water. Therefore, a strict cloning protocol that does not include spray-type cloning machines goes a long way toward preventing pythium infection.

Once you have a pythium infection, it is my experience that you have on your hands a total loss. I have never known a grower who beat pythium while managing to save the plants. Occasionally, a horticultural-strength peroxide can reverse an infestation, but unless it has been caught early, this effort is probably in vain. When pythium is discovered, the best procedure is to destroy the plants and

sterilize all equipment that may have been included in the disease process.

Prevention, thankfully, is simple: keeping everything in the grow room clean is sufficient. Washing nursery pots between use, washing tools, disinfecting the potting bench and cloning area, washing hands and donning sterile disposable gloves is critical to preventing pythium.

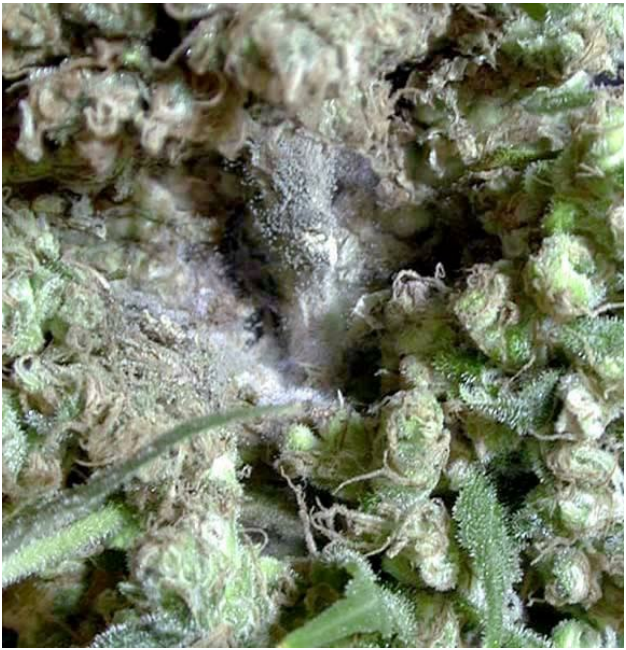
Soil or other growing substrates should not be sterilized. While there is probably pythium in any substrate, it is competing with and controlled by other microbes. Sterile media is an open invitation to pythium. Always inoculate your soil or growing media at the outset of your project with friendly fungal and bacterial cultures to prevent pythium from taking hold. Species such as*glomus intraradices* are readily available at your local grow shop and

make for an easy way to outcompete infectious microbial species. The principle is similar to the one brewers use to ferment their beer: by introducing the organisms you want to thrive in the media early on, the bad organisms cannot effectively compete because you have given the good guys a head start.

Botrytis

This is the dreaded bud rot. It strikes right at the end, after 90-percent of your work is done and you are most anxious to get through harvest and try out your pot. Thankfully, it is not very common. It also must begin with some food source, meaning a dead or dying leaf or an open wound, before it can spread to healthy plant tissue. Proper maintenance of your plants (removal of necrotic leaves, not breaking stems) combined with good humidity control

will prevent you from ever having to deal with this fast-spreading nightmare.



Detail of botrytis on previously great bud.

Unfortunately, some plant strains are highly susceptible to botrytis. If you do end up with an infection, I recommend that you discontinue running that strain and find one that is more resistant. If you are careful and you check on your plants frequently, this should still not be a problem; but if you do find a

white spot that rapidly progresses to dark grey, that's botrytis and you need to act quickly.

Carefully bag the infected bud with a plastic bag; then, using a sterile scalpel, excise the affected bud (give it a wide margin) and remove the infected plant material from your room. There are going to be billions of spores in the room now--I mention this so you are under no delusions about that. Bagging it will have taken you from a couple trillion spores down to something in the billions, and therefore helps in the management effort.

Following the removal of the infected plant material, the room's RH should be reduced as much as possible. Also, increase air flow to limit the amount of standing respired water on the surfaces of leaves and in the folds of flowers. Then, all you can do is hope for the

best.

Under other circumstances, you could try to use a fungicide; but because botrytis typically strikes when you're in the flowering stage, and because you intend to smoke these flowers, this chemical-based solution is out. I have had a couple occasions when I found botrytis, removed the affected buds, increased airflow and then saw the plants continue to flower out with no additional affected areas developing, so don't despair. The loss of a bud or two won't ruin your harvest. Do not let stinginess prevent you from cutting a wide margin of infected plant away. Better an extra bud lost now than a whole plant later.

Observe

Check on your plants frequently. Observe their growth patterns and

characteristics. Get to know them. Watch for color changes in the leaves. Veining, yellowing, necrosis and spotting are all indications that your plants need attention. Watch for small, pale-green pinprick-sized spots or little squiggly lines on the leaves that could indicate mites or thrips. Watch out for bits of powder or cotton-like growth on the leaves. Check on the roots every now and then. Check the buds during flowering. Don't panic, don't over-analyze, and resist the urge to tweak your plants; just watch. Remember, an ounce of prevention is worth a pound of cure.

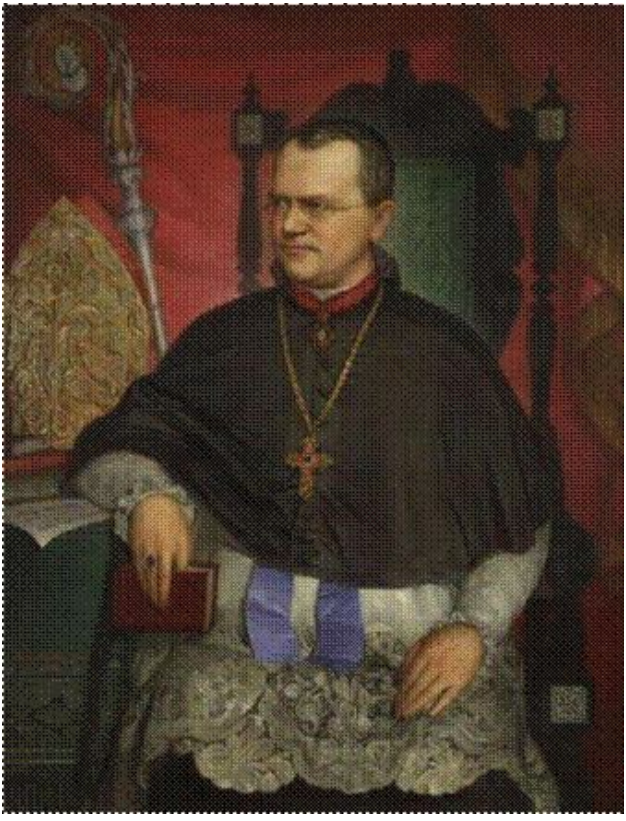
In Summary: Most problems in the grow room result because of growers who either won't leave their plants alone to just grow, are lax about cleaning or do not adhere to protocol. A good eye for developing problems will prevent common insect and fungal

infestations from getting out of hand. Once you have identified a problem, don't panic or despair; do act deliberately and decisively, giving the plants time to respond to your treatment. With the exception of pythium, you can almost always save most of your plant material if you follow the instructions given.

SECTION 3: MORE DETAIL THAN YOU NEED

Basics of Mendelian Genetics

Way back in 18-dickety-2 an Augustinian monk by the name of Gregor Mendel lived and studied at St. Thomas Abbey in what is now Brno, Czech Republic. He found himself in the monastery garden with some extra time on his hands, no access to women, and a plot of pea plants to mess around with, so he used a paint brush to selectively pollinate the pea plants. A keen observer of his plants, Mendel noticed patterns emerging in the various characteristics of the plants' offspring after outcross and self-pollination events. Peas were a fortunate choice for Mendel because they have several easily distinguished characteristics and do not exhibit partial dominance, which may have made his discoveries impossible until much later.



His work was published in 1866, but not noticed until 1900, owing to the outsized influence of another scientist by the name of Lamarck who proposed a theory of heritable acquired traits, an idea now discredited. Mendel

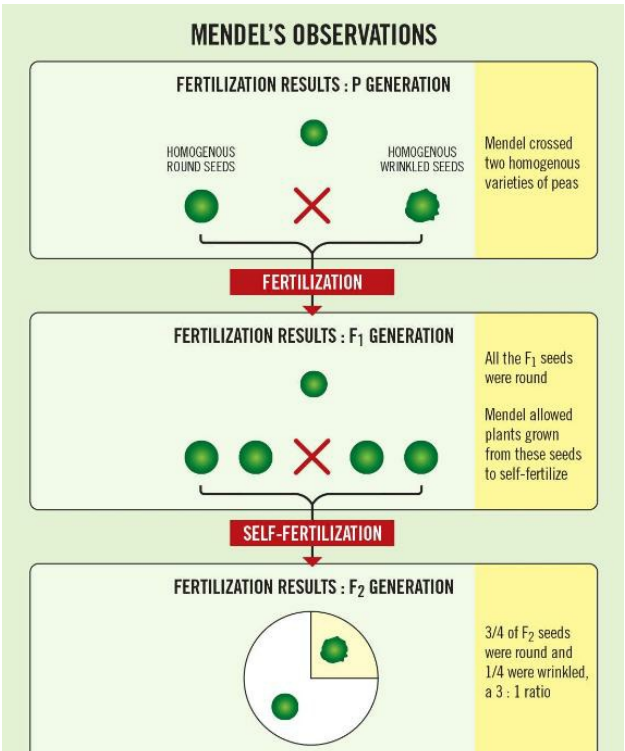
promoted what he called "units" of heritability, which we now know as genes.

Mendel noticed that pea plants inherit the following traits in an either/or fashion:

- Pods: inflated or constricted; yellow or green
- Peas: round or wrinkled; yellow or green
- Flowers: white or purple; axillary or terminal position
- Stems: short or long

Specifically, the pattern he noticed (to take the example of pea color) was that the offspring (F1--where F stands for filial, meaning offspring, and 1 means first generation) of outcrossed parents (hybrids)--regardless of pea color--

resulted in plants that produced predominantly yellow peas, and the offspring of a self-pollinated plant with yellow peas often exhibited a 3:1 yellow-to-green pea ratio.



Furthermore, subsequent generations (F2) of self-pollinated plants (pure bred, or inbred) would either show all-green, all-yellow or again, the 3:1

yellow-to-green ratio. Mendel's great insight was that each parent contributed a unit (allele) of heredity to its offspring, even when such a unit was not apparent in the offspring. He hypothesized, correctly, that certain units were dominant over other, recessive units.

This observation was a critical piece to his understanding of genetics. It demonstrated that even if both green and yellow alleles were inherited, the plant would produce yellow peas but still be able to pass along a green allele to its offspring.

What's happening then is that for each trait we can see (phenotype), two alleles--one from each parent--are contributed.

Take any trait--let's say purple or white flowers. If we cross a purple-flowered

plant with a white-flowered plant, where purple is dominant, we can see that the offspring can have either purple or white flowers. A white flower must carry the double recessive white allele (otherwise it would show up as purple), but the purple flower can have allele pairings that are either purple/white or purple/purple and still be purple in appearance.

From this hypothesis, Mendel was able to determine that these alleles were segregated (one from each parent) and randomly assigned to the offspring plant. That's his first law, called the Law of Segregation. The second observation he made was that the alleles were passed down independently of alleles that determine other plant traits (stem length, pod shape, etc.). This is known as the Law of Independent Assortment.

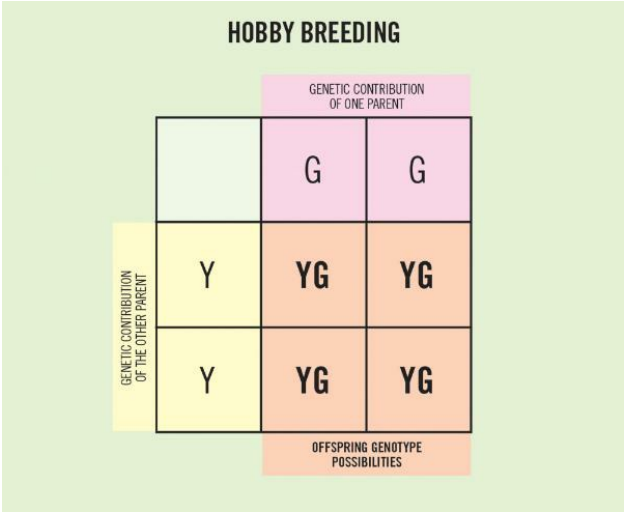
That's three big victories for Mendel (the theory of dominance plus his two laws), but he was never aware that he would make such a huge difference to our current scientific understanding of biology. When he presented these ideas in his paper,*Experiments on Plant Hybridization*, a year after he presented them in person to the Natural History Society of Brno, the scientific world was trying to make sense of the variety that appeared in hybrid offspring and had already accepted the idea that such offspring were "inherently unstable," which reflected the scientific bias at that time for "trait blending."

What Mendel was beginning to describe when he articulated his Law of Independent Assortment was the phenomenon of meiosis (halving of chromosomes) that occurs in gametes. (Please see the section on meiosis and

mitosis in Appendix IV.)

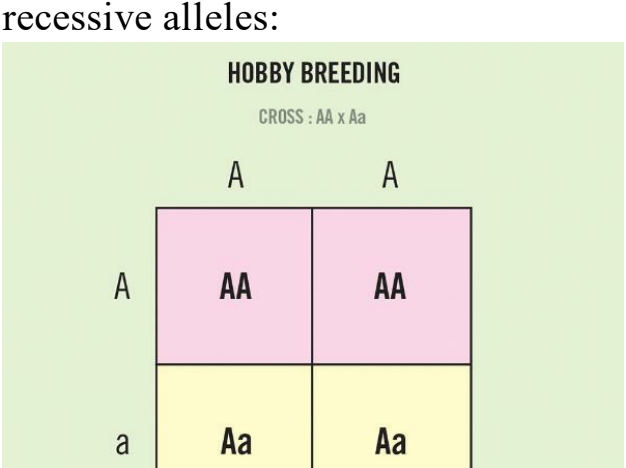
Practical Hobby Breeding

One can use the ideas developed by Gregor Mendel to predict the traits of offspring. It is especially helpful to layout the breeding project in what are called Punnett Squares, which are named after an English fellow named Reginald Punnett. Here's how ol' Reginald laid out his inheritance probability problems:



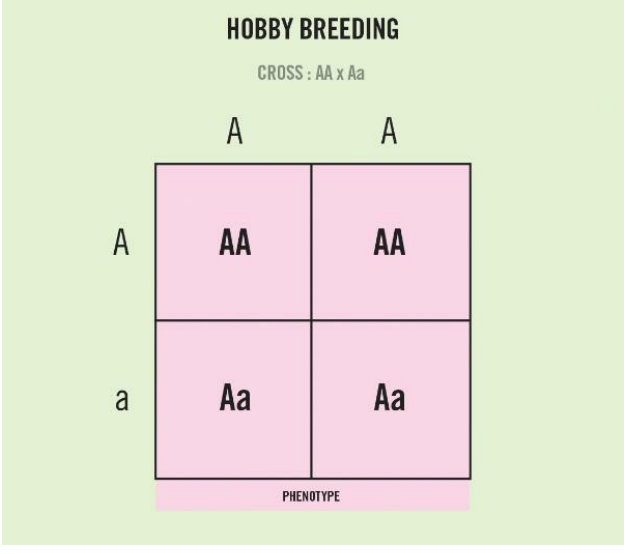
Let's have another look, but with a

different set of parents--ones with some recessive genes in the mix, where capital letters denote dominant alleles and lower case letters denote recessive alleles:



Note that the recombinations occur as one allele from each parent per trait--they are segregated. When a parent has two of the same allele, we describe this condition as homozygous; when a parent carries different alleles, it is

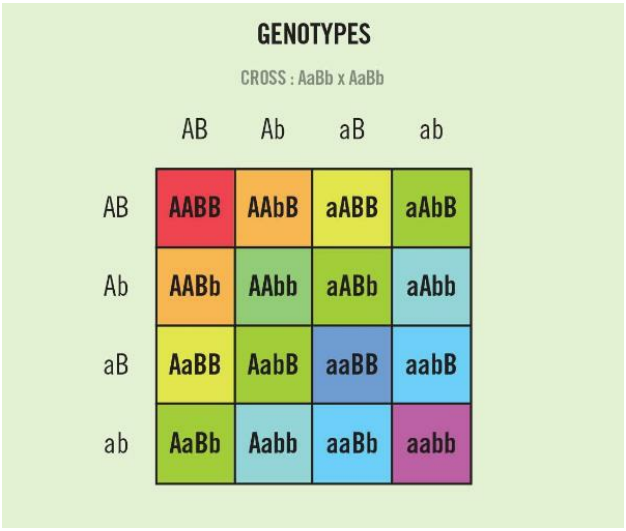
said to be heterozygous for that trait. We can see that the red and green boxes highlight the same genotypes--that is, plants with the same pairs of alleles (regardless of whether they are homo- or heterozygous). But what about the *phenotype*--the way the plant will appear? Have a look:



Because A is the dominant allele and one parent is homozygous while the other is heterozygous, the dominant A

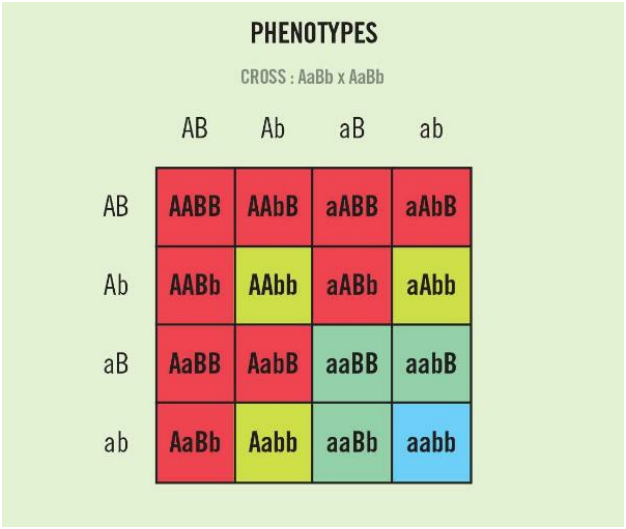
allele is the one that gets expressed--every time. So even though there are two genotypes present in the offspring (AA and Aa), there is only one phenotype (A).

Here's a look at what happens when we add another trait to the mix--so that's two traits times two alleles per trait giving us four alleles to work out inheritance probabilities, and both parents are heterozygous for each trait this time:



Note that the order of the allele in the string in each box we use is irrelevant, thus when we cross AB x ab = AaBb, this is the same as AabB, which is the same as aABb--they all show a dominant A, recessive a, dominant B, and recessive b.

In the multicolored box above, we have nine genotypes, but, because each parent is heterozygous for each trait we have only four phenotypes!



Note the ratios expressed here, because this is what makes this practical for you as a hobby breeder. You can't see genotypes, but you can see phenotypes, so keep an eye out for the ratio: 9:3:3:1. What that demonstrates is that your parent plants were each heterozygous for two traits--say early-flowering and purple-color. This information can provide you with insight when it comes time to do your next cross. (I am assuming you want early-flowering and purple-color.)

Let's say that late-flowering and green-color are the dominant traits. We will denote late-flowering as A, and green-color as B. That makes your job fairly easy since the smallest number of your plants' offspring will exhibit the traits you want (blue square). Heck, each of those plants will be homozygous and you can call it a day--you will have successfully bred the unwanted traits

out! Keep only the few desired plants, and discard the rest. Then, when you inbreed your homozygous early-flowering purple plants, all future generations will have those same traits.

