Chapter 1

What Evolution Is and Why You Need to Know

In This Chapter

- Understanding what evolution is
- Introducing the scientific field of evolutionary biology
- Realizing why evolution is relevant

Evolution. You've no doubt heard about it, and you've probably seen a show or two about it on TV, but its significance likely escapes you. Watching a bunch of scientists on the Discovery Channel dig in the dirt with little toothbrushes and get really excited about some little bit of bone or a tooth may leave you thinking, "Well, yes, those do look like teeth, and they certainly do seem old, but . . ." A tooth, you say to yourself, is hardly reason to trade high fives and uncork champagne bottles. At times like these, evolution can seem pretty slippery. After all, there's got to be more to it than a stray fossilized tooth or bone fragment.

Well, there is. Evolution explains how we (and I'm using *we* collectively to mean all living organisms: you, me, and all other animals; moss, trees, and the roses in your garden; viruses, amoebas, bacteria, and all the other little critters) came to be in all our complexity and variation. The reason scientists get excited about fossilized teeth is because findings like these are consistent with what scientists understand about the evolution of life on Earth. That single tooth is just one piece of the evolutionary puzzle; thousands more pieces exist. All together, those pieces form a picture of our genetic past and a road map that leads from a common ancestor to who, and what, we are today. It's a journey over billions of years.

This chapter gives you an overview of evolution in all its glory: what it is, how it works, and what it does. By the end, you may begin to understand what the great evolutionary biologist Theodosius Dobzhansky meant when he wrote, "Nothing in biology makes sense except in the light of evolution."

Biological Evolution at a Glance

Evolution can be defined simply as change through time, and it can refer to anything that changes. Languages evolve; tastes evolve; cultures, art forms, and football offense strategy all evolve. This book isn't about evolution in general, though, but about biological evolution: the changes, over time, in organisms.

REMEMBER

Biological evolution deals with a very specific type of change through time — changes in the frequencies of different genes — throughout an entire species, or within a single population of that species, from generation to generation. *Evolutionary biologists* — scientists who study evolution — just love that stuff. Their mission? To understand how evolution works (by figuring out what causes changes in gene frequencies) and what evolution does (by figuring out what sorts of things happen when gene frequencies change).

The following sections offer a general overview of how evolution works and what it does. Parts II and III delve into these topics in a great deal more detail.

Gene defined

Back in Charles Darwin's day, a *gene* was defined simply as the unit of heredity. People knew that specific traits, such as blue eyes or red hair, were passed from parent to child, but they didn't know exactly what a gene was or how the process worked. Today, we know a lot more:

- We know about DNA (*deoxyribonucleic acid),* which is what gets passed from parent to offspring.
- We know that DNA is a long molecule made up of a string of four *subunits* (four letters); that the order of these letters, commonly called the *DNA sequence,* stores genetic information; and that a gene is a particular sequence of a particular piece of an organism's DNA.
- We've developed the chemical techniques that allow researchers to determine the exact sequence of an organism's DNA. As a result of this ability to work with DNA, scientists have a much better handle on the details of the evolutionary process.

What this means — and why it's important enough to include here — is that by being able to identify the DNA sequence of a particular gene, scientists can measure exactly what genetic changes occur across generations. Being able to measure things, especially things like DNA strands, gets evolutionary biologists all goose-pimply. (For more information about genes and DNA, head to Chapter 3.)

What's the (gene) frequency, Kenneth?

Simply put, the *frequency* of a particular gene is how often it appears in a population. When researchers examine the DNA sequence at a particular location in a species' DNA in different individuals, they sometimes find that all the individuals have the same sequence. In this case, because only one gene (or one DNA sequence) exists at this location, its frequency is 100 percent. At other times, different sequences are present in different individuals. In this case, when more than one gene is present at this location, scientists speak of the frequencies of the different genes.

Suppose that you've discovered three different DNA sequences; call them genes A, B, and, C. If half the individuals you examine have gene A, one quarter have gene B, and one quarter have gene C, the frequencies of the three genes are 50 percent gene A, 25 percent gene B, and 25 percent gene C.

By identifying changes in the frequency of particular genes through the passing of generations, you can determine whether the organism has evolved. Using the example of genes A, B, and C from the preceding section, if you came back generations later to measure the frequency of these three genes again, and you found that the frequencies had changed, evolution has happened.

