Introduction

I have always wanted a larger pond in my new garden, and it was time to plan for it. It would be located at the top of a hill, next to a wooded area. This is a very natural area that has not been cultivated for many years. The design of the new pond had to fit into this environment and look as old as the mature trees and shrubs around it.

Pond building was not entirely new to me. I had built a few small traditional ponds in the past, and my last project was a large, multi-level waterfall and pond combination. These had all followed traditional designs and used pumps to keep the water clean. My new pond would be in an area that did not have electricity, and I didn't really want to run a new electric line to the location. I wondered, is it possible to build a pond with no electricity?

Why not just build a pond, fill it with water, and let nature take care of things? That seemed like a simple solution to the electricity problem. After much research in books and online, one point became very clear. Everybody agreed on one thing. A natural lined pond without pumps and filters would never work. In no time at all, it would become an algae cesspool of stinking organic matter. These so-called experts gave some vague reasons why it would not work, but nobody said that they had actually tried it.

My background is in chemistry and biology, and I have been studying plants and gardening all my life. I understood water chemistry, and the biology of water life. I maintained aquariums and bred fish for over ten years. One of my projects was to set up two five-foot long aquariums with no air and no filters. They contained a limited number of fish and lots of plants. All I did was feed the fish and replace some water once a

month. After five years, they were still going strong with no water quality problems and no need for chemicals. In that time, they were never dismantled for cleaning. The plants and fish grew so well that I had to remove some every six months. The key to these self-sufficient aquariums was the plants—lots of them. They were my air pump and filter, and they cleaned up the fish poop for me.

Why could I not replicate the self-contained aquariums in a pond? Mother Nature does it all of the time. Everything I knew about ponds, water chemistry, fish, and plants told me that it would work. Everything I read told me it would not.

After a lot of thought, I concluded that the experts must be wrong. I convinced myself that if a pond was designed correctly, following nature's guidelines, it would work. So I set out to prove the experts wrong.

That was eight years ago. Almost from day one, the pond was a success. In the first couple of years, I did have some algae in the pond, but that was because the plants had not yet established themselves. To be honest, I cheaped out and did not buy enough plants. Each year as the plants multiplied, the amount of algae decreased. I'll explain this key relationship later in more detail.

About four years into the project, the water was crystal clear. I could easily see to the bottom of my four-foot-deep pond. Algae were no longer a problem. The plants were healthy. The pond had lots of frogs and other insects. The fish were growing and breeding. I did nothing to maintain the pond—I didn't even feed the fish.

It has now been eight years, and I am totally convinced that man-made ponds can be successful without pumps, filters, and chemicals.

Why did my pond work when all of the experts said it wouldn't? The key is in the design of the pond. If you follow traditional pond designs and just leave out the pumps and filters, they will fail. You will have created a great place to grow algae. In a traditional pond, the pumps and filters play a critical role, and you can't just remove them.

This book will explain how to design the pond to work without equipment and chemicals and why the design works. You will gain a

new understanding of natural biological systems and how nature solves the algae problem.

As a garden designer, I always look at such projects on a more holistic basis. It is not just about adding a pond. To look right, the pond has to be part of the whole garden design. That is why I added a section to the book that talks about designing the look and feel of the pond. It is one thing to make the pond function and quite another to have it look natural.

To better understand the characteristics that make a pond look natural, I'll analyze some ponds that are not man-made. I call these "native" ponds to distinguish them from "natural" man-made ponds.

This is not just a how-to book. I am a big believer in understanding the "why." If you know why things work, you will be better equipped to solve problems as they arise. You will also be able to modify the designs to fit your own situation. The chapter on balanced ecosystems will take you back to school and provide essential background that will give you a deep understanding of the life in your pond. Consider it essential reading.

The information in this book will contradict much of what you find in other pond books and websites. In some cases, that other information is just plain wrong and is presented mostly to sell products that are not needed. In other cases, the information will be correct for traditional pond designs but will not apply to my natural designs. I have included a section about some of these issues so that you understand why the discrepancies exist.

Do traditional ponds work? Absolutely. My issue with traditional ponds is that they are not environmentally friendly. Buying expensive equipment that you don't need is not good for the environment. Using electricity when you don't need it is a waste of resources. Adding unnecessary chemicals is just bad for the environment. My natural pond design requires none of the above. Except for some water, it makes no demands on the environment.