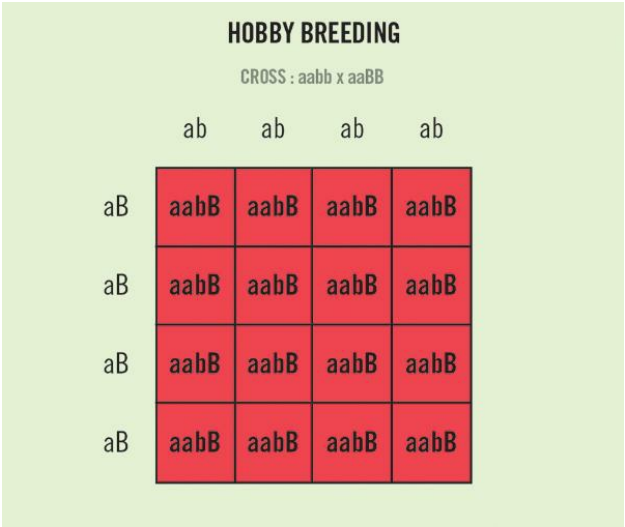
But when are things ever that easy? Let's say your audience has turned against you and your friends are now demanding green bud instead of purple. Now it's back to the breeding room and this time you want early/green plants. That's one recessive trait (early, or "a") and one dominate trait (green, or "B"). Now you have to pick the plants that are hitting in the middle ratios, which could be any of the allele combinations represented in the green squares. Unfortunately, you don't know which of the offspring-plants have two homozygous alleles for each trait that you want. What you do know is that you have two genotypes for your one

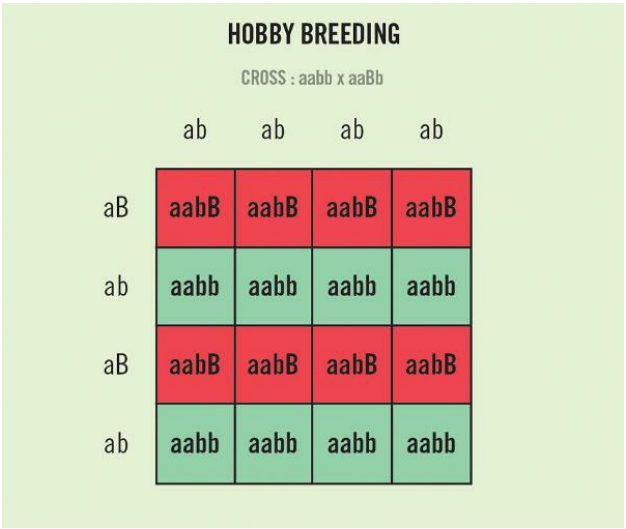
phenotype and you want to identify and keep your aaBB double-homozygous plants. How do you separate the homozygous plants from the heterozygous ones? Below, I will explain two different methods you can use.

Method One

Keep all of your plants and conduct what is called a test cross. Here's how it works: Go back to your grow room and find your recessive homozygous early/purple (aabb) plant. Next, cross your remaining plants (which you know are either aaBB or aaBb) with that known, homozygous recessive (early/purple) plant and you will be able to determine which of your plants are homozygous. This is because the homozygous ones will produce the B trait 100% of the time (BB x bb), while the heterozygous plants will

produce half purple, half green offspring (Bb x bb).



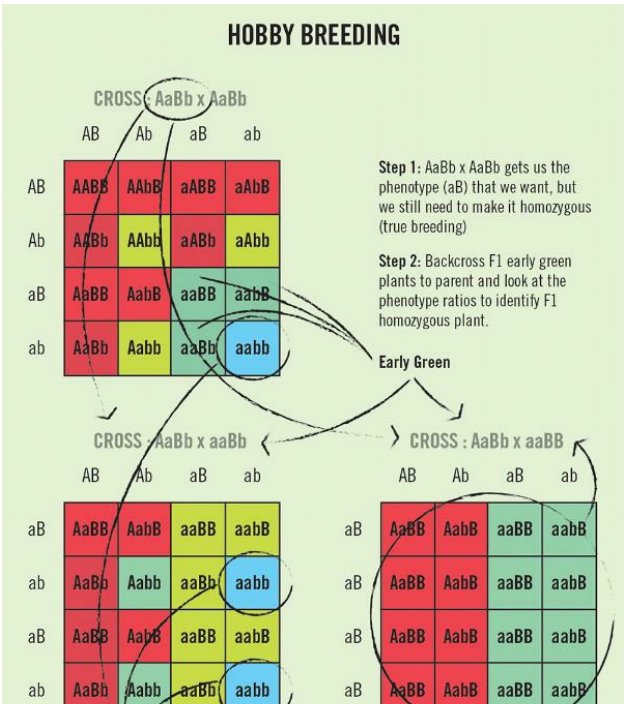


Keep only the homozygous plants and discard the rest. Congratulations, you've cleaned up your strain and you have, with only two crosses, produced a perfect, homozygous aaBB early-flowering, green plant (and, of course, you were smart enough to keep both a male and female)!

Method Two

Let's say you no longer have your

early/purple (aabb) and you have to finish the early/green strain without using a test cross. How can you do it? Well, you can breed back to your parent plants, which you know to be heterozygous for both traits (because you saw the 9:3:3:1 ratio in their offspring). Hence, your backcrosses will look like this:



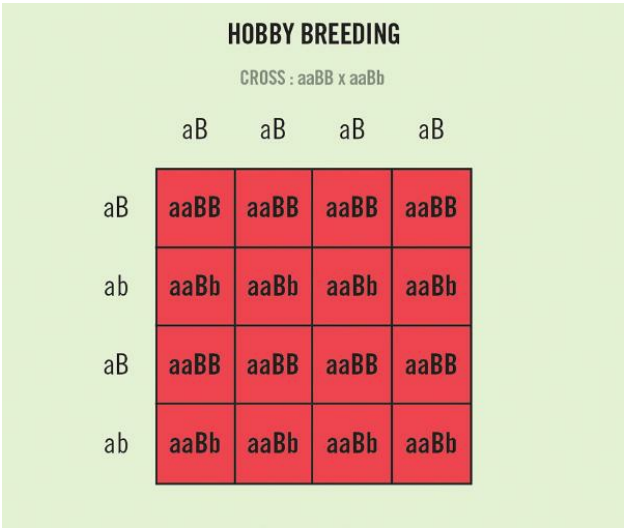
As you can see from the predicted offspring of your backcross, you will know quickly from their offspring which of the backcrossed F1 plants is your homozygous plant and you're

ready for your next step!

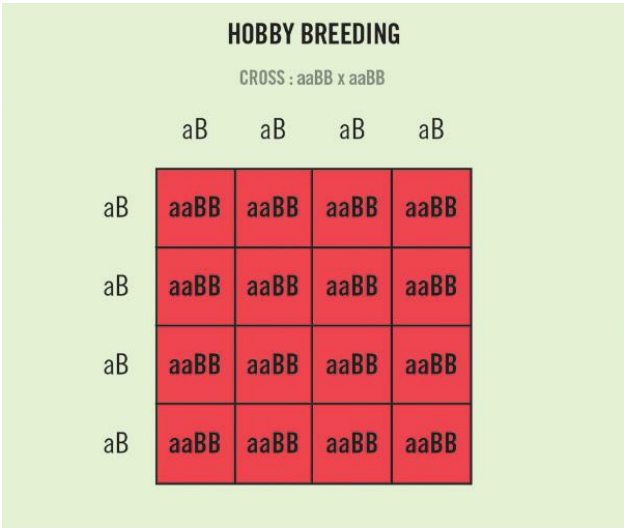
Once you have identified your "good" F1 (the plant that is aaBB), your goal is to stabilize that plant so that all offspring are aaBB, rather than falling into the half-heterozygous situation you're currently faced with (there are two genotypes represented by the green phenotype squares--aaBB and aaBb). Your objective, restated, is to find a suitable mate that will result in offspring that are homozygous for both traits--early and green (aaBB). You will need another aaBB to produce true-breeding seed stock. What do you do? Well, as it turns out, you just created an early purple plant which must be homozygous. This means you can now do a test cross and identify your homozygous early/green plant.

Note that for practical purposes, you can stop without doing a test cross.

You have already identified your "good" F1 (a plant that is aaBB), and you are now sitting in a room full of plants from that experiment, almost 44-percent of which are either aaBB or aaBb. Without even working the Punnett Square, what do you notice about these crosses? There's ZERO chance for an undesirable phenotype!



This cross's phenotype...



...is the same as this cross's phenotype!

If we were breeding a plant with a perfect flower (monoecious), we could self-cross our aaBB and we'd have pure seed stock. But we have a dioecious plant, so self-crossing is not possible (at least not without creating some problems in subsequent generations' sexual lability). For practical purposes, there is nothing left to do; your third round of breeding will contain only the plants you want

(whether you cross aaBB x aaBB; or aaBB x aaBb). It is now true-breeding! (Better still, your seed customers will not necessarily enjoy this advantage because the recessive gene is still in the plant and can show up in later generations; they will have to return to you to buy more seeds.)

As easy as that was, there are lots and lots of other traits at play; however, identifying and working with just two will still leave you with tremendous variations in your offspring. You will want to consider a number of other factors (such as yield, disease-resistance, and potency) if you are planning to breed the next super strain of pot.

Suppose you wanted to control four different traits, which isn't all that crazy. In this case, let's say you are looking for a plant with the traits of

early-flowering, purple-color, high-potency and high-yield. If they are all from heterozygous allele pairings, you will have 16 possible phenotypes and 81 possible genotypes creating those phenotypes.

This sort of breeding is not impossible to do, but to achieve the ratios you need to see, you will have to grow a LOT of plants. Compound this with the fact that you will probably have at least one of those traits already homozygous in the parent plants; add in the fact that not all traits are the result of two alleles, but often result from more than one allele pairing; further complicate things with the fact that some traits exhibit incomplete dominance; add in the likelihood that some mutations will occur given the large populations and... you've quickly got your hands full!

Breeding for more than two traits is extremely difficult, to say the least; and with a three-month grow period for each generation, you're looking at years and years of work to come up with just one good strain. This is what leads me (and, it seems, the rest of the industry) to either stick to a series of dihybrid cross experiments or engage in...

Simple Hybrid Breeding

One way you can have loads of fun with your plants while coming up with novel new strains is by simply crossing two plants you like, growing out the resulting seed and picking the plants you like best. Since most of us reproduce our plants asexually (clone), there is no need to go any further than this. Is this actually breeding? Sure it is! In fact, most plants sold on the seed market are simple F1 hybrids. Is your

new plant strain stable? No way, Jack! Have fun--and remember to share!

Hybrid Vigor

Also called heterosis, this is a fortunate phenomenon for the F1 breeder. For reasons poorly understood, when two dissimilar plants are crossed, their F1 offspring exhibit heterosis, which is a reinvigoration of the genetic line. The F1 plants, in other words, tend to outperform both parents in almost all aspects.

Mass Selection Breeding

Perhaps you have heard of landraces. These are colonies of plants that, over many generations of inbreeding, have developed some uniform growth characteristics. A large degree of genetic diversity remains in landraces; but the strain, because of

environmental pressures, does have widespread identifying characteristics and the plants are typically good-yielding while requiring little in the way of input. An example of this is the famous Malawi Gold, an African sativa. The techniques used by Mother Nature--consistently and repeatedly outcrossing genetics and applying specific pressures to eliminate the unfit individuals--can also be used by you.

The general concept is to plant large numbers of individual plants, select and cross the best from the batch, and then eliminate the worst. It's haphazard and slow on the downside; but it works to give you generalized improvements over many generations and enables you to enjoy hybrid vigor and genetic diversity for a long time.

Mutations and Bud Sports

Every so often nature presents us with a surprise. If you are on the lookout for it, you may have something truly special on your hands. In field crops, where thousands of individuals are planted, every so often a genetic mutation occurs. That mutation can result in an especially well--performing plant--or at least one with unique characteristics.

A bud sport is a branch of a plant that is distinctly different from the rest of the plant, usually as the result of some spontaneous mutation. It can be cut and propagated. Nectarines are an example of this; they are bud sports of peaches.

As you can imagine from the description, these discoveries are rare. Unless you are growing thousands of plants, finding a mutation or bud sport is akin to winning the lottery. But it does happen. I have found two bud

sports in my life, neither of which were cannabis. They occurred in my flower and vegetable gardens. You will know a bud sport when you see it and if you do, I advise you to both continue the germ line through asexual propagation until you can find a good home for it, and cross one of your clones with the best mate you can find.

How to Pollinate

We covered plant selection a bit earlier in the book, and it's worth reviewing that section again if you are planning on breeding your plants. It must be stressed that there is nothing to be gained by breeding bad plants. Should a particular recombination result in some undesirable characteristics, a responsible breeder will stop, go back up the line to the point just prior to when the undesired characteristic was introduced, and then

make another attempt. Your parent plants should represent the best you are able to find for the traits you are attempting to breed. A responsible breeder will always have clear objectives going into the project.

- **Good traits** include: short flowering-time, high-potency, heavy-yield, fungus resistance, nutrient-tolerance, short inter-nodal length, pleasant aroma, draught-resistance, and sexual stability. These traits are always desirable.

- **Ambiguous traits** include: percentage of constituent cannabinoids, terpene, flavonoids, leaf size, plant size, plant color, and auto-flowering ability. These traits are application-specific.

- **Bad traits** include: long flowering-time, low-potency, low-yield, fungus-susceptibility, nutrient-sensitivity, long inter-nodal length, foul aroma, draught-susceptibility, and a tendency to intersex (become a hermaphrodite). These traits are never desirable.

One of the biggest hurdles for cannabis breeders is the fact that this plant is dioecious. Breeders of monoecious plants enjoy the ability to self-pollinate their breeds. In cannabis, although this is possible, it is not a good idea (see Section 2: How Seed Breeders are Fouling the Gene Pool) because it introduces sexual instability into your line and can ruin your entire crop if you aren't careful.

Breeders of monoecious plants can simply isolate their plant, give a little

shake and wait out the results. For cannabis breeders, there will be situations in which you will simply have to conduct test-crosses. Aside from all this, though, is a practical concern: how to deal with pollen.

It's a messy business! Male plants finish much faster than their female counterparts (some things are universal, I guess.) They must, if they are to pollinate the females before they ripen. Plus, cannabis is a wind-pollinated plant, which means that its male flowers are structurally adapted to effectively disperse pollen--the slightest puff of air or breeze will carry its pollen great distances. This can be ruinous to your crop if you are not careful! (In Colorado, I often wonder how long it will be before a hemp crop pollinates and ruins a nearby psychoactive cannabis grow-facility's crop.) Timing is everything.

You will be best served by keeping your males separate from your females--in a different tent, room or part of the house, if at all possible.

Your best strategy would be to reduce the number of flowering sites on your male plant to a manageable few. One to three should be plenty. Reducing the foliage thusly will allow you to turn off your fans toward the end of its life. Then, keep a close watch on the ripeness of your male plant's flowers. You will know when they are fully developed because the bracts will pull back, revealing a cluster of five anthers ("bananas") hanging from the axil of your budding site. When these ripen, they split lengthwise to expose their pollen to the air. Containing this entire branch inside a polyethylene bag for the final two to four days will allow you to fully capture and contain your pollen. Transfer the pollen from

the bag to a paper envelope and keep it in your refrigerator or freezer until you need it. (Paper will allow the pollen to dry, whereas keeping it in plastic will create a mold-prone environment.) You can keep pollen indefinitely in this manner. Don't forget to label your pollen.

When the time comes for you to pollinate your breeding female (use a plant that is young, with no signs of reddening of the stigmas), you should turn off your fans and still the circulating air. Don a surgical-style mask to prevent your breath from stirring the pollen, and then, using a fine-tipped paint brush (just as Gregor Mendel did) brush some pollen onto the female buds you have selected.

It takes very little pollen to fertilize several female sites. Excess pollen will only float around and create more

seeds, so be sparing with it, but fertilize about six budding sites. You may want to bag the female branch (or branches) that you have pollinated. Doing this will help to prevent the spread of pollen; but be sure to remove the bag in a day or two or you will end up with a mold problem. Label the pollinated budding site, identifying your parent plants and date of the cross, as such:

"Seed (female) parent name X pollen (male) parent name, date of fertilization, number of generation, e.g, F1, F2, etc."

In your breeder's notebook, identify the cross, include the date and clearly state your intended breeding objective, e.g., "attempt to combine purple-flowering characteristics of mother plant with short stature of pollen plant."

After the female has been fertilized, the pollen tube will quickly begin to grow down the stigma toward the ovary, and once this has started, you may spray the female down with water. This inactivates any stray pollen but does not harm the fertilized female. Then turn your fans back on and let nature take its course. Remember, never rush.

You will know that the female seed has become ripe when the containing calyx swells and splits in such a way that you can see the seed inside. It will be hard, brownish, spotted or zebra striped and no longer green. Letting the seed finish before you harvest is critical. If you feel that you may have jumped the gun, you can tell a viable seed from an aborted one by placing it on a table and applying a medium amount of pressure with your fingertip. If the seed crushes easily, it was never viable. If it feels hard when

compressing with the pad of your finger, it will germinate. You can store your seeds indefinitely by keeping them in the refrigerator or freezer. Don't forget to transfer your label to your seeds.

As you grow the seeds out, go back to your notebook and make notes of: date germinated, days vegetated, date flowering initiated, date harvested, performance characteristics, yield, aroma, etc. If you are using Punnett Squares, now is the time to check your ratios and work back to identify and confirm parental genetics. Do you have an obvious homozygous recessive? If so, keep a clone of it; you will want it for test crosses.

Note: A fertilized female plant will finish more rapidly than an unfertilized one. It will also cease or dramatically slow down producing cannabinoids

once it has been fertilized.

In Summary: By using the principles discovered and elucidated by Gregor Mendel, the squares devised by Reginald Punnett as a tool to predict patterns of heritability, and a few techniques described here, you can breed your own pot strains. Be sure to observe carefully and take plentiful notes. See you on the cover of *High Times*!

Soil Structure and Chemistry

Why You Need to Know: If you grow in soil, learning the principles of soil chemistry is like flipping on a light in a darkened room. You owe it to yourself to learn the contents of this chapter. (Even if you do not grow in soil, it's still interesting.) Your job as a grower will become much easier once you have this knowledge.

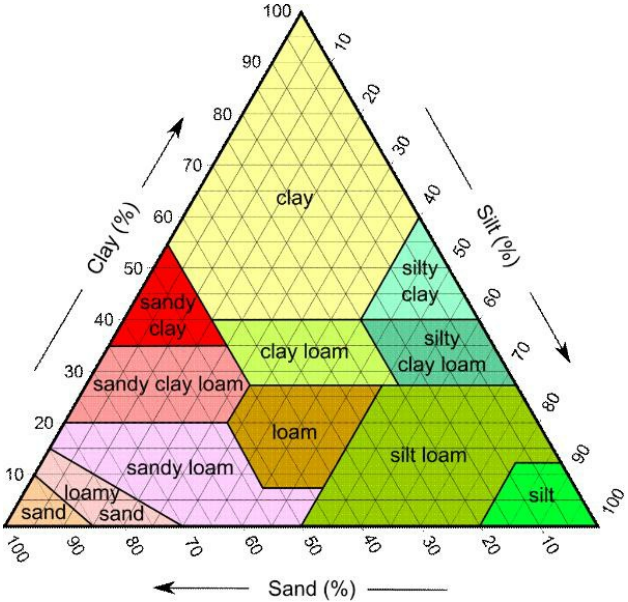
Soil is composed of three structural elements: **sand**, **silt** and **clay**. These are defined as follows:

- Sand: rock (mineral) particle between 2.0 mm and 0.05 mm in diameter

- Silt: rock (mineral) particle between 0.05 mm and 0.002 mm in diameter

- Clay: rock (mineral) particle less than 0.002 mm in diameter

The soil that is made up of these particles is named according to the predominating percentages of each. The extreme points on the USDA soil texture triangle are bad. We're shooting for the loam area.