Here's an example: Suppose that you collect a bunch of a particular kind of bacteria and measure the frequency of the gene that makes the bacteria resistant to a new type of antibiotic. In your initial count, you find that the frequency of this gene is extremely low: Less than 1 percent of the bacteria have the gene that makes them antibiotic resistant. You come back in a few years. Your original bacteria are gone, but in their place are their great-great-great-great-etcetera grandkids, and you repeat the analysis. This time, you find that 30 percent of the bacteria have the antibiotic-resistant gene. Although you haven't actually witnessed evolution, you're looking at its result: the change in the frequency of particular genes over time. The antibiotic-resistant gene appeared in less than 1 percent of the original bacteria; it appears in 30 percent of the descendents. (Go to Chapter 17 for an in-depth discussion of the evolution of antibiotic resistance in bacteria.)

In a nutshell, biological evolution is simply a change in the frequency of one or more genes through time. Scientists collect this sort of data about the occurrence of evolution all the time — not only for bacteria, but also for all sorts of organisms, both simple and complex.

The timescales of evolution

Although the changes in gene frequencies happen gradually through time, the rate of evolution isn't constant. Gene frequencies can remain constant for long periods of time and then change in response to changes in the environment. The rate of change can increase or decrease, but the basic process — gene frequencies changing over time — continues. To differentiate between these time scales of the evolutionary process, scientists use the terms *microevolution* and *macroevolution:*

- **Microevolution** refers to the results of the evolutionary process over short time scales and small changes. An example is a bacterium in a laboratory beaker experiencing a mutation that creates a gene that confers higher growth and division rates relative to the other bacteria and beaker. Microevolution, because it happens on a time scale that we're able to observe, tends to be a bit easier for us to wrap our brains around than macroevolution.
- **Macroevolution** refers to the results of the evolutionary process typically among species (or above the species level; see Chapter 11) over long periods. Nothing is different about the process; nothing special is happening. Macroevolution simply refers to the larger changes researchers can observe when evolution has been going on for a longer time and involves processes such as extinction, which may have little to do with microevolution. *Speciation,* the process whereby one species gives rise to two, is an example of macroevolution. Speciation isn't all that complicated, and scientists are getting a pretty good idea about how it works; you can find out more in Chapter 8.

REMEMBER

Other than the time frame, no difference exists between micro- and macroevolution. The process isn't any different from what scientists can observe in a test tube in the laboratory (an example of microevolution); there's just been a lot more of it.

Gene extremes: Mutation and extinction

Genes can go to extremes. At one extreme is the disappearing gene. Suppose that you measure the frequency of the three different genes at a particular site in a species' DNA and then return some years later to find that one of the genes is no longer present. That gene's frequency has dropped to zero. It's gone. It's extinct. When a gene goes extinct, the species that had the gene is still around, but at least at this particular location in its DNA, it's not as diverse.

At the other extreme, new genes can appear. The process by which the sequence of a parent's DNA is copied and passed on to the next generation is remarkably accurate. If it weren't, none of us would be here. But no process is perfect, and mistakes happen. These mistakes are called *mutations,* and they can result in a DNA sequence different from the original — in other words, a new, different gene. These new genes can affect the functioning of the organism in several ways:

- **They can have no effect at all.** Because there's a certain amount of redundancy in the code of the DNA sequence (go to Chapter 3 for the details), it's possible to change a letter here and there with no effect whatsoever. Even if the mutation does create a change, that change may not affect how the gene product functions. In both cases, the new genes don't have an impact — either positive or negative — on whether an organism survives.
- **They can result in a change that's harmful to the organism.** Most mutations that cause a change fall into this category. Even the simplest organisms are really quite complicated. If you change something randomly, most often the outcome is bad. Genes of this sort vanish as rapidly as they appear.

  Occasionally, bad mutations — which typically are destined for a short run before becoming extinct — actually *increase* in frequency. Here's how it could happen: If a gene with negative effects is present in the same critter as a gene with positive effects, the frequency of the bad gene can increase as it rides the evolutionary coattails of the really great new gene. Suppose that two mutations occur simultaneously in different locations on an organism's DNA: one resulting in a gene that is slightly harmful and another resulting in a gene that is advantageous. The slightly harmful gene may increase in frequency simply because it's along for the ride.
- **They can result in a change that's advantageous to the organism.** This class of mutations is by far the rarest, but beneficial mutations do occur. These mutations, although rare, can increase in frequency. Ultimately, they're the source of all the variation upon which evolution by natural selection acts. (Skip to Chapter 4 for more detail about the role variation plays in evolution.)