I hope you enjoy this book and that you complete your project. A pond is the most enjoyable thing you can add to your garden.

CHAPTER 1

Understanding a Balanced Ecosystem

You are sitting beside your pond, trying to take it all in. A frog chirps at the edge of a lily pad. A dragonfly skims the surface of the water. Two fish chase each other, darting in and out of the plant roots. It is all very peaceful, or at least it seems to be. In reality, the pond is a natural system undergoing continuous changes. Birth, life, and death are constant. Chemical changes are also taking place every second of every day. As large inhabitants of this pond world, we can't see most of these. We only see the bigger things that happen like the jumping frog. What seems like such a simple world is actually very complex. The great thing for us, the pond caretaker, is that nature manages all of this complexity for us. We only need to provide a hole and some water. Nature will take care of the rest, provided that we build the hole in such a way that it allows nature to do her thing. This chapter provides background information on some of the natural processes taking place in a pond.

What is a balanced ecosystem? To understand this better, we should start with the word "ecosystem." An ecosystem is defined as a biological community of interacting organisms and their physical environment. A pond is an ecosystem since it contains a wide range of organisms living both in the water and around the water. Once your pond is established,

it will be an ecosystem containing thousands of different species of life-forms. That number may surprise you, but it is certainly true. All of these organisms interact with each other, either directly or indirectly. Each organism has an effect on the others.

The goal for a natural pond is to have a balanced ecosystem, in which there are no major changes. An insect may be eaten, but it is replaced with another. Some organisms die, but as they decompose, they provide life for new organisms. No one single organism becomes so dominant that it takes over the pond. The water chemistry is stable without large variations in pH and oxygen levels. This is important since every organism has a preferred set of environmental conditions. If the pH level changes too much, a specific organism may leave or die. If all of the mosquitoes suddenly die, the frogs have nothing to eat. The heron in turn has to try and survive on skinny frogs. The pond is no longer in balance.

One of the major problems of most ponds is the growth of algae. Some algae is actually good for the pond, but too much causes an imbalance in the ecosystem that in turn leads to other problems. Too much algae is also an aesthetic problem. We don't like looking at it.

A balanced ecosystem will have small amounts of algae present. A combination of other organisms and environmental conditions will keep the algae from taking over the pond. If one of these controlling factors becomes out of balance, the algae will take over the pond. As pond caretakers it is our job to create a pond in such a way that it can become balanced. Once it has reached a balanced state, it is then our job to help nature maintain the balance. A balanced ecosystem will not allow algae to take over the pond.

In order to maintain the balance in the pond, you need to understand the various organisms in the pond as well as the effect of various environmental factors. The rest of this chapter will delve into these matters.

Oxygen Cycle

All animals, including insects, birds, and fish, breathe in oxygen and breathe out carbon dioxide. Animals that live outside of the pond have

easy access to oxygen since they can breathe in air. For the animals in the water, it is a bit more complicated. They must get their oxygen by extracting it from the water. Fish, for example, pass water over their gills and extract the oxygen in the process.

The oxygen level in air is fairly constant—it always contains the same amount of oxygen, and we therefore never have a problem breathing except in special situations like a house fire. In a house fire, the burning process creates carbon dioxide. When we breathe in high levels of carbon dioxide, we don't get enough oxygen and we suffocate.

A very similar thing happens to fish. If the oxygen level in water gets too low, they suffocate and die. Living in water is more precarious than living in air since it takes a very small amount of excess carbon dioxide to kill a fish and the amount of oxygen and carbon dioxide in water is constantly changing.

The oxygen level in air is about 200,000 ppm (20 percent), and pond water will seldom have more than 10 ppm. When levels reach 3 ppm, fish will be stressed; at 2 ppm they die. Low oxygen levels are the major cause of fish deaths in ponds. Oxygen levels affect all of the animals living in water the same way, including the ones you can't see like bacteria.