By Mikenorton (Own work) [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

I recently encountered a confused grower on an Internet forum. He was trying to grow his cannabis in buckets of sand. According to his reasoning, he could add all the nutrient he needed and could easily flush whenever he wanted to. As you may have guessed, his results were less than amazing. So,

why does this approach fail?

The problem this grower ran into is that particles of sand are big as far as plants and nutrients are concerned. Sand is big, smooth and not very "sticky" to ionic nutrients. Recall that nutrients are only useable to plants when they are in their inorganic form. What does that mean? Well, to be organic--chemically organic, that is--a molecule must have a carbon ring attached to it. It's that simple. Organic compounds are carbon-containing; inorganic compounds are not. End of discussion. We are setting politics aside--this is what a chemist will tell you.

Plants do not use organic compounds; they use inorganic compounds in ionic form. An **ion** is a molecule or atom that does not have an equal number of **protons** (+) and **electrons** (-). Because

their electrons and protons are not balanced, ions carry an electrical charge. All of the nutrients a plant needs must be in this ionic form or they cannot be used because they cannot be exchanged via active transport. Moreover, each ionic mineral has either a positive or negative charge. (If it has a positive charge it is called a **cation**; if it has a negative charge it is called an **anion**.) The charges on both the ions and the soil particles keep them stuck together like magnets and prevent the nutrition from washing away. The mineral ions adhere to, or are **adsorbed** onto, the soil particles. When lots of ionic minerals are adsorbed by the soil, it makes for lots of useable plant nutrition.

The Two Components that Make Soil Chemically Active

Sand, because of its large size, has a

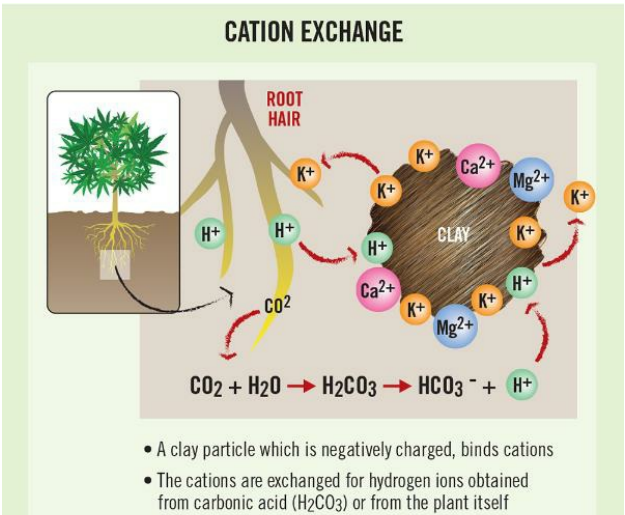
low surface-to-volume ratio and therefore a low electrical charge. Silt is smaller and has a better surface-to-volume ratio and therefore it has a higher charge. Clay is the smallest, with particles so small that you need a microscope to see them. It has a high surface-to-volume ratio, and therefore a high charge. Think of it this way: volume "dilutes" the charge; the smaller the particle, the more "concentrated" the charge.

This electrical charge allows mineral nutrient ions to stick to the constituent soil particles. Look at the soil texture triangle. You can see that, based on the percentage of sand, silt and clay, a given volume of soil may have a greater or lesser charge than another. The amount of total electrical charge in a given volume of soil is called the soil's **Cation Exchange Capacity**, or CEC for short. The more sand in a

given sample, the lower its CEC will be; conversely, the more clay in the sample, the higher its CEC will be. Also, larger amounts of organic matter, or humus, in the sample will result in a greater CEC.

Humus and clay are the two sources of chemical activity in soil. This is because they are the smallest particles in soil. Now before you run off to the compost pile and mix in a bunch of leaf mulch, you should understand a few things about organic matter. The kind of organic matter you want in your soil is not last year's garden waste. You want the tiny particles that are the result of years of bacterial, fungal and physical breakdown of such waste--the particles so tiny that they neither float nor sink in solution. These are called **colloids**. Both clay and humus particles are often small enough to remain in colloidal suspension--they have the

highest chemical activity and give your soil its CEC.



Cation Exchange Capacity

Cation Exchange Capacity is a measure of how many H^- ions can be held in 100 grams of soil. The clay and humus particles in the soil are generally negatively charged and they therefore adsorb cations. When the plant needs to absorb a cation, it secretes an H^- cation (recall the process of active

transport), which the soil particle attracts (because it is negatively charged) and in exchange releases a cation of useful nutrient. The clay (or humus) particle readily takes on the H^- because it is a lower molecular weight than the cation it is giving up ($NH4^-$, for example). The number of times 100 grams of soil can make such exchanges for H^- is referred to as its Cation Exchange Capacity. Specifically, for every milligram of H^- that each 100 grams of soil can trade out, the soil's CEC is increased by 1.

CEC 1 = 1 mg of H^- adsorbing potential of 100 grams of soil.

Since there are other cations to account for (in addition to H^-), another way to look at CEC is through milligram equivalence, or "MEQ." Let's take Ca^{--} as an example. Since calcium has a double charge to it, it can bind to twice

as many soil particle sites as can H^-, which has just the one cation. So although the soil's CEC is the same, it can only hold half as many Ca^{--} cations as it can H^-. Also, because Ca^{--} is 40 times heavier than H^- (but the soil can only hold half as many), the total weight of Ca^{--} held by 100 g of soil with a CEC of 1 is 20 mg to H^-'s 1 mg; hence, the MEQ is 20 for calcium and 1 for hydrogen.

What about anions? I'm glad you asked. After all, plants also need anions (such as nitrate, phosphorus, sulfur, boron, chlorine and molybdenum). Anions are a bit of a problem. They are not easily adsorbed onto soil particles and therefore tend to wash away. Most soils do not have an anion exchange capacity. Plants must get these anions by chance encounter as they tumble and bounce through the soil and eventually contact a root hair. Only rarely does a

soil have an AEC, or anion exchange capacity.

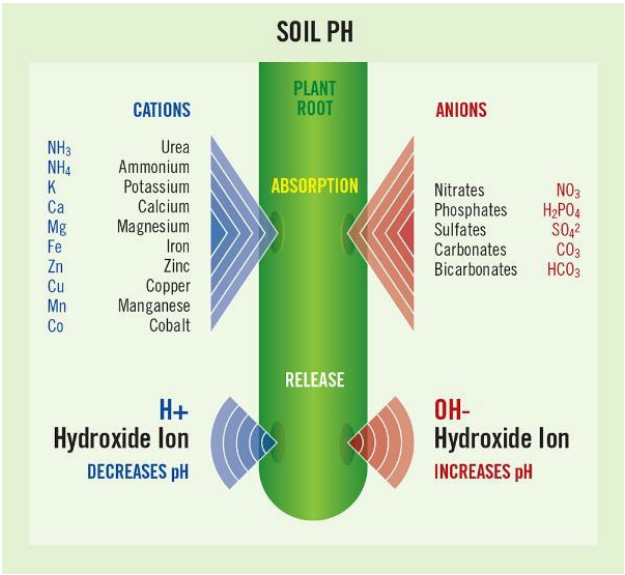
If this sounds unlikely to occur, consider the amount of root surface area a plant has. It sounds crazy, but this has been measured. A botanist by the name of Dittmer calculated the surface area of a typical winter rye plant (much smaller than a typical cannabis plant) back in 1937.[124] Crazy bastard sat there and counted the roots by category and added surface area. Here's what he found: "The 13,815,672 roots had a surface area of 2,554.09 square feet... Living root hairs on this plant numbered 14,335,568,288 and had a total surface area of 4,321.31 square feet... The root hair surface combined with that of the roots gave a total of 6,875.4 square feet."[125] How big is that? Taiz points out that it's about the size of a basketball court.[126] But he's wrong: It's enough to

completely cover one and a half NBA regulation-sized basketball courts, or fall just short of a FIFA soccer pitch!

Soil pH

Your soil is conspiring against you in an attempt to become acidic, and the longer it is in use, the more dramatic this tendency becomes. The more organic matter your soil has, the lower its pH will be. This is because as organic matter decomposes, it releases carbon dioxide, which then reacts with water to create carbonic acid (H_2CO_3) in the soil. Similarly, as minerals decompose, high concentrations of aluminum are released in forms that create acidic conditions. Add to this the use of fertilizers (which are generally acidic because of their reliance on ammonium) plus the plant itself (which tends to acidify soil during nutrient uptake by taking up

more cations than anions), and you have a situation that is precarious at best and that requires your continual vigilance. Ideally, when growing cannabis, you want to keep your soil's pH in the 5.7 to 6.5 range. Do this by periodically adding dolomitic lime.



When growing outside, things are even more challenging because you must account for rain, which is always slightly acidic (owing to CO_2 in the

atmosphere that gets dissolved in the rain). This is true even when we don't account for the phenomenon known as "acid rain," which is cause by industrial sulfur and nitrogen emissions. Rain water pH typically tests at about 5.7. And because anions do not adsorb onto soil particles as strongly as cations, they get washed away by rain and watering; this predisposes your soil to acidification even further.

Tight or Loose: The Calcium-to-Magnesium Ratio

The balance of calcium and magnesium determines how "tight" the soil is. These two cations make up the bulk of bound nutrient in the colloidal component of your soil (clay and humus). Calcium has a large ionic radius, meaning it holds colloids at a distance and flocculates (opens) soil,

whereas magnesium has a small ionic radius and holds its colloids close and therefore coagulates (closes or tightens) soil. The measure of a soil's tightness can be determined by a soils test where Ca and Mg are calculated on a MEQ/100 g basis then the level of Ca is divided by the level of Mg to give a numerical index such that:

- <2 = tight, sticky (or hard, if dry) soil
- 5-7 = just right soil
- 10 = too loose soil.

It is the ratio that matters here, not the total level of each component cation. If you have ever walked through a muddy field and had soil build up on the bottoms of your shoes, you know what a high Mg-to-Ca soil is.

In Summary: Sand, silt and clay make

up soil structure, while the organic component, humus, along with the clay, is responsible for the soil's CEC. Starting with a good initial mix and then maintaining proper soil pH is the key to growing healthy plants in soil. Now that you know what's going on in the root zone, you can more easily identify the problems when things go wrong.

Compost Teas: What We Know

Compost teas are popular, I think, because there's a witch doctor in all of us. We like the idea of "vital energy," mysterious potions, secret recipes and having an advantage over other growers. Belief in magic is seductive. But what are we doing with the compost teas, and can they help? As hinted at in Section 1, I think that compost teas are poorly-understood, but a worthy area of exploration.

I caution growers to regard with a healthy dose of skepticism any claim that compost teas are a magical solution to the problems inherent with growing great plants. There are books dedicated to growing marijuana that recommend the mixing of compost teas under the light of a full moon; there are products that promise that, because they swirl your tea in a clockwise or

counterclockwise vortex, they will impart a certain (male or female!) "energy" to your plants and cause them to thrive (I guess); and while all of this stuff may contain a kernel of truth regarding the value of compost teas, teas simply are not understood at any level of thoroughness to justify such claims.

What we *can* tell about compost teas, we have determined through analysis. We do not need to rely on anecdotal reports or hopeful metaphysics. One thing I will point out straight away is that compost is high in organic material, which means that compost tea is almost always going to be both low pH and high in sulfur. That's not a bad starting place. Since we already know that soils tend to acidify--especially when they are home to a plant--this is not a trivial point. The continuous application of an acidic nutrient

solution ("fertigation") to the root zone of your plants will eventually create a pH crisis unless you are constantly monitoring and adjusting the pH levels.

The second point to consider is that many recent studies suggest that the bacterial content of most compost teas may be their critical effective component.[127] [128] [129] This suggests to me that the introduction of beneficial species directly into your growing medium may obviate the need for compost teas. Some truly fascinating studies about beneficial bacteria and fungi have been conducted recently. For example, a group of researchers at the University of Delaware found that plants in distress put out a "root-to-shoot" distress pheromone that literally calls the soil-borne Bacillus subtilis bacteria to it for help.[130] The bacteria temporarily takes over the plant's immune response until the threatening

stressor is overcome, at which time the plant then resumes control over its own immune system. Meanwhile, nearby fungi will have responded to the call as well, and they act by symbiotically connecting root, bacillus and nutrient! Even those who don't feel much enthusiasm for plants have to admit that's pretty amazing!

A third, and final, point to consider is that the bacterial, protozoan and fungal content of compost teas changes rapidly over time and with respect to the level of aeration to which the tea is subjected. Broadly speaking, there are two types of teas: aerobic and non-aerobic. Both become extremely unstable over time, so it appears that using them soon after they are brewed may be a critical component to their effectiveness.

So far this section has been about root

zone application, but the foliar application is a promising area of inquiry, to be sure. Foliar applications of compost teas have been shown to help drastically reduce the incidence of unwanted fungal infestations.[131] [132] Most studies I have found were conducted on grapes and focused on their susceptibility to powdery mildew. The results have been mixed.[133] [134] [135] However, I have seen studies on tomatoes and curcubitas (squash) as well--all with positive results.[136] [137] Do I advocate the use of compost teas? With the limitation that they be used sparingly (on the order of two to six applications per life of the plant) and freshly mixed before being applied, yes, I do. However, I do not recommend fertigation with compost tea. That is asking for a pH crisis.

In Summary: Compost teas are exciting, but poorly understood. They

are currently the subject of intense research. The benefits of compost teas appear to be linked to soluble nutrients and microbial populations that exist in the originating compost. If you choose to use them, do so sparingly and keep an eye on your plants afterwards. The introduction of unwanted bacterial species is a possibility when using teas, so proceed with caution when selecting your source compost.

Effectiveness of CO_2

Why You Need to Know: The orthodoxy that you should supplement CO_2 at 1500 ppm is wrong.

Although cannabis has not received much attention from the scientific community--owing to its preposterous legal status--it has, thankfully, received *some*. Before we get into that, let's review the orthodoxy that I am about to challenge: 1500 ppm is the optimal CO_2 concentration for marijuana growth. This is what we are told and most believe it to be the received Wisdom of the Weed Gods; yet I believe it to be unsupported by the scientific research. I am therefore calling bullshit on the "1500 ppm CO_2 is optimal for pot growth" heuristic.

The number itself fails to pass the smell test. Always be wary of round

numbers--they are seldom to be trusted. If you don't believe me, go ahead and try to find a single scientific study demonstrating that 1500 ppm is optimal... for *any* plant. All plants have different CO_2 usage curves. Some simply like it more than others. Marijuana's response to CO_2 enrichment has been studied exactly one time[138] as far as I can ascertain (and the authors who conducted that study agree that they are the first)! We are, it seems, in uncharted territory here. It's a good thing *somebody* has bothered to look at this. We will get to the results of that study in a bit...

One thing we haven't touched on in great detail is the fact that there is more than one kind of photosynthesis; there are actually three types, and the plants that use them are known as C3, C4 or CAM plants. (They are named for the first product of carbon fixation

in the Calvin cycle that they use, where C stands for carbon, and CAM stands for Crassulacean Acid Metabolism. So, for example, a plant producing a three-carbon compound to fix CO_2 from the air is referred to as a C3 plant.) Each of the three plant types has a slightly different cellular and tissue structure. I have been presenting C3 plants in this book, since that is what concerns us (Cannabis sativa L. is a C3 plant).

C3 plants lose about 500 molecules of water for every CO_2 molecule they fix from the air, whereas C4 and CAM plants have evolved for life in dry and hot environments, respectively. A C4 plant will lose around half as many water molecules for every CO_2 molecule it fixes. For CAM plants, the number is a fraction of even that low number--usually below 100. The details of the three photosynthesis

models are not important to understand (but are given in Appendix IV Plant Processes), except to note that each uses CO_2 in differing amounts, with C3 plants being the least efficient of the three.

As of mid-year 2013[139] ambient atmospheric CO_2 levels are at 400 ppm. Previous studies have shown that C3 plants can greatly increase, and as much as double, their photosynthetic capacity when ambient CO_2 levels are doubled (at the time of such studies, CO_2 concentrations would have been at around 350 ppm, so doubling that would put CO_2-enriched plant subjects in roughly a 700 ppm environment.) C4 and CAM plants generally do not show the same increase in efficiency when tested in CO_2-enriched environments because they are already approaching their maximum CO_2 saturation point. This is because they are better at using

CO_2 to begin with.

The way that CO_2 concentrations work to enhance plant growth is intimately connected with the way the plant uses light. This makes sense, because we know that photosynthesis is the process of converting light and CO_2 into sugar. A plant can have as much CO_2 as you are able to give it, but it can't do anything with it if it doesn't have light. Conversely, when CO_2 levels are at zero, a well-lit plant can conduct no photosynthesis. Therefore, we understand that CO_2 and light are independent limiting factors.[140] Up to a point, that is. Photo-inhibition occurs in cases of too much light.[141] Most plants top out at around 1000 µmol m^2s^1 (mol per square meter per second, because it is a flow) **photon flux** (see Section 3: Measuring Light). In such instances, the plant's leaves are unable to dissipate heat fast enough and its

photosynthetic structures become damaged. Similarly, it is possible to exceed the amount of useful CO_2 given to the plant. At concentrations higher than the plant's ability to add CO_2 to the Calvin cycle, the additional CO_2 becomes useless. [142]

What this shows us is that there is a balance between where light levels rise to, and then surpass, the threshold of available CO_2, and where CO_2 levels rise to, and then surpass, the available level of light. In the first case growth is light-limited; in the second case, growth is CO_2-limited. The trick is to discover the perfect balancing point.