All the different genes in all the organisms on earth started out as mutations that, though initially rare, ended up increasing in frequency. As the source of new genes, mutations are a key part of the evolutionary process. A gene can't increase or decrease in frequency until it first appears, and mutations are how that happens.

Darwin and His Big Ideas

You can't talk about evolution without talking about Charles Darwin (1809–1882), a would-be physician and theologian whose fascination with natural history and geography led him to accept a position as gentleman's companion to the captain of the *HMS Beagle,* a ship bound for South America with the purpose of mapping the area and sending plant, animal, and fossil specimens back to England. The voyage lasted five years, from 1831 to 1836.

Several things led Darwin to speculate about the changes that might occur in species over time: the diversity of life he observed on his voyage, the geographical patterns whereby different yet obviously related species were found in close proximity to one another, and the fossils he collected that made it clear present-day species weren't the ones that had been present in the past.

Darwin returned to England in 1836, already well known in the scientific community for the specimens and detailed notes that he had sent back. By 1838, Darwin had developed in more detail his theory of how gradual changes resulting from natural selection could result in changes in existing species as well as the formation of new ones. Over roughly the next 20 years, Darwin continued to develop and refine his ideas. In 1859, he published his seminal work, *On the Origin of Species,* which laid out the foundations of evolutionary theory. The following sections hit the highlights of Darwin's ideas. His other works include *The Descent of Man, and Selection in Relation to Sex* (1871) and *The Expression of the Emotions in Man and Animals* (1872).

TIP

Find the title *On the Origin of Species* a bit cryptic? Roll the full title around your mouth for a while: *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life.* The shorter version may not be as descriptive, but it certainly is easier to remember — and say! You can read it (and all of Darwin's other works) at `http://darwin-online.org.uk/`.

REMEMBER

Darwin didn't use the word *gene;* instead, in his work, he referred to *characters.* Yet because his ideas focused on *heritable* characters (that is, those that can be passed from parent to offspring), his "characters" are directly linked to genes.

Natural selection

One of Darwin's big ideas was what he called *natural selection,* the mechanism that he proposed to explain what he called "descent with modification" — that is, changes in an organism through subsequent generations. (Today, we'd say that natural selection explains how gene frequencies could change over generations.) This big idea, explained in depth in Chapter 5, is both remarkably insightful and remarkably simple, which explains why it's stood the test of time.

Basically, Darwin recognized that some characters get passed from one generation to the next and others don't. What he wanted to understand was *how* descent with modification could have occurred. What was the underlying driving force? He concluded that the driving force was the process of natural selection: Not all individuals in a given generation have an equal chance of contributing to the next generation. Some are selectively favored; some are selected against.

Darwin surmised that natural selection worked the same way as the process of artificial selection used in animal husbandry and agriculture:

- **Artificial selection:** Since before Darwin's time, people have been selectively breeding animals and plants: chickens that lay more eggs, cows that make more milk, pansies that are brighter and last longer . . . and the list goes on. Essentially, humans have been pretty apt hands at spurring evolution in agriculturally important plants and animals. *We* decide which genes are more likely to make into the next generation. The cows that produce more milk are the ones that we selectively breed to produce better dairy cows; the ones that make less milk, we eat. As a result of the choices we humans make as selecting agents, we can dramatically alter in a relatively short period the characteristics of the organisms we breed.
- **Natural selection:** Darwin realized that if humans, by the process of artificial selection, could create such major differences over the extremely short period of time, then the natural environment, acting over a much longer time scale, could have produced much larger changes. Darwin called his process *natural selection* because the natural environment, not humans, was the selecting agent.

REMEMBER

In artificial selection, farmers and breeders determine which characters they like and work to propagate in their produce and livestock. In natural selection, the same type of selection occurs, but the selecting factor isn't man, but nature, or the environment in which the organism exists. To help you understand the difference between artificial and natural selection, consider the cow. In the barnyard, farmers selectively favor the cow that makes the most milk; in the wild, natural selection favors the cow that can make enough milk to feed its calf and still do all the other things the cow needs to do to survive on its own.

Whether natural selection favors an individual is a function of the individual's particular heritable characters. Some heritable characters increase the probability that the individuals containing them will contribute to the next generation; some characters decrease the probability that individuals will contribute to the next generation. What all this means is that organisms in the first category reproduce more than do the organisms in the second category. *That's* what makes one generation different from the next, the next different from the one that follows it, and the one that follows it different from the one that comes later . . . and so on and so forth, ad infinitum.