Bacteria also play a critical role in the oxygen cycle. I'll discuss bacteria in more detail below, but for now think of bacteria as having a biology

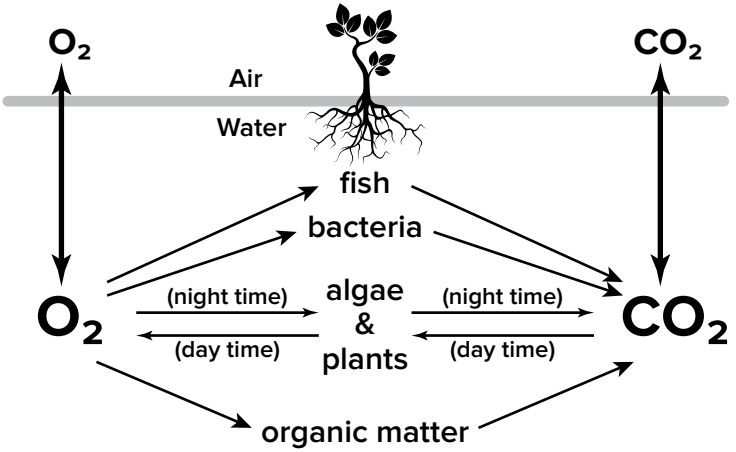

FIGURE 1
Oxygen cycle

similar to humans. They breathe in oxygen, and give off carbon dioxide. Bacteria are vital to maintaining a balanced ecosystem, and their death causes numerous problems for a pond. This is the primary reason for keeping oxygen levels high.

You may be familiar with the fact that plants use carbon dioxide during photosynthesis and give off oxygen. What is not as commonly known is that plant roots absorb oxygen all of the time, even during photosynthesis. Plants that have roots in the water and their leaves outside the water are sucking oxygen out of the water and releasing it into the air, thereby reducing oxygen levels in the water. Even at night when photosynthesis stops, these plants continue to remove oxygen from the water.

Fully submerged plants also affect oxygen levels. During the day, when the sun is shining, these plants will, through photosynthesis, add more oxygen to the water than they take out through their roots. When nighttime comes, the plants stop photosynthesis and stop adding oxygen to the water. But the roots continue using oxygen from the water. The oxygen levels in a pond at night are lower than during the day, and this can be a real problem for animals. If levels fall too low during the night, they may die.

Algae are plants, and they produce oxygen during the day and use up oxygen during the night. This is one of the main reasons that algae levels need to be controlled in a pond. High levels of algae will reduce oxygen levels at night and kill fish, insects, and bacteria.

Temperature also affects oxygen levels. Warm water holds less oxygen than cold water. Warm temperatures also increase fish activity that increases the consumption of oxygen. If it is cloudy, plants photosynthesize less, producing less oxygen. On a warm, cloudy summer day, the fish are active and the water holds less oxygen. This can be the hardest time for fish to get enough oxygen.

In addition to the effects of plants, animals, and temperature, other processes affect the oxygen level in ponds. One of the most significant is the exchange of gases between water and air. At the surface of the pond where the water and air meet, there is a constant exchange of gases.

Oxygen moves from water to air, and from air to water. It is moving in both directions at the same time. When the oxygen levels are low in the water, most of the movement is from air to water, increasing the level of oxygen in the water.

Carbon dioxide is also a gas and does the same thing. It is moving from water to air and back again. When CO_2 levels are high in water, most of the movement is out of the water, resulting in lower CO_2 levels in the water.

This exchange of gases happens all of the time, night and day, and is critical for maintaining balanced gas levels in the pond. In winter, things change when the surface of the pond freezes. The ice prevents the gases from being exchanged between the water and the air. Without gas exchange, the level of CO_2 in water increases, and if the level gets too high, the animals start to die. When fish die in winter, it is usually the high CO_2 levels that kill them, not the cold temperatures.

Anything that causes the top layer of water to move will increase the speed at which gases exchange. Wind making ripples on the water increases air exchange that helps to maintain a balanced ecosystem. Moving water with pumps, waterfalls, and fountains have the same effect as wind, but they are not needed in a properly made natural pond.

There is one final process taking place in your pond that can have a dramatic effect on the oxygen levels in water, and that is decomposition. Both animals and plants produce waste products. All types of animals, including bacteria, poop in the water, and plants shed leaves, seeds, and flowers into the water. When plants and animals die, they add even more organic matter to the pond. All of this organic matter eventually decomposes. This decomposition process uses oxygen, and produces CO_2.

It is critical that a pond maintain correct oxygen and carbon dioxide levels. The best way to ensure that this happens is to take a balanced approach. Keep the number of organisms in a balance to each other. Too many fish requires more oxygen. Too much algae produces too much CO_2. Not enough surface area relative to the total volume of water means that the air exchange at the surface of the water will not be adequate.