Circling back to the issue at hand, which is optimal CO_2 *plus light* concentrations for the growth of marijuana, these levels have yet to be elucidated. However, as mentioned

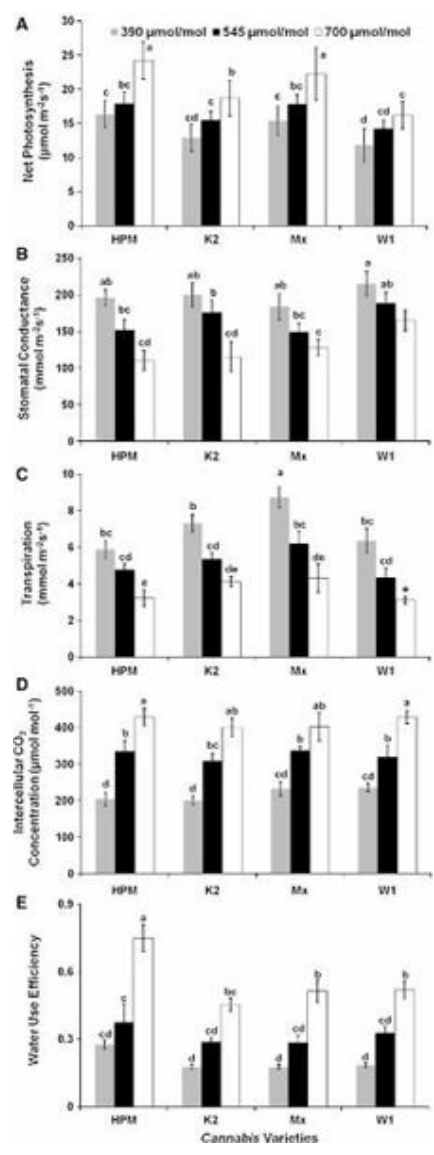
earlier, I have been able to find one study[143] that was funded in part, amazingly, by the National Institute on Drug Abuse (NIDA), which is under the Department of Health and Human Services. (In other words, the U.S. government paid these guys to study pot, so big tip-o-the-hat to them!) This study examined the degree to which CO_2 increases cannabis growth. It's rather technical as these things are wont to be, so let me break it down for you. The scientists measured the effect of CO_2 using several metrics, the most important of which were water use efficiency (WUE), net photosynthesis (P*n*), internal(Ci)-to-external(Ca) CO_2 concentration (Ci:Ca ratio) and stomatal conductance (*g*s).

Unsurprisingly, net photosynthesis increased when CO_2 concentrations were increased. We all expected that. What you might not have expected,

however, was that as CO_2 levels were increased, stomatal conductance *decreased*, and this, in turn, increased water-use efficiency. To repeat: as CO_2 increased, stomatal conductance decreased--the plant did not "breathe" more heavily; it breathed more efficiently. This *seems* counterintuitive because, as those of us who have experienced a CO_2 enriched environment know, when CO_2 concentrations are increased, the room feels warmer and more humid. We may assume that the plant is transpiring more water in the form of vapor. In absolute terms, it is. In relative terms, however, that is not the case. The room feels warmer because CO_2, a greenhouse gas, does not reflect long wavelength radiation well and, because water has a high heat capacity, that radiation sticks around in the moistened air longer. In a CO_2 enriched environment, plants are able

to function more efficiently in much the same way as you would if you were to supplement oxygen while you, say, ran on a treadmill. We can see from this study that internal leaf CO_2 concentrations increase, so that's where the CO_2 is going. It's accumulating in the leaf mesophyll.

Unfortunately, this study stopped testing at 700 ppm of CO_2 supplementation. We therefore do not know where the improvements plateau. But, what *does* the study show us? Check out the results.


A
390 µmol/mol
545 µmol/mol
700 µmol/mol
Net Photosynthesis (µmol m-2s-1)
B
Stomatal Conductance (mmol m-2s-1)
C
Transpiration (mmol m-2s-1)
D
Intercellular CO2 Concentration (µmol mol-1)
E
Water Use Efficiency
HPM
K2
Mx
W1
Cannabis Varieties

from study

In the left column is the metric measured for each of four different strains: HPM (High Potency Mexican Variety), K2, MX and W1 (from Switzerland). Across the top you can see the color coding for increase in CO_2 (where umol/mol can be read as ppm because they are fractional equivalents). It's pretty clear that CO_2 works to increase photosynthesis at least as far as the studied 700 ppm level. Unfortunately, the middle level tested (545 ppm) did not show a statistically significant increase over baseline, so we can't even extrapolate past 700 ppm.

To my knowledge, the point of diminishing returns has never been rigorously studied. We know that there is such a point, because at high enough levels of CO_2, the Calvin cycle simply cannot fix the CO_2 fast enough. What

level? Depends on the plant. In many species of plant, what we would consider to be a fairly normal level of CO_2 supplementation is known to decrease photosynthesis. Rice, for example, tops out at around 1200 ppm and then begins to decline, resulting a net reduction in yield of 25 percent by 2500 ppm.[144]

It has also been found that the ability of CO_2 to enhance growth is dependent upon the source form of N that is being provided to the plant.[145] When the source form of N is NO3- instead of NH4+, CO_2 slows down growth *enhancement* rather dramatically (i.e., the improvement curve is cut--half as steep, in this study). The other thing that happens in elevated CO_2 environments is that heavy-metal uptake is increased.[146] Thankfully, cannabis, though a fairly aggressive accumulator of heavy metals, tends to

concentrate them in the root tissue and not in the buds or shoots.[147] Finally, it has been observed that CO_2 growth stimulation is often a short-term phenomenon. The effects of CO_2 enrichment over the long term have yet to be studied.

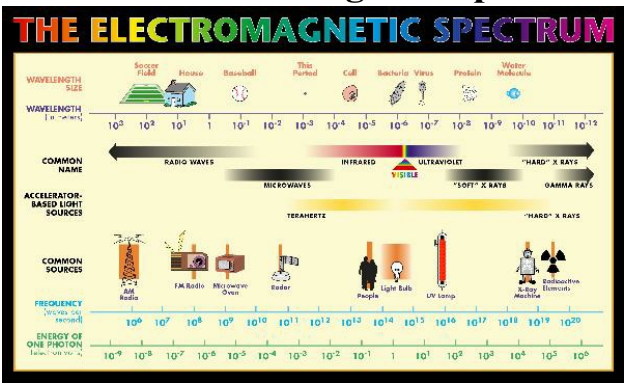
In conclusion, I hastily point out the obvious: plants in a room that is not supplemented with either plenty of fresh air or CO_2 are going to underperform because they are being slowly suffocated. They need CO_2 and it seems obvious from both anecdotal evidence and scientific literature that CO_2 supplementation works. But the stunning fact is that how much we should supply to our marijuana plants and for how long has not yet been determined. I'm predicting that the answer isn't going to be "1500 ppm of CO_2 all the time."

In Summary: CO_2 supplementation is not as simple and straightforward as the cannabis community has been led to believe for decades. The fact is, we just don't know how much to add or at what intervals. It is obvious to me that supplementation does help, but I have long suspected that the peak level is closer to 900 ppm than the canonical 1500 ppm. That's just my guess, but the limited research that is available hints that I could be right.

Measuring Light

Why You Need to Know: Lumens, lux, footcandles, PAR watts... a visit to the grow shop's lighting section is enough to make anyone confused! Let's get this sorted out...

This is the **electromagnetic spectrum**:



Original text : http://son.nasa.gov/tass/content/electrospectrum.l
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Or, rather, it is a graphical representation of all of the

electromagnetic radiation that we know of. As you can see from this illustration, the visible portion of the electromagnetic spectrum is a narrow piece of the overall bandwidth--about 2-percent of the total. Light is, therefore, a subset of electromagnetic radiation.

If human beings had the organs to perceive other parts of the spectrum, the world would look much different. Without instruments, though, our eyes perceive only this (roughly) 380-780 nm range. Infrared we can feel with our sense of touch-it is heat. We can also feel the after-effects of ultraviolet radiation; it gives us sunburn. These invisible portions are still photon radiation. Plants, we already know, are able to "see" even less of this than we can--about 5% of the visible spectrum. Plants are almost "blind" between 500 and 600 nm. That corresponds to the

green portion of the spectrum.

Light is a form of radiation, and, we are illuminated by this form of radiation every day. Because of these two fundamental aspects of light, terms can get confusing. In the first instance we have an aspect that is measured in terms of radiation-radiometrics; and in the second, we have measures of how people perceive light with their eyes-photometrics. Radiometrics (for our purposes) concerns optical radiation: ultraviolet, visible and infrared. Photometrics concerns human perceived radiation: the visible range from 380-780nm.

- **Radiometrics** is how we measure the electromagnetic spectrum. All of it. (But we will only concern ourselves with photon radiation.)

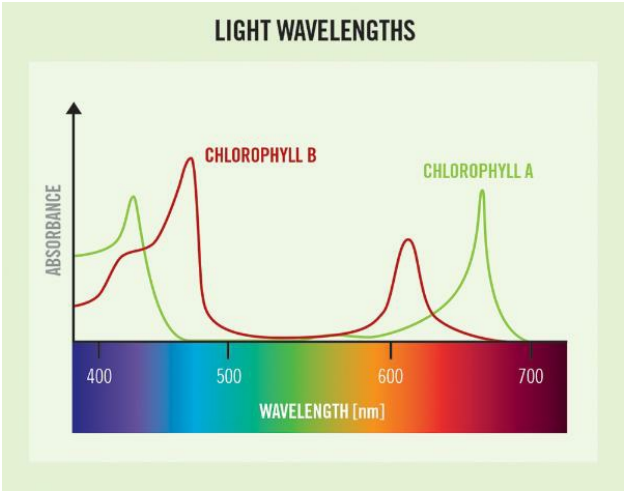
- **Photometrics** is how we measure the visible spectrum of the electromagnetic spectrum between 360 and 830 nanometers; it measures only visible light as seen (and defined) by the healthy human eye.

These two metrics are identical in theory, differing only in scope and the terms they employ to describe various quantities.

In gardening, we also have the consideration of how *plants* perceive light. We see plants as green. It's a three-way interaction. Light. Plant. Our eyes. Human eyes perceive light in the wavelengths between about 380 to 780 nm (give or take a bit), which covers the colors of blue, green and red. Light strikes an object and is reflected to our eyes. The optical radiation that is not

absorbed by the object is reflected and that is what we perceive as the object's color. Plants do not use green light (or, rather, they use it inefficiently), so it is reflected away and they appear green to us. Clearly, this means that plants perceive light differently than we do.

What we see and what plants "see" are entirely different concerns. This is why many manufacturers market their horticultural lamps in terms of PAR watts where PAR stands for Photosynthetic Active Radiation. They are telling you that their product emits radiation that is useful-or visible, to pursue the analogy-to plants. But what of the "watts" portion of PAR watts?



To understand this, you must understand the difference between power and energy. Energy is measured in joules and is a fundamental physical property inherent in matter and radiation. A watt is a measure of power. Power is energy over time. That's enough for our purposes.

The other thing you need to understand is that light is measurable as both a wave form and as quanta called photons. For lighting we use photons.

Photons can be counted, which is why we use them here.

Now, hang in there while I lay down some terminology for you. I'm putting these terms here so you can refer back to them as I explain what they mean. First I will give the radiometric term, then I will give the photometric equivalent.

- **Watts** are used to measure *radiant flux*. This is all of the photon *power*.

- **Lumens** are used to measure *luminous flux*. This is just the *visible* photon power.

Let's turn those around:

- **Radiant flux (watt):** the amount of radiant energy emitted, transmitted, or received per unit time

- **Luminous flux (lumen):** the amount of visible energy emitted, transmitted, or received per unit time

Those definitions concern time; they are relevant to flow, which is why the word flux appears in them.

Now let's add density:

- **Radiant flux density (W/m²):** radiant flux per unit area

- **Luminous flux density (lm/m²):** luminous flux per unit area

These definitions concern the amount of photons per unit area, in other words, their density. Getting the hang of it? Good. Now, we are going to add direction to the mix:

- **Radiant intensity (W/sr):** flux (power) emanating from a

surface per unit solid angle, also called a *steradian* (the definition of "steradian" is coming up...)

- **Luminous intensity (lm/sr):** visible flux (power) emanating from a surface per unit solid angle. That's lumen per steradian (1 lumen per steradian is a **candela**)

Still with me? Let's add density to the direction in order to get:

- **Radiance (W m^2 sr^1):** radiant flux density emanating from a surface per unit solid angle (steradian)

- **Luminance (lm/m^2/sr):** illuminance per unit solid angle (steradian)--the density of visible light in a single

direction

Finally, let's add a surface for the radiation or light to strike:

- **Irradiance (W/m²):** radiant flux density incident on a surface

- **Illuminance (lm/m² OR lm/ft²--more below):** visible flux density incident on a surface -- note the two possible measures. They are as follows:

    - lumen/meter² is called **lux**

    - lumen/foot² is called a **footcandle**

Irradiance is measured per unit surface area. So even if you cut the surface area in half (or whatever you want to cut it by) you would still have the same irradiance because the flux is the same per unit surface area.

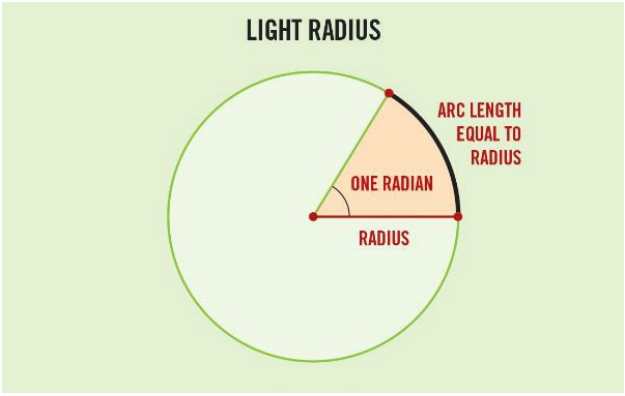
Now: What the hell is a steradian? It's a three-dimensional angle, but instead of degrees, we are going to use the SI (metric) system and use radians.

If you think of any light-emitting source in your grow room you will likely agree that its light is released in all directions from its source. Yes, the excited, glowing elements inside horticultural lamps are 3 to 4 inches in length, and the base that screws into the socket is effectively blocked, but radiation is emitted in all directions from its source even if it is blocked. (Even fluorescent tubes emit light in all directions, though their emission is distributed from a linear source as opposed to a point source.)

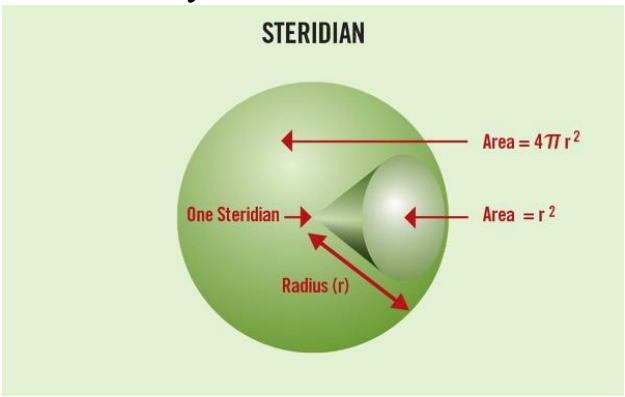
If we think of that emission as being spherical (which it roughly is), we can visualize the fact that as we move away from the source, the light

becomes "diluted" by area, much in the same way that the skin of a balloon stretches as the balloon is inflated.

Imagine drawing a circle on an inflated balloon. The area from the center, or vertex, of the balloon to the outer surface demarcated by the circle is an area that is conical. This cone is called a **steradian**. A steradian is a three-dimensional **radian**. A radian is an angle cut out of a circle (like a slice of pizza) where the outer length of the circumference cut (the arc of our pizza crust) is equal to the length of the radius (the line from center to edge):

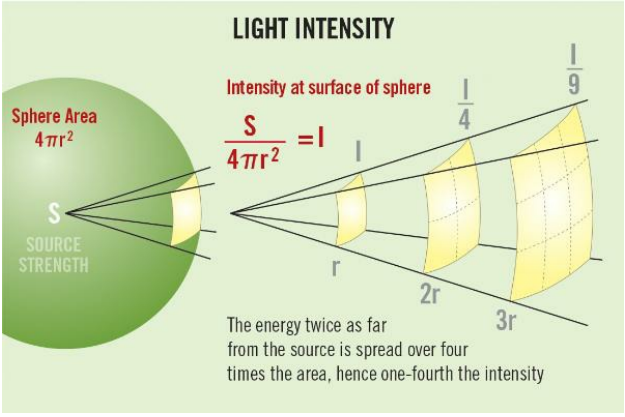


The circumference of a steradian is measured in terms of area instead of length because we are now operating in three-dimensional space. The surface area of a sphere is $4\pi r^2$ and *the surface area of a steradian is* r^2 (steradian = r^2), so, substituting steradian for r^2, the surface area of a sphere is 4π*steradian*. So, we have the whole balloon, which we can measure, and we have the solid angle of the balloon called a steradian. The steradian allows us to measure light directionally.



We know from experience that as we

gain distance from a source of light, its intensity drops off. If you look at the increase in area of the steradian as the sphere from which it is derived grows, this decrease in intensity is clearly dramatic. In fact, it decreases geometrically, according to the **inverse square law**, which states that the intensity of the source radiation is a fraction of the surface area over which it is divided.



So an area measured at two times the distance from the source is one-fourth as intensely lit; and area measured at

four times the distance is one-sixteenth as intensely lit.

Light intensity (whether measured in radiometric or photometric units), therefore, must be measured per unit of surface area. The quanta of radiant energy striking a surface per unit of time is known as **flux**. Think of flux as a flow of light as it passes through a detecting apparatus (e.g. your eye, a telescope, a meter, or a leaf).

The intensity of human-perceived light is measured in luminous flux. As we know, flux is a flow, and a flow can only be measured in rate; therefore a time dimension is needed. That time dimension is (unsurprisingly) one second. Each unit of luminous flux is called a **lumen**. A lumen is equal to the amount of light emitted per second in a unit solid angle of one steradian from a uniform source of one **candela**. The

measure of human-perceived light as it strikes a surface is known as **lux**. One lux is equal to one lumen per square meter.

What's a candela? It is a measure of intensity that is, believe it or not, approximately equal to the intensity of light given off by a common lit candle. (In fact, it replaces the old unit measure, **candlepower**, which called for a specially-designed candle made from sperm whale oil.) In technical terms, one candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540 x 10^{12} Hz and has a radiant intensity in that direction of 1/683 watt per steradian. What is interesting to note here is that the frequency given in this definition, 540 x 10^{12} Hz, corresponds to 555 nm, which is the wavelength of green light. Yep, the human eye is most sensitive to

green light, just the color that plants reject. So what good are lumens to plants?

Light Penetration: Light, we know, loses intensity by the inverse square of its distance from its source. Many people are confused about how this applies to fluorescent lights, which are linear sources of light. Most growers believe that point-source lights (HID's) penetrate more deeply into the canopy than linear-source lights (fluorescents). This a complex problem and its explanation is not simple, though there is a simple rule-of-thumb you can use.

The depth of penetration of light into a canopy is determined by many factors, the most important of which is the shape and growth habits of the leaves on the subject plants. As you can imagine, a pine needle intercepts less light than a maple leaf. Other important

factors include: the ability or propensity of the plant to orient its leaves toward light; at which level of the plant (top, middle or bottom) it does this; and the overall shape of the plant (conical, spherical, vertical, etc.). Each of these factors has a dramatic effect on light penetration into the canopy.

Cannabis plants tend to hold their new leaves erect while they grow, gradually presenting them so that they are horizontal to the plane of the ground (they are **erectophile** as they emerge, and change to **planophile** as they mature). In its natural state, this plant's growth pattern is roughly conical. The canopy of marijuana gradually increases in density as measured from top to bottom. When we train our plants (SCROG), we make the entire canopy as close to planar as possible. This obviously maximizes

the incident angle of the light and minimizes the need for deep canopy penetration.

What about that rule-of-thumb? In general, the absorption of light increases exponentially as it descends into the canopy.[148] This is a highly-abbreviated version of the science involved in such measurements, but it is good enough for practical purposes.