In case you're curious: Survival of the fittest

Although he didn't coin the phrase *survival of the fittest,* Darwin did make it a household term. Many people assume (erroneously) that it means the natural order mandates that the strong survive and the weak die away. But to Darwin and other evolutionists, *survival of the fittest* is simply synonymous with *natural selection.* In other words, those organisms that possess selectively favored heritable characters are the ones that pass their genes into the future with the most success.

This sidebar marks the first and the last time you'll see this phrase in this book. Why?

- **It's problematic.** The phrase doesn't clarify the concept Darwin was trying to explain (although he no doubt thought it did; otherwise, he wouldn't have used it). To express the concept more clearly, Darwin could have used the term *survival and differential reproduction of the fittest,* but that's just not as sexy.
- **It doesn't make much sense semantically.** In beginning a study of evolution, students often say, "Well, if evolution is survival of the fittest, and the fittest are the ones that survive, that seems pretty circular." Indeed, it is.
- **Even evolutionary biologists never use it.** They use *natural selection* instead.

Don't let any of this get in the way of your developing an understanding of the term *fitness,* however; that word is crucially important to understanding evolution. Head to the section "How 'fitness' fits in with natural selection" for details.

Here's an example: Imagine a population of lions. Half the lions have the work-hard-run-fast-and-catch-lots-of-gazelles character. The other half have the sit-around-and-be-lazy character. It's tough in the Serengeti, and only the lions with the work-hard-run-fast character manage to store up enough energy to reproduce and raise offspring successfully. If you reanalyze this population after a few generations have passed and find fewer lions with the lazy character, that's evolution driven by natural selection!

Speciation

Darwin realized that because individuals differ in the characters they have, and because these differences affect their chances of survival and reproduction, some characters are more likely to get into the next generation than others. He also realized that as a result of this process, the frequency of characters changes over generations. Pass through enough generations, and the sum of all the little evolutionary changes may result in an organism that's evolved into an entirely different species.

Here's a quick example: Imagine you have two populations of the same animal. Each population lives in a different place, and the populations rarely interbreed. The selective forces in those two places — the combination of things we call the environment — is different. In one environment, it's good to have a long beak; in the other environment, a short beak is better. Other significant environmental differences exist as well. It's very wet on one side of the mountain range and very dry on the other, for example. In two such different environments, gene frequencies change in one way in the first location and another way in the second. Over a long period, the two populations become so different that they can no longer interbreed. They have become different species.

Today, scientists can identify all the stages of speciation in the natural world. They can find pairs of species that seem to have diverged from a single species very recently, and they can find pairs of populations that appear to be on the verge of becoming separate species. In some cases, the two populations are so close to becoming different species that all it would take is some minor habitat change to push them that last little bit and turn one species into two. For more detailed information about speciation, head to Chapter 8.

The idea of speciation got Darwin into a lot of hot water, and it's a hot-button issue today because it links organisms to common ancestors, which is all well and good for things like fish, oak trees, and invertebrates. But when you throw humans into the mix — whoa, Nelly. To read more about the conflict between evolutionary science and those who deny it, head to Chapter 22.

How "fitness" fits in with natural selection

The process of evolution by natural selection is driven by differences in *fitness,* or how successful an organism is at getting its genes (or characters) into the next generation. In short, fitness is all about how well an organism reproduces. Characters (or genes) that increase an individual's fitness are more likely to be passed to the next generation than genes that don't. This process is how the frequency of genes changes through time.

In the evolutionary process, fitness has nothing to do with how buff you are. It's purely a measure of the differential reproductive success among different individuals, which is a fancy way of saying that it refers to how successful an individual is at producing offspring. If one individual produces twice as many offspring as the next individual, all other things being equal, it's twice as fit.

Understanding adaptive characters

Some evolutionary changes are *adaptive,* meaning that a character has changed as a result of natural selection in a way that makes that character better suited to perform its function. Here's an example of the process of adaptation: Gazelles run away from cheetahs. The slow gazelles get eaten, leaving the faster gazelles to reproduce. In the next generation, the gazelles are faster on average than those in the past generation, because the run-away-from-cheetahs character has evolved. Being able to run really, really fast is an adaptation.

REMEMBER

It's not always easy to tell whether a particular character is an adaptation because sometimes things that appear to be adaptive characters aren't. Suppose that you have a cat and decide to put its food outside. At some point, you notice that birds eat the cat food. Knowing a bit about evolution, you think that eating from the cat dish may well be good for the birds; they probably have more energy to sing songs, build nests, and raise baby birds. If you observe such successful foraging behavior in a different environment, you might conclude that the birds are foraging in your cat dish as the result of natural selection. But eating cat food isn't an adaptation (the birds haven't evolved to eat out of cat dishes); it's opportunistic. The food's available, and the cat . . . well, he's probably trapped behind a patio door. For more about adaptive characters, go to Chapter 5.