Moderation is the key. These topics will be revisited as we go through the design process. Proper design of the pond will eliminate the need for pumps and ensure that you don't have to worry about oxygen levels.

Nutrients

The term "nutrient" can be defined as a substance, either element or compound, that promotes growth and health in living things. The main nutrients we are interested in are the nutrients that plants use. They are the same compounds found in fertilizer—the nitrogen, phosphorus, potassium, and other minor elements.

Nutrients are critical to plants. They absorb the nutrients either through their roots, or in plants like algae that don't have roots, through their cell walls. In both cases, the nutrients are necessary for the plant to grow and carry out key functions like photosynthesis.

Plants use 20 to 30 different nutrients, but most of these are required in very small amounts that are usually found in pond water. The nutrients needed the most include nitrogen, phosphorus, and potassium. Potassium is rarely deficient in established ponds, and we can ignore it. Nitrogen and phosphorus are two nutrients that pond owners need to understand better.

The common form of phosphorus is a molecule called phosphate (PO_4), which at low levels is good for the growth of plants and bacteria. The problem with phosphate is that it accumulates in ponds and can cause problems.

The water you used to fill the pond will contain some phosphate. Water running off nearby fields will carry phosphate into the pond, adding significant amounts if the field was recently fertilized. The rocks used to line the edge of the pond will probably contain phosphorus that will slowly leach into the water. The food used to feed fish will add more phosphorus. Insects and animals that enter the pond will add phosphate when they die, as does plant material when it decomposes in the pond.

Phosphate is a salt that remains behind in the pond after water evaporates. This is the same process you see when boiling water evaporates and leaves the salt deposit behind inside your kettle. As water evaporates over time, the phosphate levels in the pond will increase.

A very similar process has been going on in nature. Over the past 40 years, most lawn fertilizer contained high levels of phosphate, much more than the plants need. The excess washed into local rivers and lakes where it started to accumulate. Soaps that contained high phosphate levels added to the accumulation. All of this excess phosphate in our waterways led to algae blooms, among other problems. Algae grow best with high levels of phosphate.

The phosphate in most lawn fertilizer has now been removed since most soil in North America has plenty of phosphorus and does not need more. Soap products have also been modified to contain far less phosphate. In the last 10 to 20 years, we have seen a steady improvement in algae levels of local waterways.

It is important to design and maintain your pond to minimize the accumulation of phosphate.

Nitrogen, a major nutrient for plants and the one that may be in short supply, is available in several chemical forms. The air we breathe is 80 percent nitrogen, but it is in the form of a gas, N_2. Plants and animals cannot use this nitrogen, but some types of bacteria can. Nitrogen is also found in nitrate and ammonium, which plants and microbes can use.

Microbes, particularly bacteria, convert one form of nitrogen to another as shown in figure 2. They are able to take nitrogen gas from the air and turn it into the other forms of nitrogen. This is critical for plant growth. They also take nitrate and ammonium and convert them back to a nitrogen gas, which escapes from the water into the air. This last point is very important. Unlike phosphate, the microbes are able to remove excess nitrogen from pond water.

Another form of nitrogen found in water is ammonia, which for the purposes of our discussion is the same as ammonium. Ammonium is a

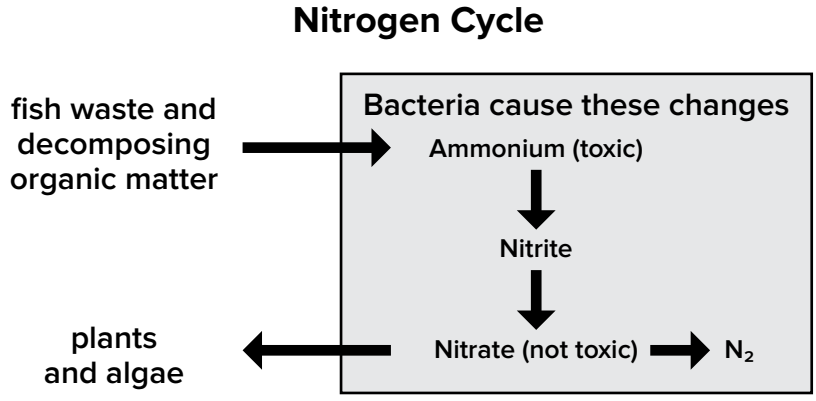

FIGURE 2
Nitrogen cycle

waste product of animals and is produced during the decomposition of organic matter. Unfortunately, this form of nitrogen is deadly to animals even at low levels. Fortunately, bacteria convert ammonium to nitrate, which is then safe for animals.