Other factors that affect the penetration of light include light source intensity, light wavelength and the incident angle of the light. Light intensity makes a big difference in the quantity of light (or total photon flux density) that reaches the lower level of the canopy, but not in the overall *percentage* of light (which drops off and is absorbed at a more-or-less constant rate). So, to circle back to the example of fluorescent-source light penetration

versus HID-source light penetration, the percentage of light penetrating the canopy is roughly the same, all other factors being held equal; but because of the greater initial radiance, the total PFD is greater with the HID-source light, meaning a greater *quanta* of light reaches the lower branches.

Light wavelength makes a big difference too, and is one reason why the absorption curve is not perfectly exponential. Leaf tissue is nearly transparent to light near the far-red end of the spectrum, so this light passes right through without diminishing nearly as much as light in the photosynthetically active ranges does. PAR light is absorbed more quickly than other portions of the spectrum.

Incident angle of light also significantly affects penetration because it makes such a substantial

difference in intensity. As you know, sunlight at noon is much more intense than sunlight at sunset or sunrise. With leaf tissue, the same holds true. Light that is directly above the canopy is more intense than light that enters from an obtuse angle, a greater amount of which is reflected. This means that the plant's ability to angle its leaves toward the light impacts penetration measurements.**Pendulous** and erectophile leaves allow for greater penetration than planophile leaves.

In Summary: From a practical standpoint, growers will want a light that can produce lots of lumens per energy input. This is called luminous efficacy. Luminous efficacy is lumens per watt. High luminous efficacy saves us money and is a critical component upon which the whole enterprise of growing indoors pivots. But we also want our plants to be able to use the

light that we supply so it should fall within the spectrums of 450 to 500 nm and 650 to 700 nm--the range of photosynthetic active radiation (PAR). When we consider how useful a light source is to our plants what we want to look at is photosynthetic photon flux area density (or PPFD for short), which is a way of identifying where the greatest wavelength density is coming from. PPFD is a sum of all the photons emitted from a light source in the 400 to 700 nm wavelengths. Since plant scientists study photosynthesis from the standpoint of quanta of photons input in the two bandwidths given above, PPFD is their preferred way of measuring the input side. It makes sense--why would they care about useless wavelengths of light? But, do note that PPFD is the sum of all photons between 400 and 700 nm (including the green light in the 500 to 650 nm range), so even this is not a

perfect measure of PAR. For that, we need to measure yield photon flux (YPF), which considers the weighting of various wavelengths--and plant photosynthetic response to them--of the source spectrum.

Quick Start Guide to Vegetative Propagation (Cloning)

Why You Need to Know: What we refer to as cloning--vegetative propagation through tissue culturing--is not a difficult thing to do successfully if you understand what's happening in the plant when your cut is rooting. Cloning is an invaluable skill to hone and one that will serve you well your entire growing career, so you are well-advised to learn it.

Though there are many ways to propagate plants asexually, the one best suited to cannabis is the simple cutting of growing shoots. Soil layering is not advisable because it usually results in broken stems and air layering is a cumbersome process that is worth doing only if you want an exceptionally large new plant.

The steps involved in rooting cuttings are:

1. Making the cut
2. Applying the hormone dip
3. Incubating the cutting until rooted

Making the cut - Cutting your plant is a simple matter of choosing a growing tip and cutting one or two nodes down from the apex. If you cut more than that, there will be too many leaves on your cutting, and this can result in excessive water loss. Some growers like to either use a diagonal cut or slice the stem lengthwise because this increases the interior surface area that will be exposed to hormone. I find this to be unnecessary, especially when using an alcohol-based rooting agent. Soft green plant-tissue is easily penetrated by such agents. Of course, if you want to cut your plants this way, I see no harm in it.

Making all of your needed cuttings, plus a few extra, should be done in one step. I like to do my pruning and cutting at the same time. I keep my pruned branches segregated by strain (and labelled accordingly) and then take

cuttings from those branches when I am done pruning. Pruned branches and cuttings should be placed in water while you are working in order to maintain the flow of water through the xylem. The threat here is that a break in flow-continuity can result in the introduction of a gas bubble (embolism) that, in a narrow stem, the plant cannot repair, and this will result in the loss of your cutting. So, cut the branch, drop it into clean water, and leave it there until you are ready for hormone treatment. Taking a few extra cuts will allow you a margin of error.

Applying the hormone dip - To prepare your cuts for dipping, make sure that they are cut at, or just above, the third node and that they have top leaves as well as a pair of leaves at the second node. Trimming the leaves as pictured optional, but I like to do it because it makes for a neat, uncluttered

appearance and reduces transpiration (by reducing stomata count).

At this point, you will want to set up your clone tray. Cleanliness is of paramount importance. I prefer to use new seedling plastics when I clone because I know them to be free of contaminating pathogens. You will also need a humidity dome. Set this up in advance so that you can move quickly after you dip.

You can use almost any neutral growing medium. I find the more porous ones to be preferable to the brown cellulose plugs, which tend to become anoxic sooner. My favorite rooting medium is Cultilene(R) grow blocks cut into pieces, soaked in 300 ppm grow fertilizer, and squeezed to eliminate excess solution. Of course, you can use almost any product you like--vermiculite is probably the

cheapest option and it works just fine.

The rooting hormone is always a form of auxin, which you may recall reading about in earlier chapters. Auxin, as we already know, causes the elongation of plant cells and is the chemical that is responsible for plant tropisms. When auxin is applied to the stem of a plant, the cells become undifferentiated and, if kept in the dark, will eventually form root tissue.

Common commercial forms of auxin are indole-3-butyric acid (IBA), 1-naphthaleneacetic acid (NAA), and indole-3-acetic acid (IAA). You will most frequently find IBA in commercially available products, though a few brands include more than one form. More is not better. Over-application of auxin will cause callousing and stall the rooting process. Therefore, it is important to

follow the instructions that are given on the bottle. It is equally important to use distilled water. Tap water can damage the hormone, and bacteria and fungi in infected water will proliferate when exposed to hormone.

I have two favorite brands of rooting hormone. They are Dip'N Grow(R) and Wood's(R) Rooting Compound. (As always, I'm not in this for product placement; I am just letting you know what I have found to be most effective.) I like these products because they contain both IBA and NAA, they are alcohol-based and the manufacturers seem to have done some research regarding solution strength (based on the results I have consistently gotten using their products as directed). I also appreciate that a bottle of either one will last a long, long time.

Because these two brands are alcohol-based, it is important that you make your cuts first, and then dip them all at once before inserting them into your chosen media. Otherwise, significant evaporation will take place while you work, and this will change the concentration of your solution. Regardless of your favorite brand, I find this method to be an advisable protocol. Dip time will vary depending on the product used--one to five seconds is typical. A one one-thousand, two one-thousand, three one-thousand verbal count works just fine. Using a stop-watch is probably overkill.

Incubating the cutting until rooted - After you have dipped your cuttings, insert them into your rooting cubes and then pop the cube into the insert/tray if you haven't already done so. Take time to label your strains adequately! If you

are not taking many cuttings, alternating insert receptacles is a good way to keep things neat. When you're done dipping and inserting, add a little clean water to the bottom of the tray--just enough to fill up the ridges--and put a dome over it. I open the vents to allow a little circulation. Maintaining humidity is important. Keep the cuttings under moderate 18 to 24 hour light. If you have done everything as directed, you will have roots in seven to ten days.

If it takes much longer than 14 days, it's time for diagnosis. Split open a rooting cube so as to avoid damaging any roots that may have grown and look at the immersed stem. If it is white and thick with callous, you have used too much hormone; cut back on strength next time. If they are green and starting to root, add a bit more hormone next time. If they are mushy or infested with

fungus gnats, clean up your act, buddy!

In Summary: Vegetative propagation is a skill that will serve you throughout your entire growing career. Understanding how to do it right will prevent the introduction of unwanted

pathogens into your plants and will prevent delays in rooting. Also sharing rooted cuttings with other growers is a great thing to do.

More Troubleshooting: Nutrient Detail

Why You Need to Know: Educational purposes only.

I include this information in the appendix for your edification only. It is not meant to be used as a means of diagnosing problems. If you attempt to identify single-nutrient deficiency or toxicity you will soon find yourself immersed in a byzantine quagmire of second-guesses and impossible-to-confirm (unless you can do leaf-tissue analysis) diagnoses. It is a sure route to headaches and compounded problems. Further underscoring the futility of such an approach is the simple fact that you will probably not be able to buy single-nutrient supplements anyway. Instead, go back to my simple rule for troubleshooting:

Look at the whole plant. If it has spotted leaves (and there are no bugs or molds), it is probably either overfed or the pH is too low. If it has chlorotic leaves at the top of the plant, add micro nutrients. If it has chlorotic leaves at the bottom of the plant and the chlorosis is progressing upward, add macro nutrients (N especially).

Nutrient	Ionic Forms Used	Function
Nitrogen (N)	NO^{3-}, NH^{4+}	Used in amino acids, needed for photosynthesis facilitates carbohydrate utilization, stimulates roo growth, makes

		other nutrients useable.
Phosphorus (P)	H_2PO^{4-}, HPO_4^{2-}	Component of ATP, component of DNA and RNA, used in proteins, metabolic processes, photosynthesis and respiration; affects root development, maturation (ripening), flowering and fruiting.
Potassium	K^-	Associated

(K)		with overall vigor of the plant, regulate many function including opening and closing of stomata, wate uptake, essential for photosynthesi Remains in ionic form.
Calcium (Ca)	Ca^{2+}	Needed for healthy shoot

		and root tips, used in fruiting, cell wall component. Remains in ionic form.
Sulfur (S)	SO^{4-}	Used in amino acid production, contributes to aroma, flavor (not always pleasantly).

Magnesium (Mg)	Mg^{2+}	Needed in chlorophyl, enzymatic, fat an sugar making processes. Needed for seed germination. Remains in ionic form.
Silicon (Si)	SiO_4^{4-}	Structural

		component in cell walls, improves draught resistance.
Chlorine (Cl)	Cl^-	Used in shoot and root growth. Remains in ionic form.
Iron (Fe)	Fe^{2+}, Fe^{3+}	Catalyzes chlorophyl synthesis.
Boron (B)	B_3BO_3, $B(OH)_3^-$	Used in metabolism of N, pollen germination,

		cell division, fruiting, hormone movement.
Manganese (Mn)	Mn^{2+}	Used in synthesis of chlorophyl, co-enzyme. Remains in ionic form.
Sodium (Na)	Na^{-}	Used in pyruvic acid cycle, synthesis of chlorophyl, can substitute for K^{-} in many plants. Remains in ionic form.

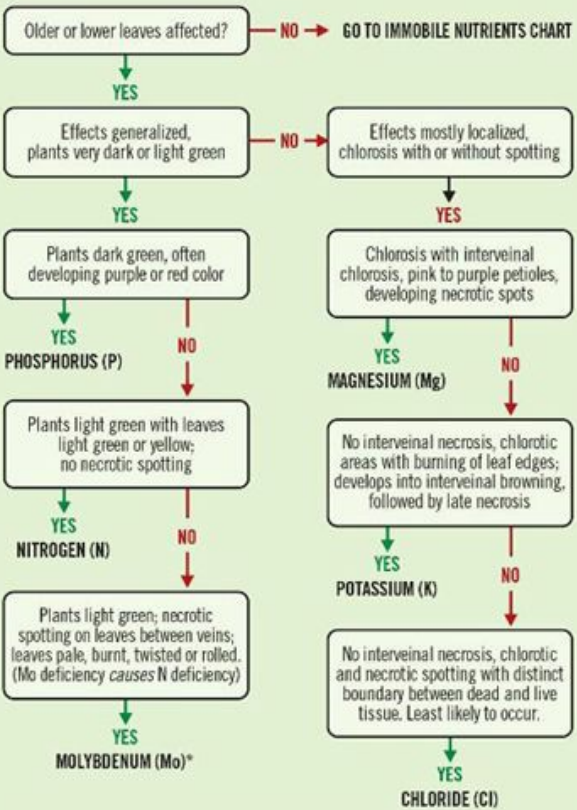
Zinc (Zn)	Z^{-}	Used in enzyme activity, formation of chloroplasts, auxin, and starch.
Copper (Cu)	Cu^{-}, Cu^{-}	Enzymatic activity, chlorophyl synthesis, catalyst in respiration.
Nickel (Ni)	Ni^{-}	Necessary for seed development,

		key to N metabolism.
Molybdenum (Mo)	MoO_4^-	Used in conversion of nitrate to useable form.

And finally, a **Problem-Solving Flow Chart**. Why did this take so long?

PROBLEM-SOLVING FLOW CHART

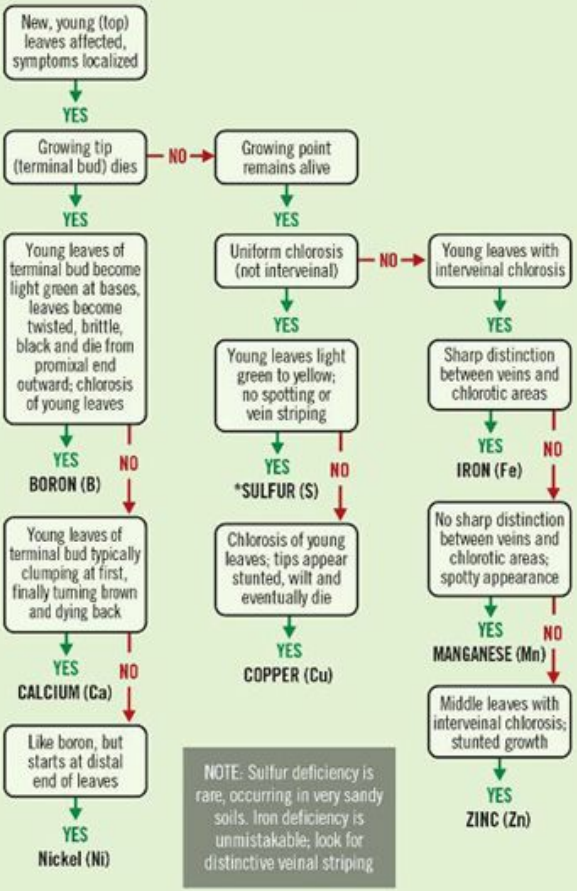
MOBILE NUTRIENTS



NOTE: This flow chart is for nutrient deficiencies, not toxicities. It also does not address disease. In most cases, it is best to treat for all micros or macros.

PROBLEM-SOLVING FLOW CHART

IMMOBILE NUTRIENTS



Getting Into (or Staying Out of) the Business

If you are considering entering the marijuana industry, you should consider a few things you may have overlooked. First and foremost, if you want to grow and sell marijuana, and you don't have $2M to spend, you can stop reading right now. There are other ways to get into or service the industry with business models that require less startup capital, but you will have to be creative to make one of them work. Cash-on-hand of $500,000 is a good minimum for a small-service enterprise startup. If you have less than that, I think your odds at succeeding long-term are severely narrowed.

With that out of the way, I want to write about a few more often-overlooked aspects of living inside the marijuana industry that you may have

failed to consider.

Why You Should Stay Out of the Marijuana Industry

Your Privacy Is History

I have helped many entrepreneurs get into the medicinal marijuana business. The first thing I always want to know from a potential client is: Why? Why do you want to do this? People entering this industry are subjected to a level of scrutiny that is almost beyond comprehension to those who have spent their lives in the private enterprise. Unless you have been in the military, work for the government in a high-level position, have been subjected to an extensive background check, or work in an agency that handles fissile material, you probably do not realize the extent to which your life will be exposed to the scrutiny of

public officials.

Every aspect of your company will be examined, recorded and subjected to audits. I don't mean you must record everything and store the records in case regulatory officials want to audit you. I mean you must record everything and store the records because the regulatory officials *will* audit you. What do I mean by everything? Every. Thing. Every order, every plant, every plant's date of creation, date of harvest, its wet weight, dry weight, weight of waste, when and how the waste was disposed of, when and where it was delivered for sale, which route the driver took to deliver it, what time the driver left and arrived, what the product weighed upon delivery, and the video footage of all of this (growing, processing, storage, delivery and sale). Additionally, the inventory of containers for your product must be

maintained, the temperature of the water coming out of your hot water tap is regulated, the techniques and dates used to sterilize equipment, the sterilization chemical used, the duration of contact the implement had with the sterilizing chemical, material safety data sheets for all of your chemicals, fire inspection reports, building inspection reports, and police inspection reports. Trash dumpsters are surprise-inspected, water and waste runoff is checked for toxicity, equipment is inspected for UL approval, and the list goes on.

Regulation is intense and there are new regulations being created almost monthly. All of this adds to your overhead and distracts you from conducting business.

If that sounds a little onerous to you (and it is), you should reconsider your

motivation to enter the industry. Do you simply want to be around the plants? Has it always been a dream of yours to grow thousands of your favorite plant? Are you motivated by the desire to facilitate social change? Are you motivated by financial gain? There are other, easier ways to accomplish all of those objectives.

It's More Work than You Bargained for

Work is another aspect that many people underestimate. It would be hard to overstate the number of businesses that enter this marketplace having hired a grower who has assured management that he (it is also a male-dominated industry) is an expert grower. This self-assessment is usually based on the fact that the grower has successfully grown a few dozen plants (maybe more) in a buddy's basement during his

college years, and he figures all he has to do is more of the same. Wrong. Big time wrong.

The proliferation of work that comes along with growing and maintaining thousands of plants is not well represented by a logarithmic curve, but by a mathematical one. More plants equals more work, and there is no way around it. Even automation does not answer this problem adequately, because whatever automation you adopt must then be constantly monitored. The only answer to this problem is hiring and paying lots of well-trained employees. That eats away at your profit margin quickly.

Competition Is Both Fierce and Unfair

If you want to get into the business for financial gain, realize that there are far

easier ways to make money. The overhead is going to crush you unless you are prepared to wage, and win, a marketplace war. If you are in a medicinal state with a limited number of licenses available, this is less of a concern. But even people who are lucky enough to be so situated must be prepared for a future free-market situation. If you are entering the business in a free-market state, your competition is going to be fierce. You may have done your pro-forma on what you thought was a conservative per-ounce price of say $250 but will be caught flat-footed when the winter glut drops prices to $100 an ounce.

Winter glut? Yes. California outdoor-grown pot floods the market between Thanksgiving and New Year's Eve, and those growers have a much lower cost of goods sold than you do, what with no electric bills and ten-pound plants.

$1,500 pounds are everywhere. There is a reason why California didn't go recreational in 2010, and that would be because the black market growers voted against it.

The Public Can Turn Against You

How about a local proposition to ban your already-established enterprise? It can happen. I've fought it myself (and won, thankfully, but many other have not been so lucky). The dispensaries that made it through years of hurdles in Ft. Collins, CO survived everything I described above only to be shut down unceremoniously by a local ordinance. Longmont, CO's board of trustees unilaterally shut down the industry without even taking the issue to vote!

The fact is, a handful of "concerned" citizens with control issues and too much time on their hands can do a lot

of damage to your business, even if they don't ultimately get their way and shut you down entirely. These people, and the officials who regulate your business, neither understand nor care that they could be ruining your livelihood or the livelihoods of the people you employ. They sleep well and get paid no matter what happens to you. It's a no-risk proposition for them, and an all-in proposition for you, and that makes for an unfair starting place. Get used to it.

Lawmakers Are Not Sympathetic

As a result of pressures placed on them by these few protestors, lawmakers will think nothing of requiring you show up for hearings on short notice, levying additional fees (I mean tens of thousands of dollars), requiring you to change locations or having you retool your entire operation in order to suit

their latest whim. This will happen. I guarantee you, it will happen.