The Study of Evolution, Post-Darwin

Darwin had only a vague idea of what genes were and didn't know squat about DNA, but he hit the evolutionary nail on the head. Today, scientists know that the process of evolution by natural selection occurs pretty much the way Darwin first proposed it: Natural selection results in changes over time in any given population, and good genes (those that make the organism more fit — that is, more successful at surviving long enough to reproduce) become more frequent over time. Still, scientists' understanding of evolution has continued to evolve as they expand the theory of evolution to include some elements Darwin was unable to address:

- **Many DNA mutations are selectively neutral.** The DNA code contains a certain amount of redundancy, which means that many changes in the DNA don't result in a fitness advantage or a fitness cost. The extent to which these genes increase or decrease in a population has entirely to do with chance.

- **Chance can be an important factor contributing to the change in gene frequencies through time.** Imagine that half the deer in the forest have blue eyes, and half have brown eyes. Now suppose that a couple of trees fall over and accidentally crush a couple of deer with blue eyes. All other things being equal, the next generation will have a higher proportion of the brown-eyed gene than the previous generation. Evolution has happened, but *not* as a result of natural selection. (Yes, I know that deer don't have blue eyes; it's just an example.) For more information on how chance factors into the evolutionary process, head to Chapter 6.

  I can imagine what you must be thinking: Two deer more or less are hardly going to make much of a difference. In a large population, you'd be right, but in a small population, a few deer more or less can make a difference that would be noticed in the future. When the population is large, chance events aren't as important, but when the population is small, random events can have larger repercussions.

- **Not all the characteristics of any particular organism are positively correlated with fitness.** This idea stems from scientists' understanding that not all evolutionary change is the result of natural selection. Sometimes, it's the result of chance; sometimes, it's the result of bad genes hitching a ride into the future with the good genes that made the organism more fit.
- **The environment affects fitness.** Populations in different places experience different selective forces. A gene for being able to survive a long time without water, for example, may offer a fitness advantage in the desert, but it may have rather negative consequences in a rain forest. Interaction between the gene and its environment is important in determining whether a given gene increases or decreases fitness.

Sickle cell anemia is an example of how the environment determines whether a particular gene increases or decreases fitness. The gene that causes sickle cell anemia produces a slightly different form of hemoglobin. The most extreme case occurs when someone has two copies of the sickle cell gene: one from the mother and one from the father. But even having just *one* sickle cell gene causes illness. At first glance, it seems obvious that this gene wouldn't increase anyone's fitness, yet it's present in high frequencies in certain areas of Africa. By examining the system from an evolutionary perspective, scientists learned an interesting thing about the sickle cell gene: Having a copy of this gene helps protect against malaria, which is present in those areas of Africa where the gene occurs at high frequency. So yes, it's bad to have this gene in the current era in the United States. But in the days before antimalaria drugs, it was a good gene to have in parts of Africa.

Applying Evolution Today

Evolution is interesting purely for its own sake, but of course, I *would* think that, having devoted years to studying, teaching, and writing about it. But evolution is good for more than just student lectures and small talk in academic circles: Understanding what evolution is and how it works makes all sorts of things possible. The following sections give a small sampling of how scientists apply aspects of evolutionary biology. You can find many more examples throughout this book.

Conservation

Understanding evolution helps conservationists in their efforts to protect endangered species. When resources are limited, as they often are, scientists have to make choices about which natural areas to protect and which populations of species to focus on. Understanding evolution can help them decide where to devote resources.

For example, many people think that the key to protecting endangered species is to conserve the maximum number of individuals possible. But understanding evolutionary biology and the patterns of variation present in natural populations helps us recognize that the real key is conserving genetic variability. If two populations are genetically different, part of a viable conservation management plan is maintaining this diversity, for two reasons:

- This diversity is a characteristic of the species that the scientists are trying to protect.
- The naturally existing variation allows the species to respond to future changes in the environment.

Another thing that evolution teaches — specifically, evolution by random events — is that we can't allow endangered populations to reach critically low numbers. In small populations, the variations scientists are trying to conserve — the very essence of what makes a particular species unique — are at risk of being lost due to random events that would be insignificant in a larger population. (For more information on the role chance plays in small populations, go to Chapter 6.)