Since ammonium is so toxic to animals, the levels must be kept low. Keeping fish levels low reduces fish waste that in turn reduces ammonium levels. Excluding fertilizer will also maintain lower levels. As I explain later, the main way to control ammonium levels is through the use of microbes.

Two other nutrients are calcium and magnesium, and most pond water will have enough of them for plant growth. Rocks in the water will add more of both. These are the salts that make tap water hard. If your tap water is hard, you are adding more calcium and magnesium each time you add some to your pond and their levels can get too high. This is one good reason to use rainwater to top up your pond.

Like phosphate, these two salts will accumulate over time because they have no way to escape into the air. As water evaporates, it will leave the salts behind to slowly accumulate. These two nutrients are not harmful to animals except in very high concentrations, but eventually they may pose a problem in a pond.

pH

The pH of your water indicates how acidic or alkaline it is. A pH value of 7 is neutral—neither acidic nor alkaline. A value above 7 indicates the water is alkaline, and below 7 it is acidic. All aquatic life-forms have an optimum range in which they want to live. Most life-forms can live outside this range, but then they are more likely to have diseases and nutrient deficiencies.

Plants like to be in a range of 6 to 7.5. Fish prefer a pH between 7 and 8 and will die below 5 and above 9. Plants are a bit more flexible, but you might have to select them carefully at extreme pH ranges.

The original pH of the pond will be determined by the pH of the water used to fill it. Over time biological processes will add CO_2 to the water making it more acidic. The pH also varies depending on the time of day. During the day, plants under the water, including algae, are using up the CO_2 for photosynthesis and the pH goes up. At night, photosynthesis stops and plants produce CO_2 that lowers the pH. The pH is lowest before sunup and highest at dusk. This daily swing depends on a number of factors, but can easily change by a full pH unit.

Rain has a natural pH of 5.5 and can be more acidic in high pollution areas. A heavy rain can reduce the pH of the pond significantly.

The pH also affects the toxicity of ammonium, which is more toxic at high pH, and less so at low pH.

By now you might be feeling that all of this chemistry is very confusing and that pond keeping might not be for you. Don't worry about that. One of the benefits of making a natural pond over the traditional designs is that you don't have to be concerned about pH and ammonium levels. I'll show you how to design the pond so that nature does all of this for you.

Algae

Most algae are green, but brown ones do exist. Although they don't have roots or leaves in the traditional sense, most are able to photosynthesize. There are many types of algae but we can simplify things by considering only two types; filamentous or string algae and planktonic algae.

Planktonic algae consist of single cells that are fully self-sufficient. They are able to reproduce, absorb CO_2 and nutrients, and make food using photosynthesis. The individual cells are too small to see by eye. In a pond, they make the water look green, blue-green, or brown, and if there are a lot of them, the water looks like pea soup. This coloration is called an algae bloom and can involve many different species of algae.

Filamentous algae are also green single-cell organisms, but they join together to form long hair-like strands—the filaments. The algae attach themselves to rocks under water, and as more algae cells are added, the strands get longer and longer, forming large floating masses of stringy clumps. When it floats on the surface of the water it is called pond scum. This is the algae most people want to get rid of. Filamentous algae also photosynthesize.

All ponds have some algae, and this is actually good for the ecosystem because they serve as a food source for protozoans, insects, and fish. They are a vital part of the aquatic food chain, but too much algae becomes a nuisance. It is not aesthetically pleasing, and it can interfere with fishing and swimming. Excess algae can have a detrimental effect on the balanced ecosystem. During the night, algae produces CO_2, and too much algae can increase the level to a point where it becomes toxic to animals. The excess CO_2 also lowers the pH, which can also cause problems.

An algae bloom grows quickly filling the pond, and then it crashes, as it outgrows the availability of nutrients and cells start to die. This seems like a good thing, but the dead algae falls to the bottom of the pond, starts to decompose, and can produce high levels of CO_2 and ammonium, both of which are problems for the animal population.

It all comes down to having a balanced ecosystem. Some algae is acceptable and good for the pond. Too much is a problem.