There is something about the personality of a person who wants to make laws that is anathema to seeking simple solutions. The only thing that the lawmakers Know (capital K) is that *something* needs to be regulated here. They don't know what exactly, but a good place to start is, oh... everything. And if you spot something they missed regulating, be ready, because they'll also spot it eventually. If you are one of the first (and you will be unless you put this off until 2024), you get to be the butt of that joke for the foreseeable future.

The People Who Made It Happen Are Excluded

There aren't going to be many activists who end up minted as marijuana

millionaires. The people who made this happen are not the business people who are entering the field now. Or, at least, very few are. It is sad to see these people being excluded by the industry they created. At some point, the Budweiser of marijuana is going to get in and many of the activist-entrepreneurs will be transitioned out. At that point, the lineage from activist to activist-entrepreneur to big-business will be nothing but history.

Why You Should Get Into the Marijuana Industry

It Is Right for Some People

If you've read this far and you're still with me, the marijuana industry may be right for you. Here is what I love about it this industry, and why I'm still in it:

It's Just

Ending prohibition is the right thing to do. Being part of history is exciting and is the kind of thing that the people who are doing it will not regret later in life. Stories will be told to children and grandchildren about how it all came down and what you did to participate in the watershed ending of this prohibition. That is something to feel good about. Such achievements only come at great effort and expense.

The People Are Great

It's a small industry at present, and right now, everyone knows everyone else. Except for some normal inter-office gossip and occasional petty in-fighting, by and large, the people I know in this industry are fabulous. They have a common goal and have not lost sight of what they are working to achieve. They care passionately about what they do, support one another, are

extremely smart and are all in it together. Most of the regulatory officials are solid, easy-to-get-along-with people, too. (The agencies they work for can be difficult, but the individuals themselves are sincerely trying to do good by their communities.) For now, at least, that's the way it is.

Hard Work Is Rewarded

For every ten people who got in to the business and then dropped out, there is one person who got in, got his or her shit together and succeeded. Yes, the negatives-list is longer than the positives-list. That's only because the negatives are tangible. The positives are largely intangible and have to do mostly with how you want to conduct your life--or how you want to feel about how you conducted your life when you look back on it years from

now. As frustrating as this industry can sometimes be, for me anyway, the few positives simply weigh a lot more than the many negatives.

The people who worked their asses off for years to get things up and running and who are out in front of new regulations are amply rewarded. They have done more than just build a business; they helped to build an entire industry. They are making money, they feel good about what they do and they deserve their success. They help people. They grow pot. They get paid to do it. You can tell who they are by the bags under their eyes and the smiles on their faces. They are my friends, and I am proud of them.

Appendix I - Further Reading

There are several great texts on marijuana cultivation, and I highly recommend two of them. They are Robert Connell Clarke's excellent *Marijuana Botany: An Advanced Study: The Propagation and Breeding of Distinctive Cannabis*, which is worth its price for the appendices alone; and Greg Greene's thorough and accessible *The Cannabis Grow Bible: The Definitive Guide to Growing Marijuana for Recreational and Medical Use, Second Edition*.

For those who are looking for more complete details about the treatment of cannabis disease, you can do no better than*Hemp Diseases and Pests* by J. M. McPartland, R. C. Clarke, and D. P. Watson. For advanced reading on the physiology of plants in general (you will be surprised how much such

reading can help you in your pursuit of the perfect cannabis plant), I recommend the gold-standard text on the subject, *Plant Physiology* by Lincoln Taiz and Eduardo Zeiger, now in its fifth edition.

No cannabis grower worth his salt can stand to be ignorant of the policy disaster known as the War on Drugs. For more on this shameful chapter in American history, I highly recommend you pick up a copy of *Friedman and Szasz on Liberty and Drugs: Essays on the Free Market and Prohibition* by Milton Friedman and Thomas Szasz. For that matter, anything by Thomas Szasz is worth your time; *Ceremonial Chemistry: The Ritual Persecution of Drugs, Addicts, and Pushers* is especially enjoyable. Also do not miss Michelle Alexander's outstanding *The New Jim Crow: Mass Incarceration in the Age of*

Colorblindness or Radley Balko's alarming *Rise of the Warrior Cop: The Militarization of America's Police Forces*.

Appendix II - Glossary

ab.sorb *transitive verb* /əb *zorb*/

to take in or soak up.

a.chene *noun* /eI *kin*/

a small, dry, hard seed that is attached at a single point and that does not split open when it is mature.

ac.tive tran.sport *noun*

the movement of ions or molecules across a cell membrane into a region of higher concentration, assisted by enzymes and requiring an expenditure of energy.

ad.sorb *transitive verb* /əd *sorb* or əd *zorb*/

to gather (a gas or liquid) to a surface.

aer.o.bic *adjective* /eI *ro* bihk/

occurring or living only in the presence of oxygen.

al.lele *noun* /ə *lil*/

one of two or more versions of a gene. An individual inherits two alleles for each gene, one from each parent. If the two alleles are the same, the individual is homozygous for that gene. If the alleles are different, the individual is heterozygous.

al.log.a.my *noun* /ə *la* gə mi/

the process of cross-fertilization in plants. (Cf. autogamy.)

an.gi.o.sperm *noun* /*aen* ji ə spərm/

a flowering plant that holds its seeds within an ovary.

an.i.on *noun* /*aen* aI ən/

a negatively charged ion. (Cf. cation.)

an.ther *noun* /*aen* thər/

the part of a flower's stamen that bears pollen.

Ar.chae.a *noun* /*ahr* kee uh/

one of the three-domain system (the other are Bacteria and Eucarya) which includes halophiles (inhabit extremely salty environments), methanogens (produce methane), and thermophiles (thrive extremely hot environments).

A.T.P *noun* /*eI ti pi*/

a biochemical compound that serves to store energy in all living cells; adenosine triphosphate.

au.tog.a.my *noun* /o *ta* gə mi/

in botany, self-fertilization, as of a flower with its own pollen. (Cf. allogamy.)

aux.in *noun* /*awk* sən/

any of a group of organic compounds, often plant hormones, that affect plant growth.

ax.il *noun* /*aek* sihl/

the upper angle between a leaf, flower, twig, or the like, and the stem or branch from which it grows.

Bac.te.ri.a *noun* /*baek* ti ri ə/

one of the three-domain system (the other are Archaea and Eucarya). Bacteria are one-celled microscopic organisms of various shapes that are often agents of fermentation and putrefaction and that, in some cases, cause disease.

boun.dar.y lay.er

the layer of fluid closest to the surface of a solid past which the fluid flows: it has a lower rate of flow than the bulk of the fluid because of its adhesion to the solid.

bract *noun* /*braekt*/

a leaflike part usually located below a flower or flower cluster.

C3 Car.bon Fix.a.tion

C3 carbon fixation is one of three biochemical mechanisms, along with C4 and CAM photosynthesis, used in carbon fixation. It is named for the 3-carbon molecule present in the first product of carbon fixation in the large subset of plants known as C3 plants, in contrast to the 4-carbon molecule products in C4 plants

C4 Car.bon Fix.a.tion

C4 carbon fixation is one of three biochemical mechanisms, along with C3 and CAM photosynthesis, used in carbon fixation. It is named for the 4-carbon molecule present in the first product of carbon fixation in the small subset of plants known as C4 plants, in contrast to the 3-carbon molecule products in C3 plants

Cal.vin Cy.cle *noun*

a cycle of biochemical reactions taking place in the chloroplasts of plants during photosynthesis, in which carbon dioxide is fixed and six-carbon sugar is formed; also called Calvin-Benson cycle. Named for Melvin Calvin, Nobel prize-winning chemist.

ca.lyx *noun* /*keI* lihks or *kae* lihks/

(calyces, calyxes) the outermost part of

a flower, composed of usually green sepals.

can.de.la *noun* /kaen *del* ə/

the basic unit of intensity of light, equal to one sixtieth of the intensity of one square centimeter of a radiating body at the temperature of solidification of platinum.

can.dle.pow.er *noun* /*kaen* dəl *paU* ər/

an obsolete unit expressing luminous intensity, equal to 0.981 candela. Originally defined in England by the Metropolitan Gas Act 1860 as the light produced by a pure spermaceti candle weighing one sixth of a pound and burning at a rate of 120 grains per hour.

can.o.py *noun* /*kae* nə pi/

the overarching, rooflike cover of

upper foliage in a forest or planting.

capitate *adjective* /*kae* pə teIt/

ending in a distinct compact head.

car.pel *noun* /*kar* pəl/

the female organ of a flower, consisting of a modified leaf that forms a single pistil or one member of a compound pistil, in which the seeds mature.

cat.i.on *noun* /*kae* ti ən or *kae* ti an/

an ion with a positive charge. (Cf. anion.)

cell *noun* /*sel*/

a microscopic unit of plant or animal life, usually containing a nucleus and surrounded by a very thin membrane.

cel.lu.lose *noun* /*sel* yə los/

an inert carbohydrate that is the main element of plant tissue.

chem.o.type *noun* /*ki* mo taIp/

a chemically distinct entity in a plant or microorganism.

chlo.ro.phyll *noun* /*klo* rə fIl/

the green pigment in the leaves and stems of plants that is necessary for the production of plant food by photosynthesis.

chlo.ro.plast *noun* /*klo* rə plaest/

a small oval green bit of protoplasm that contains chlorophyll and is the location of photosynthesis.

chro.mo.some *noun* /*kro* mə som/

one of the tiny, threadlike, DNA-containing bodies found in the cell nuclei of all plants and animals, responsible for transmitting hereditary characteristics.

cir.ca.di.an *adjective* /sər *keI* di ən/

denoting or concerning behavioral or physiological activities that recur at about twenty-four-hour intervals, such as sleep rhythms.

clay *noun* /*kleI*/

earth that consists mainly of hydrated silicates of aluminum, the constituent particles of which are less than 0.002 mm in diameter.

clone *noun* /*klon*/

an organism produced asexually from a single ancestor and genetically replicating it.

Co.he.sion-Ten.sion mech.a.nism

col.loid *noun* /*ka* loId/

in chemistry, a suspension of a very finely ground or divided substance in a gas, liquid, or solid, such that suspended particles tend not to settle out.

con.cen.trate *noun* /*kan* sən treIt/

something in concentrated form, such as juice or flavoring. (verb) To make or become denser or purer by the removal of certain elements, especially the solvent of a solution.

con.vec.tion *noun* /kən *vek* shən/

the motion or transmittal of heat through a liquid or gas because of the natural rising of the heated parts and sinking of the cooled parts.

cor.tex *noun* /*kor* teks/(cortexes, cortices)

the outermost layer of the stem or root of a plant, bounded on the outside by the epidermis and on the inside by the endodermis.

Crass.u.la.cean Ac.id Me.tab.o.lism (CAM) *noun* /*kraes* ə *leI* shən/

a type of photosynthesis exhibited by many succulent plants in which carbon dioxide is taken up and stored during the night to allow the stomata to remain closed during the daytime, thus decreasing water loss.

cu.ti.cle *noun* /*kyu* tih kəl/

the outer, waxy layer of the leaf. This layer's primary function is to prevent water loss within the leaf.

cyst.o.lith *noun* /*sIst* ə lIth/

a mineral concretion, usually of calcium carbonate, occurring in the epidermal cells of certain plants.

dark re.ac.tions *noun*

the second stage of photosynthesis (also called the the Calvin Cycle) that does not require the presence of light. It involves the fixation of carbon dioxide and its reduction to carbohydrate and the dissociation of water, using chemical energy stored in ATP.

der.mal tis.sue *noun* /*duhr* məl *tI* shu/

Also called the epidermis, this is the tissue of a plant other than the ground, and vascular tissues. The outer protective layer of the primary plant body (the roots, stems, leaves, flowers, fruits, and seeds). The epidermis is usually one cell layer thick, and its cells lack chloroplasts.

di.cot.y.le.don *noun* /*daI ka* tə *li* dən/

a member of a large group of flowering plants that bear two embryonic seed leaves at sprouting, such as oaks, beans, and cabbages. (Cf. monocotyledon.)

dif.fu.sion *noun* /dih *fyu* zhən/

a mixing of molecules of different substances, that results from random thermal motion.

di.lute *transitive verb* /dih *lut* or *daI lut*/

to make (a solution) thinner or less concentrated by adding more solvent.

adjective Decreased in concentration or strength, especially as a result of adding something else; diluted.

di.oe.cious *adjective* /*daI i* shəs/

especially of plants, having the male and female reproductive organs in separate individuals.

do.lo.mite *noun* /*do* lə *maIt*/

a sedimentary rock, similar to limestone, that consists mainly of this mineral.

dom.i.nant *adjective* /*dam* ə nənt/

in genetics, of a gene or trait that masks the influence of a recessive when the two appear together. (Cf. recessive.)

e.da.phic *adjective* /ih *daf* ik/

of, produced by, or influenced by the soil.

e.lec.tron *noun* /ih *lek* tran/

a negatively charged particle, considered a fundamental unit of matter, that exists independently or outside the nucleus of an atom.

en.do.der.mis *noun* /*en də* dərməs or *en do* dərməs/

an inner layer of cells in the cortex of a root and of some stems, surrounding a vascular bundle.

en.dog.e.nous *adjective* /*en da* jə nihs/

1. coming or produced from or developing within, as certain spores, or due to internal conditions, as certain diseases. (Cf. exogenous.)

2. of, pertaining to, or constituting the metabolism of elements of living tissue containing nitrogen.

ep.i.der.mis *noun* /*e* pə *duhr* mihs/

in many plants and other organisms, an outer protective layer of cells.

e.rect.o.phile *adjective* /ih *rekt* ə faIl/

predominantly vertical arrangement of leafs in a plant or crop.

noun

plant characterized as such. (Cf. planophile.)

e.ti.o.late *transitive verb* /*i* ti ə *leIt*/

to keep (a plant or the like) a light color by preventing exposure to sunlight; blanch; bleach.

intransitive verb to whiten or lose color, as a plant lacking sunlight.

eu.di.cots *noun* /*yoo* də katz/

an angiosperm having two cotyledons

in the seed; they are the largest group of flowering plants.

Eu.car.y.a *noun* /*yoo* kar *ee* uh/

one of the three-domain system (the other are Bacteria and Eucarya). A domain of organisms having cells each with a distinct nucleus within which the genetic material is contained.

ex.og.e.nous *adjective* /*ek sa* jə nihs/

1. having external causes or origins. (Cf. endogenous.)

2. in botany, of or pertaining to a process of growing in diameter by addition of successive layers under the bark; cambial.

fert.i.ga.tion *verb* /*fuhr* tih *geI* shən/

the application of fertilizers, soil amendments, or other water-soluble

products through an irrigation system.

fil.a.ment *noun* /*fI* lə mənt/

a threadlike structure, stalk that connects to and holds up the anther.

fil.i.al *adjective* /*fI* li əl/

denoting the generation or generations after the parental generation.

flac.cid *adjective* /*flae* sihd/

without firmness; soft; flabby. (Cf. turgid.)

flor.i.gen *noun* /*flo* rih gen/

the protein responsible for controlling and/or triggering flowering in plants. Florigen is produced in the leaves, and acts in the shoot apical meristem of buds and growing tips.

flow.er *noun* /*flaU* ər/

the seed-bearing part of a plant, consisting of reproductive organs (stamens and carpels) that are typically surrounded by a brightly colored corolla (petals) and a green calyx (sepals)

flush *noun* /*fluhsh*/

a brief but heavy gush or flow, especially of water. *transitive verb* to wash out, clean, or empty with a swift gush or flow of water.

flux *noun* /*fluhks*/

in physics, the rate of flow of matter or energy considered as a fluid.

foot-can.dle (foot candle) *noun* /*fUt* kaen dəl/

a unit of illumination equal to that

produced by one candela at a distance of one foot, or to one lumen per square foot.

gam.ete *noun* /*gae* mit/

a mature reproductive cell, such as an egg or sperm, that is capable of uniting with another cell to form a new organism.

gene *noun* /*jin*/

a section of a chromosome that determines the structure of a single protein or part of one, thereby influencing a particular hereditary characteristic, such as eye color, or a particular biochemical reaction.

gen.o.type *noun* /*je* nə *taIp*/

1. the genetic makeup of a living creature. (Cf. phenotype.)

2. a collection of living creatures with the same genetic makeup.

gla.brous *adjective* /*glae* brəs/

having no hair or fuzz; bald; smooth.

glu.cose *noun* /*glu* kos/

a form of sugar that occurs naturally in fruits, plants, and animal tissues; grape sugar.

ground tis.sue *noun* /*graUnd tI* shu/

The tissue of a plant other than the epidermis, and vascular tissues.

guard cell *noun* /*gard* sel/

each of a pair of curved cells that surround a stoma, becoming larger or smaller according to the pressure within the cells.

gyp.sum *noun* /*jIp* səm/

a mineral, hydrated calcium sulfate, that resembles chalk and is used to make plaster of Paris, plaster and wallboard, and fertilizers.

he.red.i.ty *noun* /hə *re* dih ti/

1. the genetic transmission of traits or tendencies from parent to offspring.

2. the collective traits or tendencies inherited in such a way.

her.maph.ro.dite *noun* /hər *mae* frə *daIt*/

1. an individual with both male and female reproductive organs.

2. an organism, such as an earthworm or plant, that characteristically possesses both

male and female reproductive organs.

het.er.o.zy.gous *adjective* /*he* tə rə *zahy* guhs or *he* tə ro *zahy* guhs/

having two different alleles at corresponding positions on homologous chromosomes.

ho.mo.zy.gous *adjective* /*hoh* muh *zahy* guhs or *hoh* mo *zahy* guhs/

having the same alleles at corresponding positions on homologous chromosomes.

hu.mus *noun* /*hyu* məs/

a dark organic material, composed of partly decayed leaves and plants, that adds nutrients and water-retaining ability to soil.

hy.brid *noun* /*haI* brihd/

the offspring of two plants or animals that differ genetically as to species, variety, breed, or the like.

adjective

produced by cross-breeding.

hy.per.ton.ic *adjective* /*haI* pər *ta* nihk/

having a higher osmotic pressure than a particular fluid, typically a body fluid or intracellular fluid.

hy.po.ton.ic *adjective* /*haI* pər *ta* nihk/

having a lower osmotic pressure than a particular fluid, typically a body fluid or intracellular fluid.

il.lu.mi.nance *noun* /ih *lu* mə nəns/

the intensity of light per unit of area on a surface exposed to light;

illumination.

in-vitro *adjective, adverb* /in *vi* tro/

(of processes or reactions) taking place in a test tube, culture dish, or elsewhere outside a living organism.

in-vivo *adjective, adverb* /in *vi* vo/

(of processes) taking place in a living organism.

in.flo.res.cence *noun* /*In* flə *re* səns/

a cluster of flowers or a single flower on a plant.

in.or.gan.ic *adjective* /*In* or *gae* nihk/

of a chemical substance, not containing carbon.

i.on *noun* /*aI an* or *aI* ən/

an atom, group of atoms, or molecule that bears a positive electric charge as a result of electron loss or a negative charge as a result of electron gain.

ir.ra.di.ance *noun* /ih *rey* dee uhns/

the radiant flux incident on unit area of a surface (normal to the direction of flow of radiant energy through a medium). It is measured in watts per square metre (W/m^2).

i.so.mer *noun* /*aI* sə mər/

a chemical compound that has the same kind and number of atoms as one or more other compounds, but differs from them in structural or spatial arrangement of the atoms and therefore in its properties.

i.so.ton.ic *adjective* /*aI* sə *ta* nihk/

1. equal in tension.