Agriculture

Although humans have been breeding plants and animals for thousands of years, recent understanding of the evolutionary process lets us attack this task in a more scientific fashion. Following are some highlights in the field of agriculture, courtesy of our understanding of the evolutionary process and principles:

- **Advancements in breeding:** Understanding the detail of the evolutionary process can help us devise new breeding strategies. Head to Chapter 11, which explores in detail a breeding program that successfully bred chickens that produced more eggs by selecting for chickens that got along well together in chicken coops — definitely not the normal situation and something that had been a serious problem in chicken farming before these developments.
- **Crop variation:** The presence of genetic variation allows populations to respond to environmental changes; in the absence of such variation, populations can be destroyed by a sudden environmental change. Plant genetically similar crops over wide areas, and you run the risk of an agricultural disaster. Case in point? The Irish potato famine. Across Ireland, genetically identical potato plants were cultivated; a disease that attacked one potato turned out to be able to destroy them all, with horrific results.

- **Crop history:** Evolutionary biology allows scientists to understand the history of crop plants. Corn, for example, was domesticated by Native Americans, but for the longest time, biologists had no idea what wild plant it was derived from. Now, detailed studies of the evolutionary relationships of plants allow scientists to identify the wild plant from which corn was artificially selected. Having found the parent plant, scientists can study the genetics of how this plant survives in the presence of insects and microbial pests, which can only help in the quest to develop even better corn.

Medicine

The field of evolutionary biology affects the medical profession in three key ways: figuring out what has happened, understanding what is happening now, and trying to predict what will happen in the future to human disease. All three help researchers devise strategies for prevention and treatment of health problems big and small.

One area of particular medical importance is the evolution of microbes — the viruses, bacteria, and other microscopic critters that cause infection — that are increasingly resistant to antibiotics. The more researchers know about how and why microbes evolve as they do, the better they'll be able to counteract the effect of those microbes. Consider, for example, the virus that causes AIDS. Reconstructing evolutionary history has allowed researchers to trace the spread of human immunodeficiency viruses (HIV) across the globe, as well as to determine the relationships among human viruses and the immunodeficiency viruses of other animals. From these studies, scientists know that these viruses don't always cause disease in their hosts. By studying related harmless viruses, researchers may be better able to understand exactly why HIV is so dangerous in humans.

The study of evolutionary biology also guides treatment of diseases. The highly successful triple drug therapy that's been amazingly beneficial to HIV-positive individuals is the direct result of scientists' knowledge of how antibiotic resistance works in microbes: Even though mutations in the HIV virus render it resistant to medications, it's more difficult for the virus to evolve resistance to all the drugs at the same time. Finally, by examining how HIV evolves resistance to medicines, scientists hope not only to design better medicines, but also to identify how best to design a vaccine.

Chapters 17, 18, and 19 are chock full of information about the role of evolutionary biology in the fight against disease.

One Final Point: Just How Evolved Are You?

Evolution isn't a race to some cosmic finish line. No species is more evolved than the next. Every living thing is descended from the same common ancestor. All the different lineages have been evolving for exactly the same length of time. True, humans are better than pine trees at doing the things humans do, but we can't stand outside in the sun and soak up energy — something that pine trees do very well. The reason life is so different is that different environments select for different outcomes.

Neither is evolution a climb to the top of some life-form ladder on which the "higher" orders take over the top rungs (we humans are at the tippy-tippy top) and the "lowlier" creatures hang around the base. In fact, not all evolution results in more complex life forms. This point may seem like a small one, but it's actually quite important and is easily lost when most people think of evolution in terms of the "monkey-to-man" graphic — the one that shows the evolution of man in a series of stages, from monkey to ape to caveman to investment banker. Although you can make an argument that the caveman gave way to the investment banker and therefore forms a valid time series, other primates are still around and are just as evolved as humans are.

Evolution *can* lead to greater complexity, but it doesn't always. Over the history of the earth, since the first single-celled life forms, there was really nowhere to go but up in terms of size and obvious physical complexity. But as soon as larger, more complex critters evolved, the possibility existed that some would evolve simpler forms. Parasites, for example, have lost many of the functions that they can scam off their hosts. The eyes of cave-dwelling organisms constitute another example. Absent the need for the complex structure of the eye, mutations that cause a reduction in the eye can pile up.

P.S: Just between you and me, I do sometimes think of myself as being a bit more evolved than a bacterium — but then I think of the incredible biochemical diversity that bacteria are capable of, and I realize the error of my ways.