Animals

Birds and mammals are not affected too much by the biology and chemistry going on in the pond. They use the water mostly for drinking, and if it is not suitable for them, they will just go somewhere else. They do,

however, depend on the pond for food, and so it is essential that amphibians, fish, and insects are prospering in the pond so that they attract mammals and birds—provided that is what you want.

Amphibians are a central part of pond life, and their natural habitats have been decimated in recent years. Building backyard ponds is one way to help them survive, while at the same time providing enjoyment for us. Amphibians are very sensitive to chemicals in the water and to sudden changes in water quality. If frogs live and breed in your pond, it is a reliable indicator that your water quality is good.

Very little is known about the water quality required by insects, but you will find them in just about every pond. Although the type may vary from pond to pond, there are always lots of insects in the water. If your water source is drinking water, it will be of a suitable quality for insects.

Fish are sensitive to poor water quality, which will make them more susceptible to diseases and possible death. It is difficult to treat fish in a pond for sickness, so it is better to prevent it by keeping the water quality high.

One of the main requirements for fish is the oxygen level. When it gets too low, fish can't breathe, they get sick and die. The fish will tell you when the levels are getting low by spending most of their time near the surface where oxygen levels are higher. If they continually gulp for air, they are telling you that oxygen levels have reached a critical point.

Because of their large size, relative to other pond life, fish also produce a lot of waste, which contains ammonium and other organic material. The ammonium can cause problems right away if levels are too high. The other organic material is slowly decomposed by microbes into nutrients, which in high levels cause long-term problems. The easiest way to control the amount of fish waste is to reduce the number of fish.

Fish are the one pond animal that people want to feed. All other animals find their own food, but for some reason, people feel that fish need to be fed. That may be true in an aquarium, but it is not necessary in a natural pond. Let the fish feed themselves. They will eat algae, which

reduces the algae problem, and insects and their larvae, keeping their population in check. If there is not enough food available, fish will simply grow slower, which means less fish waste. I never feed the goldfish in my pond, and they grow and breed all on their own. Stop interfering with nature and let your fish be part of the balanced ecosystem.

Trees and Shrubs

Although trees and shrubs don't affect the pond directly, they do significantly influence the pond's ecosystem. Trees can provide a significant amount of shade that will reduce the amount of algae in the pond, since algae only grows well in full sun. The reduced light under trees also affects other plants. Most pond plants like to have full sun or at least partial sun. A pond with too many trees will not be able to grow enough healthy plants. Adding shrubs around the edge of a pond not only looks more natural than a field or grass, but it also provides shelter for larger animals and birds. It makes it easier for them to visit the pond for a drink. The shrubs also attract more insects to the pond ecosystem, which in turn attracts more birds and predatory insects like dragonflies. The life around the outside of the pond extends the size of the pond ecosystem, and can easily include your entire backyard.

Trees and shrubs sound like they are a perfect addition to a pond, but they also cause a problem. In fall, these woody plants shed their leaves which drop into the water. Even evergreen plants loose leaves and needles at some point in their development. All of this extra organic matter will decompose and increase the nutrient levels that make it easier for algae to grow.

Plants

This book is all about creating natural ponds, and in a natural design, plants play a critical role. You might think that this role is an aesthetic one since all of the plants growing in and around a pond make it look natural. Although true, that is not the main reason to add plants. They are critical for maintaining water quality and keeping algae in check.

The following discussion applies to all plants that have their roots in the water, including cattails growing along the shoreline, water lilies on the water, or even fully submerged plants. They all need CO_2, water, and nutrients to photosynthesize. Plants that have leaves above the surface get CO_2 from the air; those that only have leaves below the surface extract CO_2 from the water.

Since water is readily available, there is one key requirement, nutrients, that most plants absorb through their roots. Submerged plants also absorb them through their leaves or cell walls. Nutrients are used in photosynthesis and all other functions in a plant, including growth. Throughout this chapter, we have discussed ways in which nutrients enter the pond. Plants are the only natural way to remove nutrients from the water, keeping the water quality high for other pond inhabitants.

Algae compete with other plants for nutrients. Fortunately, they only thrive if the nutrient level is high. Other plants will prosper in water with lower amounts of nutrients, but algae will not. This is the secret to maintaining a natural algae-free pond. It has to be designed so that there is a good balance between the number of plants and the amount of nutrients being added to the pond. As long as plants can keep the nutrient level low, algae will not grow.