2. of or showing equal osmotic pressure.

la.bile *adjective* /*leI baIl* or *leI* bihl/

1. subject to or ready for change; adaptable.

2. unstable, as chemical elements or compounds.

leaf.let *noun* /*lif* liht/

any of the segments or blades that form a compound leaf.

L.E.D *abbreviation* /*el* i *di*/

abbreviation of "light-emitting diode," a semiconductor diode that emits light when electrified, used for displaying readings on electronic watches, calculators, and the like.

light re.ac.tions *noun*

the first stage of photosynthesis during which energy from light is used for the production of ATP.

lu.men *noun* /*lu* mən/

(lumens, lumina)

a unit of measure of the flow of light, equal to the flow from a light source of one-candle strength, measured on a unit surface at a unit distance. (abbr.: lm)

lu.mi.nance *noun* /*lu* mih nəns/

the measure of brightness of a light source or a luminous surface in candelas per unit area.

lu.mi.nous flux *noun* /*lu* mih nəs *fluhks*/

the measure of the rate at which perceived light flows through a given area.

lu.mi.nous flux density *noun* /*lu* mih nəs *fluhks den* sih ti/

a measure of the rate of flow of luminous energy per unit time, evaluated according to its ability to produce a visual sensation. The SI unit of measure for luminous flux density is the lumen (lm).

lu.mi.nous in.ten.si.ty *noun* /*lu* mih nəs ihn *ten* sih ti/

the quantity of visible light that is emitted in unit time per unit solid angle (steradian). The SI unit of luminous intensity is the candela (cd).

lux *noun* /*luks*/

(luces, luxes)

a unit of illumination equal to one lumen per square meter.

mei.o.sis *noun* /maI *o* sihs/

the process in which the diploid chromosomes of a cell are replicated once, followed by two divisions of the nucleus, to give rise to four haploid cells that may develop into gametes or spores.

mem.brane *noun* /*mem* breIn/

1. a thin, flexible, tensile layer of tissue that separates, connects, lines, or covers various structures, such as organs, in living organisms.

2. a bilayer of lipid molecules that serves as a covering for cells.

mer.i.stem *noun* /*mae* rih stem/

a region of plant tissue, found chiefly at the growing tips of roots and shoots and in the cambium, consisting of

actively dividing cells forming new tissue.

mes.o.phyll *noun* /*mez* uh fil or mes uh fil/

the inner tissue of a leaf, containing many chloroplasts.

me.tab.o.lism *noun* /mə *tae* bə lih zəm/

the physical and chemical processes by which food is converted by a living organism to provide energy and produce and maintain cells and tissues.

mi.to.sis *noun* /*maI to* sihs/

1. duplication and division of the nucleus of a dividing cell.

2. cell division in which this process occurs.

mon.o.cot.y.le.don *noun* /*ma* nə *ka* tə *l*i dən/

a member of the subgroup of flowering plants that produce only one seed leaf, usually bear leaves with parallel veins, and do not grow in width by means of a vascular cambium. (Cf. dicotyledon.)

derived forms:

monocot (n.)

mo.noe.cious *adjective* /mə *ni* shəs/

in botany, having both male and female flowers on each individual plant.

mon.o.typ.ic *adjective* /*ma* nə *tI* pihk/

of a biological species, being the unique representative of one's gender, family, or higher taxonomic classification.

node *noun* /*nod*/

a usually thickened part or joint of a plant stem, from which a leaf or bud may grow.

or.gan.ic *adjective* /*or gae* nihk/

of or pertaining to compounds that contain carbon. (Cf. inorganic.)

os.mo.sis *noun* /az *mo* sihs or as *mo* sihs/

the passage or diffusion of a liquid through a semipermeable membrane until the concentration is the same on both sides of the membrane, or the tendency of a liquid to diffuse in such a way.

outcross *verb* /a*Ut* kraws/

breed (an animal or plant) with one not closely related.

noun
an animal or plant produced as the result of outcrossing.

o.va.ry *noun* /*o* və ri/

(ovaries)

in a flowering plant, the lower section of the pistil that contains the ovules or seeds and that enlarges to form the fruit.

pal.i.sade cell *noun* /*pae* lih seld *sel*/

plant cells found within the mesophyll in leaves of many plants, right below the upper epidermis and cuticle. They are vertically elongated, a different shape from spongy mesophyll cells beneath them in the leaf.

pen.du.lous *adjective* /*pen* jə ləs or *pen* də ləs or *pend* yə ləs/

hanging downward; suspended so as to swing or sway.

pet.al *noun* /pe təl/

one of the separate, modified leaves, usually of a different color from the plant's other leaves, that form the outer part of a flower head.

pet.i.ole *noun* /*pe* ti ol/

the thin stalk by which a leaf is attached to a stem.

pH *abbreviation* /pi *eIch*/

a symbol for a measure of the degree of alkalinity or acidity of a solution, determined by the concentration or activity of hydrogen ions therein (often followed by a number, with seven indicating neutrality, zero to six indicating acidity, and eight to fourteen indicating alkalinity).

phe.nol *noun* /*fi nawl* or *fi nal*/

a poisonous white acidic compound found in the tars of wood and coal, or derived from benzene, and used primarily as a disinfectant or antiseptic.

phe.no.type *noun* /*fi* nə *taIp*/

1. the observable traits of an individual or group, especially as a function of genetic composition and environment. (Cf. genotype.)

2. an individual or group that exhibits these traits.

pher.o.mone *noun* /*fe* rə *mon*/

any of a group of chemical substances produced by a plant or animal to elicit a response or behavior from another of the same species.

phlo.em *noun* /*flo* əm/

the soft tissue in vascular plants that contains tubes and other cellular and fibrous material used to conduct food.

pho.tom.e.try *noun* /fo *ta* mih tri/

the measurement of light, especially its intensity or fluctuation.

pho.to.per.i.od *noun* /*fo* to *pir* i əd/

the period of time each day during which an organism receives illumination; daylength.

pho.to.re.vers.i.ble *adjective* /*fo* to rih *vuhr* sih bəl/

Describing any compound or system that can exist in two forms, and can be changed from one to the other by the appropriate influence of light.

pho.to.syn.the.sis *noun /fo* to *sIn* thə sihs/

the process in plants by which sunlight, with the help of chlorophyll, is converted to chemical energy that is used to synthesize inorganic compounds into organic ones, especially sugars.

Pho.to.syn.thet.ic Ac.tive Ra.di.a.tion (PAR)

the spectral range of solar radiation from 400 to 700 nanometers that photosynthetic organisms are able to use in the process of photosynthesis.

Pho.to.syn.thet.ic Pho.ton Flux Den.si.ty (PPFD)

the photon flux density of PAR, also referred to as Quantum Flux Density. This is the number of photons in the 400-700 nm waveband incident per

unit time on a unit surface.

phyl.lo.tax.y *noun* /*fI* lə *taek* si/

1. the arrangement of plant leaves along a stem, or the principles governing this arrangement.

2. the study of these principles.

phy.to.chem.is.try *noun* /*faI* to *ke* mih stri/

the branch of chemistry that deals with plants and the substances they produce.

phy.to.chrome *noun* /*fahy* tuh krohm or *fahy* to krohm/

a blue-green pigment found in many plants, in which it regulates various developmental processes.

pig.ment *noun* /*pIg* mənt/

the natural coloring matter of animal or plant tissue (as in chlorophyll).

pis.til *noun* /*pI* stihl/

the organ of a flower that contains the ovule or ovules.

plan.o.phile *adjective* /*plein* ə faIl/

predominantly horizontal arrangement of leafs in a plant or crop.

noun

plant characterized as such. (Cf. erectophile.)

plan.tae *noun* /*plaen* teI/

the taxonomic kingdom comprising all living or extinct plants

pol.len *noun* /*pa* lən/

the fine-grained powder that a flowering plant produces which, when transferred to another plant of the same species, fertilizes that plant's seeds.

pol.y.morph *noun* /*pol* ee mawrf/

an organism or inorganic object or material that takes various forms.

pol.y.tip.ic *adjective* /*pol* ee *tip* ik/

Having several variant forms, especially containing more than one taxonomic category of the next lower rank.

prop.a.gate *transitive verb* /*pra* pə *geIt*/

to reproduce (offspring) or cause to reproduce.

pro.tein *noun* /*pro* tin/

any of a group of complex organic compounds containing nitrogen and composed of chains of amino acids, found in all living organisms and considered essential to all animal life processes.

pro.ton *noun* /*pro* tan/

an elementary particle of matter in the nucleus of all atoms, having a positive electrical charge.

pu.bes.cent *adjective* /pyu *be* sənt/

covered with soft down or fine, short hairs.

pul.vin.us *noun* /puhl *vahy* nuhs or puhl *vi* nuhs/

(pulvini)

an enlarged section at the base of a leaf stalk in some plants that is subject to

changes of turgor, leading to movements of the leaf or leaflet.

ra.di.an *noun* /*reI* di ən/

a unit of angle, equal to an angle at the center of a circle whose arc is equal in length to the radius.

ra.di.ance *noun* /*reI* di əns/

the flux of radiation emitted per unit solid angle (steradian) in a given direction by a unit area of a source.

ra.di.ant flux *noun* /*reI* di ənt *fluhks*/

the rate at which radiant energy such as heat or light flows through a given area.

ra.di.ant flux den.si.ty *noun* /*reI* di ənt *fluhks den* sih ti/

the radiant energy in a beam of

electromagnetic, thermal, or acoustic radiation passing through a unit normal section per unit time. The SI units for these quantities are watts per square meter (W/m^2). Also called irradiance.

ra.di.ant in.ten.si.ty *noun* /*reI* di ənt ihn *ten* sih ti/

in radiometry, a measure of the intensity of electromagnetic radiation. It is defined as power per unit solid angle. The SI unit of radiant intensity is watts per steradian ($W. sr^1$).

rad.i.om.e.try noun /*reI* di *a* mih tri/

in optics, a set of techniques for measuring electromagnetic radiation, including visible light.

re.cep.ta.cle *noun* /rih *sep* tə kəl/

the part of a flower stalk where the parts of the flower are attached.

re.ces.sive *adjective* /rih *se* sihv/

in genetics, of an allele or trait whose influence or characteristic does not appear when combined with a masking or dominant allele or trait. (Cf. dominant).

noun

in genetics, a recessive allele or trait. (Cf. dominant).

root cap *noun* /*rut* kaep/

a protective cap of parenchyma cells that covers the terminal meristem in most root tips.

root hair *noun* /*rut* heIr/

a filamentous extension of an epidermal cell near the tip of a rootlet that functions in absorption of water and minerals.

ro.sal.es *noun* /ro *zol* əs/

an order of dicotyledonous plants having flowers with the petals separate or in some members of the family Leguminosae more or less united, a partly united calyx, epigynous or perigynous stamens, and one or more carpels

ro.sid *noun* /*ro* sid/

the rosids are members of a large monophyletic clade of flowering plants, containing about 70,000 species, more than a quarter of all angiosperms.

sand *noun* /*saend*/

loose grains of finely ground rock, often including quartz, the constituent particle of which are of a size between 2.0 mm and 0.05 mm in diameter

seed *noun* /*sid*/ (seed, seeds)

the small part of a flowering plant that is capable of growing into a new plant.

sel.fing *transitive verb* /*self ing*/ slang (See autogamy.)

se.pal *noun* /*si* pəl/

one of the leaflike parts that enclose an unopened flower.

ses.sile *adjective* /*se* sihl or *se saIl*/

1. of a leaf or the like, attached at the base directly to the stem of the plant.

2. unable to move freely; permanently fixed.

silt *noun* /*sIlt*/

fine sediment deposited by water, as of

earth, clay, or sand, the constituent particles of which are between 0.05 mm and 0.002 mm in diameter.

sko.to.phile (scotophile) *noun* /*skot* ə faIl/

an organism that requires or has an affinity for darkness. (Cf. photophile.)

sol.ute *noun* /*sal* yut/

the substance that has been dissolved to form a solution.

so.lu.tion *noun* /sə *lu* shən/

a liquid mixture in which the minor component (the solute) is uniformly distributed within the major component (the solvent).

sol.vent *adjective* /sal vənt/

able to dissolve another substance.

noun

a substance that is able to dissolve certain other substances.

sta.men *noun* /*steI* mən/

(stamens, stamina)

the stalklike part of a flower that produces and bears the pollen.

ste.le *noun* /*sti* li or *stil*/

(stelai, steles)

the central core of vascular tissue in plant stems and roots.

ste.ra.di.an *noun* /stuh *rey* dee uhn/

(steradians)

the SI unit of solid angle, equal to the angle at the center of a sphere

subtended by a part of the surface equal in area to the square of the radius. (abbr.: sr)

stig.ma *noun* /*stIg* mə/

(stigmas, stigmata)

part of a plant that receives pollen; pistil.

stip.ule *noun* /*stIp* yul/

either of a pair of small, leaflike parts at the base of a leaf in plants such as the bean, pea, or rose.

sto.ma *noun* /*sto* mə/

(stomas, stomata)

any of various microscopic openings in the epidermis of a leaf or stem through which gases and water vapor are exchanged.

sto.mat.al con.duct.ance *noun* /kən *dək* təns/

usually measured in µmol m^2s^1, is the measure of the rate of passage of carbon dioxide entering, or water vapor exiting through the stomata of a leaf.

style *noun* /*stahyl*/

(in a flower) a narrow, typically elongated extension of the ovary, bearing the stigma.

tax.on.o.my *noun* /*taek sa* nə mi/

in biology, the system of classifying plants and animals by grouping them into categories according to their similarities.

ter.pene *noun* /*tuhr* pin/

any of several unsaturated

hydrocarbons, derived from resins and oils, that are used primarily in medicines and perfumes.

tran.spir.a.tion *noun* /tran spuh *rey* shun/

the process of water movement through a plant and its evaporation from aerial parts, such as from leaves but also from stems and flowers.

tri.chome *noun* /*trik* ohm/

a small hair or other outgrowth from the epidermis of a plant, typically unicellular and glandular.

tro.pism *noun* /*tro* pih zəm/

in biology, the turning or growth of an organ or organism toward or away from an external stimulus such as light, gravity, or nutrients.

tur.gid *adjective* /*tuhr* jihd/

swollen, as from a fluid or inner pressure.

vas.cu.lar tis.sue *noun*

the tissue in higher plants that constitutes the vascular system, consisting of phloem and xylem, by which water and nutrients are conducted throughout the plant.

watt *noun* /*wat*/

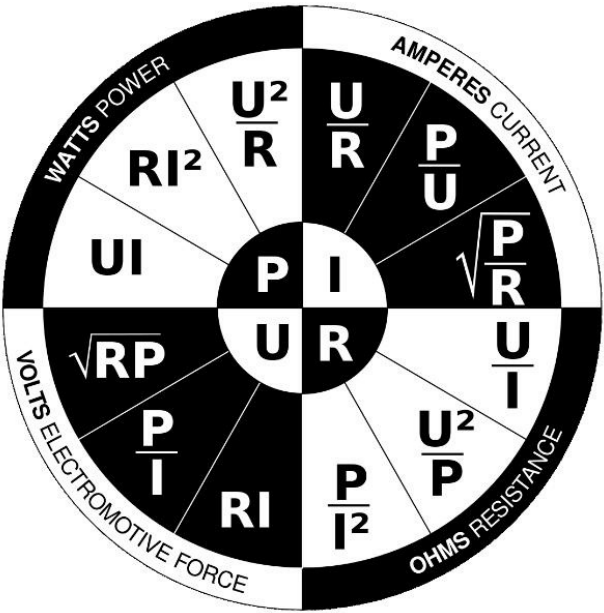
a unit of electrical power equal to the current of one ampere produced by the electromotive force of one volt, or to one joule per second. (abbr.: w, W)

xy.lem *noun* /*zaI* ləm/

a plant's woody tissue that carries water and mineral salts.

Appendix III - Useful Information

Electrical Calculations



Duct Pneumatics

Imperial Units (remember when shopping fans: CFM is an Imperial measure)

vi = qi / Ai

= 576 qi / (pi di2)

= 144 qi / (ai bi)

where

vi = air velocity (ft/min)

qi = air flow (cfm)

Ai = area of duct (square feet)

di = diameter of duct (inches)

ai = width of duct (inches)

bi = width of duct (inches)

Metric Units

vm = qm / Am

= 4 qm / (pi dm2)

= qm / (am bm)

where

vm = air velocity (m/s)

qm = air flow (m3/s)

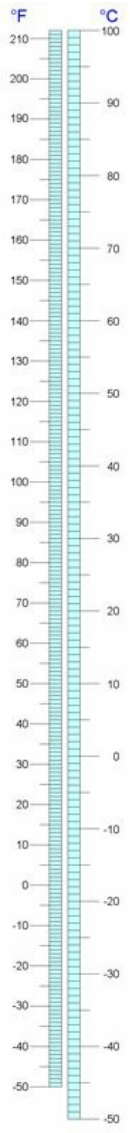
Am = area of duct (m2)

dm = diameter of duct (m)

am = width of duct (m)

bm = width of duct (m)

Temperature Conversion


°F
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-30
-40
-50

Light Efficiency Math

Here's how to determine whether purchasing an LED is right for you.

1. Figure out what you are already using in kilowatt hours (KHW) per month and multiply that by your cost per KWH to get your monthly cost. You can find all you need to know on your electric bill. Let's look at an example:

> 1000 watt HPS on 12 hours/day all month at 10c per KWH.
> 1000 watts = 1 KW x 12 x 30 = 360 KWH x $.10 = $36 per month to run your 1000 watt HPS lamp.

1. Determine what your new LED will cost to run for the same period under the same conditions. For example, if you intend to replace your 1000 watt HPS with

an LED unit rated at 600 watts, you would simply multiply your $36 by 60%, and you can see that you'd be spending $21.60 per month, which is a savings of $14.40 per month.

2. Recall that sometimes you will be running your lamp 24 hours/day for the month. The percent savings is the same but the total saving jumps to $28.80 per month for that month.

3. Figure on two months of 12-hour lighting and one month of 24-hour lighting per cycle. $14.40 + $14.40 + $28.80 = $57.60 per cycle.

4. Four cycles per year gives you an annual energy cost savings of $230.40.

Because you no longer have to buy a

new HPS lamp every year, you can calculate your Return on Investment (ROI) Period using the following equation:

Investment / (Energy Savings + New Lamp Expense Savings) = ROI

To continue with our example, suppose you are trying to calculate your ROI period if you purchased an LED for $1200. In this case:

$1,200 / ($230.40 + $100 replacement lamp savings) = 3.6

You would have a 3.6-year ROI period.