Plants can do more than just keep nutrient levels low. Floating plants like water lilies cover the surface, which shades the water. As light levels are reduced, the amount of algae is also lowered since they only grow in high light levels. Floating plants do double duty in the pond; they reduce nutrient levels and available light.

Microbes

The term "microbe" is a general label for a wide variety of small microscopic life-forms, including bacteria, fungi, and single-celled and multicelled animals. It normally includes planktonic algae, but I will exclude algae when I refer to microbes.

You can't see individual microbes with your naked eye, but pond water has thousands of different species. You can see them when they

congregate in vast numbers on the pond liner or on rocks. Many people feel that these communities, frequently called slime, should be removed; most pond books and websites recommend a yearly cleaning. They suggest going to such an extreme as emptying the pond and scrubbing the liner.

These microbe communities play a critical role in the ecosystem of the pond. In maintaining a natural pond, you try to grow the microbes and keep them healthy and happy—you don't scrub them away.

High levels of ammonium, which is produced by fish and decomposing organic matter, can kill pond animals. The microbes, especially the bacteria, are able to digest the ammonium and convert it to nitrates which are much less toxic to animals. In a normal pond, filtration systems are used to house these microbes. The natural pond just uses slime on the pond liner and rocks to accomplish the same thing.

Microbes also use nutrients to grow. As nutrient levels get high, microbes multiply into large communities and use up excess nutrients, competing with the algae and plants. Unfortunately, too much growth causes nutrient levels to become scarce and microbes start to die. These dead microbes add to the problem of too much organic matter, which leads to more nutrients and the cycle starts all over again. A healthy plant community helps keep these growth cycles in check.

One of the most important groups of microbes is bacteria. Of the two basic types, aerobic bacteria like to live in an oxygen-rich environment just like humans. The word "aerobic" means "requiring oxygen." The other type, anaerobic, do not require as much oxygen. They live and prosper in water that has a very low level of oxygen.

A healthy pond contains mostly aerobic bacteria. These are the ones you want because they play a big role in keeping the water clear and balanced. Most ponds also have some anaerobic bacteria, found on the bottom where oxygen levels are low due to decomposing organic matter.

The bottom of the pond accumulates most of the organic matter as it falls into the water. Tree leaves, dead animals, and dead microbes all settle there, creating what is known as pond sludge. As this organic matter

decomposes, it uses up the oxygen at the bottom and makes a perfect breeding ground for anaerobic bacteria, which continue the decomposition process but more slowly than aerobic bacteria. With time the sludge layer usually gets thicker and thicker.

The sludge itself does not cause a great problem, but the anaerobic bacteria produce hydrogen sulfide, also called rotten egg gas, which is poisonous to pond life. This heavy gas tends to stay at the bottom of the pond. As long as it is not disturbed, you will not notice it. If it is disturbed, you will definitely smell the problem.

Maintaining Balance in the Ecosystem

People talk about balanced ecosystems as if nature were able to maintain them indefinitely. To some extent this is true. If you compare a native pond this year to last year, you will probably not see much difference. Even over ten years, things don't change a lot, and it is not surprising that the system is considered to be "in balance." But it's not.

Every native pond is evolving and changing over time. It is disappearing. The pond slowly fills with organic material and more and more plants, eventually becoming a bog as the water level lowers. In the distant future, it will dry up completely.

The pond you build will also want to go through the same changes. If left completely alone, it will eventually be dry land. The good news is that it takes very little effort to stop this natural progression. Your pond can be kept balanced and unchanged for a long time.

This chapter has discussed a number of biological and chemical systems that happen in every pond. I am sure that you have noticed that they are all interrelated. Each system needs to be managed and controlled, or else it affects all other systems. You might be sitting there scratching your head, thinking that you can't possibly control all of these systems correctly. You are right—you can't.

The natural pond system described in this book is designed so that it takes care of all of these systems for you, automatically. All you have to do is design the pond correctly from the start and follow a few simple rules.

Don't have too many fish because they poop too much. Use lots of plants because they keep nutrient levels low so algae do not grow. Include water lilies to shade the water. Don't clean your pond because the microbes are working for you.

The remaining chapters will address the design requirements and the pond rules in more detail. You will start to understand how easy it really is to have a natural pond with a balanced ecosystem.