That's not the whole picture, though. This equation assumes no change in product yield. Yield must be figured in as well. For example, if the annual difference in bud yield is lowered by $100, your ROI Period just went out to

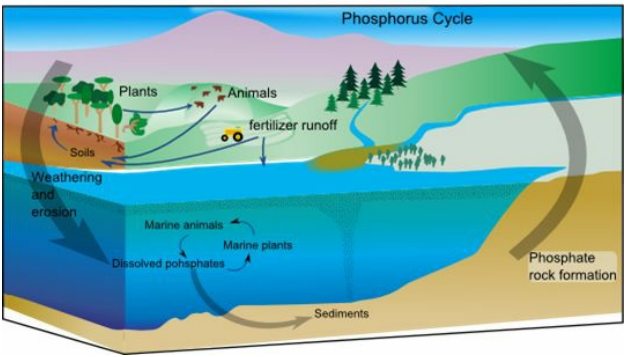
5.2 years. You can see how this difference is significant and should be a factor into your decision. Therefore, we can update our equation by calculating the ROI period as:

LED cost / (energy savings + replacement lamp savings +/- difference in yield)

I say plus or minus because your yield could increase, though it probably won't.

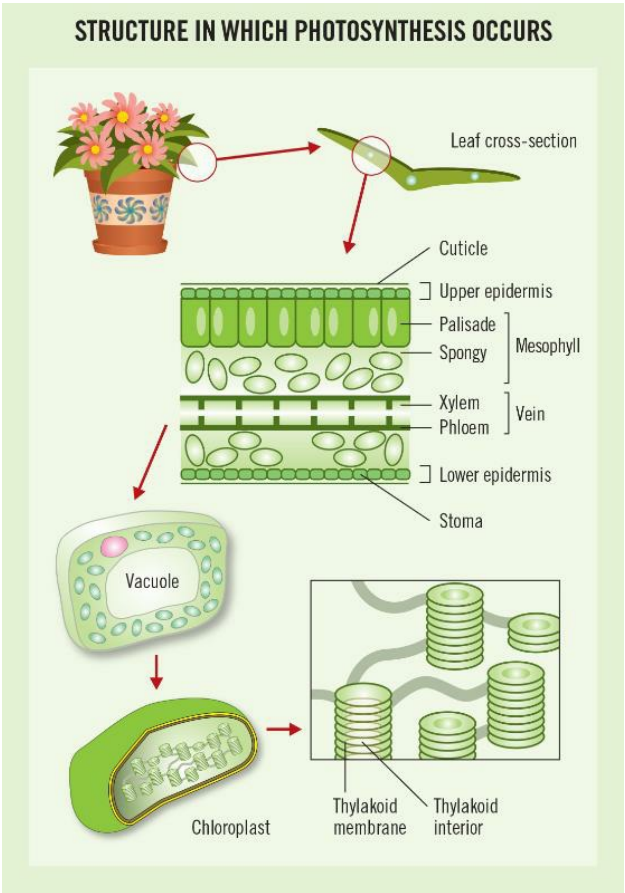
Appendix IV - Plant Processes

We covered the Nitrogen Cycle in the text; here is the Phosphorus Cycle:

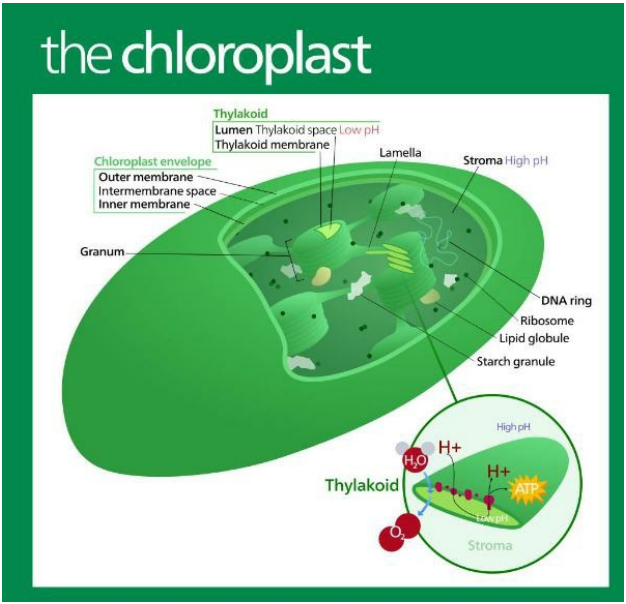


By Bonniemf Incorporates work by NASA Earth Science Enterprise [CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

Drill-down to chloroplasts, where photosynthesis occurs



Chloroplast detail:



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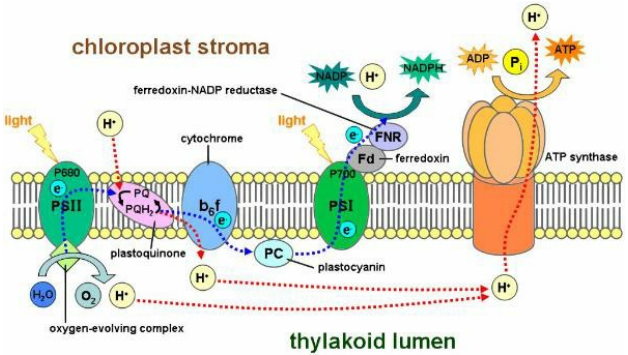
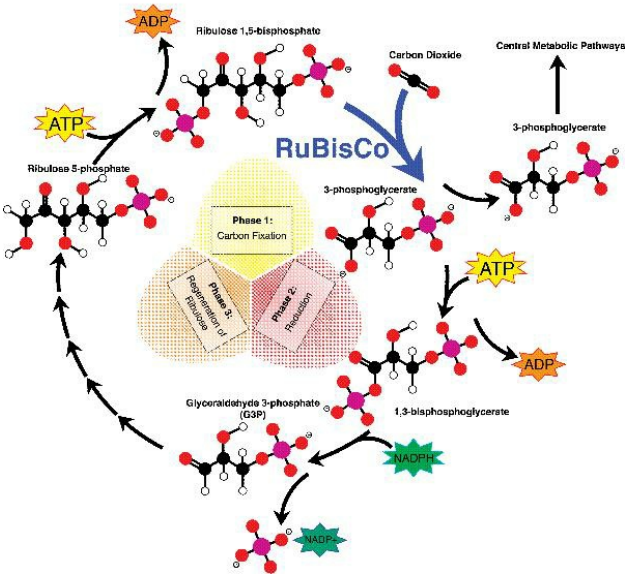
Basic photosynthesis reactions:

The light reactions:

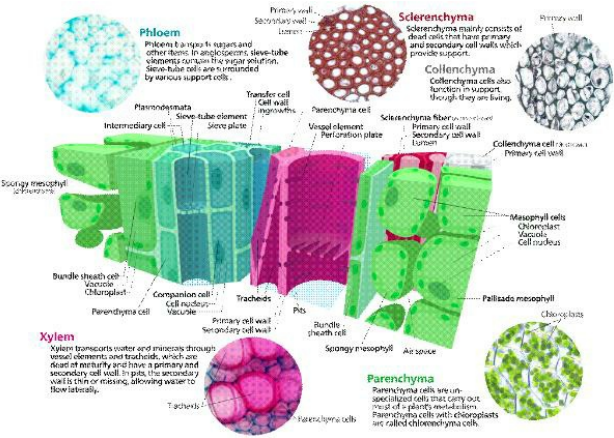


By Tameeria at en.wikipedia [Public domain], from Wikimedia Commons

The dark reactions (Calvin Cycle):



Green plant cells detail



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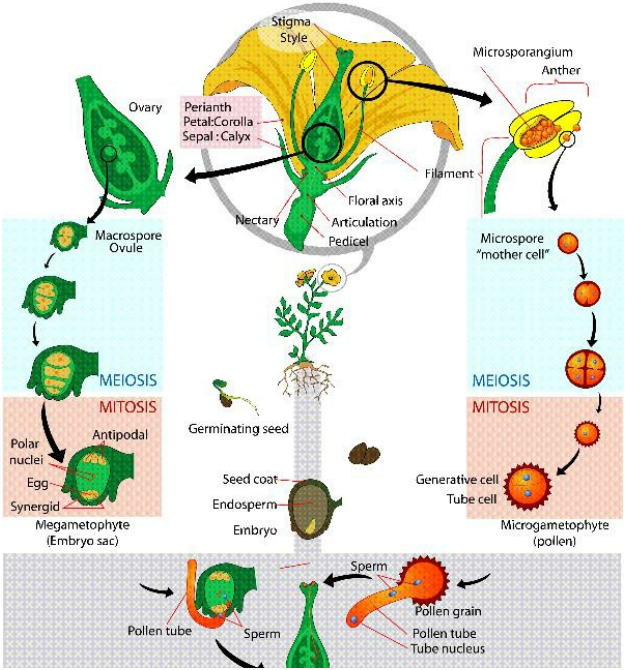
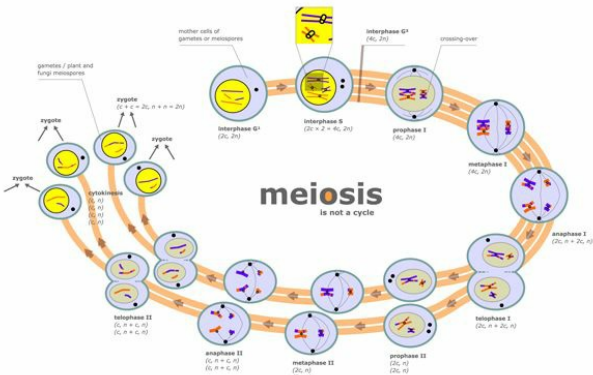
Angiosperm life-cycle



By LadyofHats Mariana Ruiz [Public domain], via Wikimedia Commons

Meiosis



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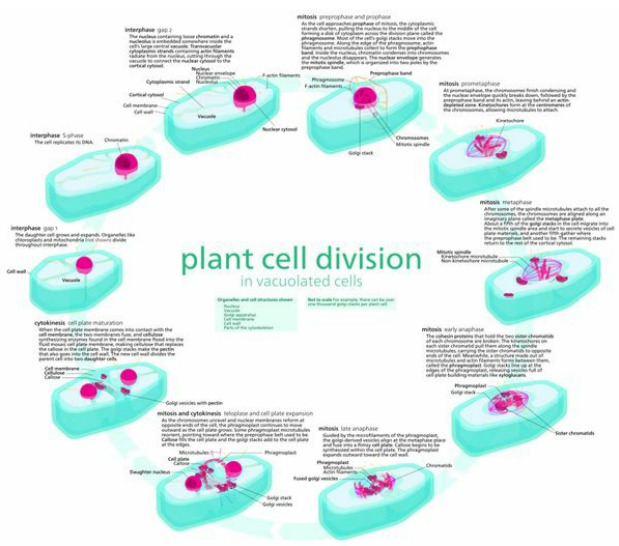
Mitosis



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Appendix V - Quiz and Answers: Test Your Understanding of Marijuana Husbandry

1. The three types of plant tissue are:

   A. root, vascular and leaf

   B. vascular, ground and aerial

   C. ground, stem and leaf

   D. dermal, vascular and root

2. As a grower, the six variables you need to control are:

   A. nutrition, media pH, air, temperature, water and light

   B. nutrition, air, temperature, humidity, water and light

   C. air, temperature, humidity,

CO_2 level, soil and water

D. medium, pH, soil, air, water and light

3. The father of modern taxonomy is:

A. Aristotle

B. Gregor Mendel

C. Carl Linnaeus

D. Jean-Baptiste Lamarck

4. The three key types of psychoactive marijuana in descending order of mature height are:

A. indica, sativa, chinensis

B. indian, sativa, ruderalis

C. sativa, indica, ruderalis

D. afghanica, sativa, indica

5. The best sequence for preparing nutrient solution is:

A. Add water, add nutrient, add more water until target ppm is reached, check and adjust pH, rest, apply.

B. Add nutrient, add more water until target ppm is reached, pH, apply, check pH later.

C. Add water, add nutrient, check and adjust pH, apply.

D. Add water, add nutrient, add more water until target ppm is reached, rest, check and adjust pH, apply.

6. Spider mites have hit your plants, but you have caught them early. Your best course of action is:

A. Throw the plants out if still very young; otherwise apply a miticide according to instructions printed on the bottle. Apply again in three days, and again three days after that. Call your friends and offer them cuts of your great new strain.

B. Stop what you are doing, panic, consider the tripartite plant disease framework and see if you can determine the vector that brought the mites in and address the source if appropriate. Apply a miticide according to instructions printed on the

bottle; apply again in three days, and again three days after that.

C. Stop what you are doing, consider the tripartite plant disease framework and see if you can determine the vector that brought the mites in and address the source if appropriate. Scrap the plants if still very young, sterilize and start fresh; otherwise apply a miticide according to instructions printed on the bottle, apply again in three days, and again three days after that.

D. Stop what you are doing, consider the tripartite plant disease framework and see if you can determine the vector that brought the mites

in and address the source if appropriate; scrap the plants if still very young, sterilize and start fresh. If the plants are nearly finished apply pyrethrins or botanical oils to manage until plants can be harvested; otherwise apply a miticide according to instructions printed on the bottle, apply again in three days, and again three days after that.

7. The endogenous hormone that allows us to manipulate plant growth is:

A. phytoestrogen

B. auxin

C. testosterone

D. giberellin

8. The end product of photosynthesis in a C3 plant is:

A. sugar

B. 'taters

C. THC

D. auxin

9. Most plants have trichomes. Really great plants have:

A. trichomes that produce THC

B. three kinds of trichomes that produce THC

C. four kinds of trichomes, only one of which does not produce THC

D. all of the above are true

10. The *tendency* to change sexes within a plant's life is called:

    A. hermaproditism

    B. sex lability

    C. dioecy

    D. intersexing

11. Osmosis is:

    A. one of three fluid transport mechanisms in the plant

    B. the transportation of solvent through a semipermeable membrane to a concentration of higher solute in the direction that tends to equalize concentration on either side of the membrane

    C. important because it creates

turgor in a healthy plant

D. all of the above

12. Light is a critical variable to control in that:

A. an increase in daylength signals the plant to flower.

B. it is a limiting factor to CO^2 utilization and therefore photosynthesis.

C. mimicking autumn colors with HPS lamps induces flowering.

D. under the right color temperature, plants can exceed their genetic potential.

13. The flowering signal in plants is known as:

A. Pfr

B. Pr

C. The Hourglass Model

D. florigen

14. Gregor Mendel discovered the way what functions in plants?

A. heredity

B. alleles

C. phloem

D. A and B

15. When growing in soil, one can reasonably expect that, over time, the soil will:

A. acidify

B. toxify due to added nutrient

C. convert nitrate to nitrite

D. stay basically the same

16. Organic nutrients are preferable to synthetic chemical nutrients because:

A. plants prefer organic nutrients.

B. organic source nutrients are cheaper.

C. organic source nutrients tend to be better for the health of soil-dwelling organisms.

D. the good vibes make for sweeter tasting bud.

17. The best measure of light when applied to horticulture is:

A. lumens

B. radiant flux

C. PAR watts

D. PPFD

18. Nitrogen is an important nutrient because:

A. the more you pour on the plants, the bigger it gets!

B. it can be safely eliminated from the feeding regimen during flower-ing.

C. it is used in the production of amino acids, which are the building blocks of proteins, including DNA and RNA.

D. it never burns.

19. Vegetative propagation is useful because:

A. it allows growers to perpetuate and refine their ability on the same strain over many crops.

B. plants so propagated are genetically diverse.

C. it's easier than ordering seeds every time.

D. plants so propagated display heterosis.

20. CO_2 supplementation is a great way to stimulate growth because:

A. there is a marked increase in net photosynthesis up to 1500 ppm.

B. it reverses the water potential of the plant.

C. without added CO_2 plants will suffocate.

D. CO_2 is a limiting factor in plants' ability to conduct photosynthesis.

21. You have crossed a wide-leaf, early-flowering plant with a wide-leaf, late-flowering plant where narrow-leaves are dominant and early flowering is recessive. Your late flowering parent is heterozygous for that trait. Your F1 offspring will look like which of the following:

A. 25% wide-leafed/early-flowering; 25% narrow-leafed/early-flowering; and 50% wide-leafed/late-

flowering

B. 50% wide-leafed/early-flowering; and 50% wide-leafed/late-flowering

C. 25% wide-leafed/late-flowering; 25% narrow-leafed/early-flowering; and 50% narrow-leafed/late-flowering

D. 25% wide-leafed/late-flowering; 25% narrow-leafed/early-flowering; 25% narrow-leafed/late-flowering; and 25% wide-leafed/early-flowering

22. Your plant is gradually yellowing on its bottom leaves, but the top is green. Your best course of action is to:

A. pour some Awesome

Product on it right now!

B. wait to see what happens next.

C. add a good macro nutrient because this is what happens when macros run low.

D. add a good micro nutrient because this is what happens when micros run low.

23. Your buddy, Scooter, tells you that you need to do a better job flushing next time because your bud is harsh smoking. You should:

A. cure a little longer.

B. slow down your drying process a bit next time.

C. do nothing because he still

owes you from last week.

D. A and B

24. Photosynthesis is conducted in which part of the plant cell?

A. the Golgi Apparatus

B. the Calvin Cycle

C. the chloroplasts

D. the nucleus, in eukaryotes

25. The majority of the bound nutrient in the colloidal component of your soil is made up of:

A. humus and clay

B. magnesium and calcium

C. topsoil and perlite

D. fish emulsion and bat guano

1)D; 2)A; 3)C; 4)C; 5)D; 6)D; 7)B; 8)A; 9)D; 10)B; 11)D; 12)B; 13)D; 14)D; 15)A; 16)C; 17)D; 18)C; 19)A; 20)D; 21)B; 22)C; 23)D; 24)C; 25)B

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Questions and comments are welcomed. You may contact the author through his website: MJAdvisor.com.

A portion of profits from the sale of this book are donated to organizations dedicated to ending the War On Drugs.

1. http://www.regulatemarijuana.o marijuana-alcohol-act-2012

2. With the exception of federal law, which has fallen behind cultural mores. The federal logic, as ever, is that because the War On Drugs is a spectacular failure, it is even more important that we intensify it.

3. http://www.famm.org/Repositor 924(c) gun MMs.pdf

4. Washington messed this up somehow--there is no personal growing allowance in Washington, which makes their law next-to-useless politically.

5. http://sos.wa.gov/assets/electio

6. (Male Incarceration Rate by Race/Ethnicity) "The custody incarceration rate for black males was 4,618 per 100,000. Hispanic males were incarcerated at a rate of 1,747 per 100,000. Compared to the estimated numbers of black, white, and Hispanic males in the U.S. resident population, black males (6 times) and Hispanic males (a little more than 2 times) were more likely to be held in custody than white males. At midyear 2007 the estimated incarceration rate of white males was 773 per 100,000."

"Across all age categories, black males were incarcerated at higher rates than white or Hispanic males. Black males ages 30 to 34 had the highest

custody incarceration rate of any race, age, or gender group at midyear 2007."

Sabol, William J., PhD, and Couture, Heather, Bureau of Justice Statistics, Prison Inmates at Midyear 2007 (Washington, DC: US Department of Justice, June 2008), NCJ221944, p.7.

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7. Aside from a few small island nations that kowtow to US drug policy, the next closest country is Rwanda, followed by Russia. Rwanda, ladies and gentlemen, is our closest peer in percent of population incarcerated.

http://www.prisonstudies.org/ir
area=all&category=wbpoprate

8. For example, between 1999 and 2010 the federal private prison population increased 784%

http://sentencingproject.org/doc

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107. Me. It's a fact now.

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109. What?!

110. No, it's not.

111. Unless you study soil as an academic discipline, then this is not at all how fertilizers are viewed.

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