

Part One

Understanding Your Situation

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Grasping the Basics of Heart Disease

Section 1.1 of Chapter I, *Atherosclerosis, Heart Disease, and Heart Attack*, explains the development and progression of heart disease. you will learn why some people are more susceptible to heart disease than others, what plaque does in your arteries, how stress and other factors can trigger a heart attack, why it is unwise to wait for detectable symptoms before concluding that you may be vulnerable to having a heart attack, and how the atypical symptoms of many Indian heart attack victims put them at a disadvantage to prompt diagnosis. You will also learn about the similarities and differences between a stroke and a heart attack, the most common conditions, consequences, and complications of heart disease, how doctors diagnose them, and some of the procedures they use in treating heart disease and heart attacks. ♦

The next section, *Heart Disease among Indians Living Abroad*, builds up a systematic case by looking at the incidence and prevalence of heart disease, heart attacks, and cardiac mortality among populations of Indians living in many different countries, and comparing these rates to those of other groups living in the same countries. This section highlights particular studies such as the landmark CADI and Framingham studies. Since the environment in each of the countries examined is constant for all the populations who live there, the implication is strong that any differences in heart disease rates must be largely attributable to two things: either heredity differences that create different levels of vulnerability or protection among various groups, or variations in lifestyle such as diet, nutrition, and daily activity level. Indians appear to have both. ♦

Section 1.3, *An Epidemic on the Indian Subcontinent*, parallels Section 1.2 but focuses its lens on Indians on the subcontinent itself and wonders whether living in a developing-country environment has conferred any advantage on them regarding heart disease. Heart disease, after all, has often been considered a "rich man's disease," brought on by a sedentary lifestyle in front of a big-screen TV and a high-calorie diet rich in cakes, prime-cut meats, and other fatty foods. People in developing countries, who live a hardier, more active, and more abstemious life, were thought to be much less susceptible to cardiovascular disease. As you will learn from Section 1.3, today the actual truth appears to be quite different. Even rural Indians are fast catching up to the high rates of heart disease first observed among Indian emigrants living abroad. ♦

The final section of Chapter I, *Malignant Heart Disease in Young Indians*, looks more closely at three features that make heart disease in Indians particularly serious: it (a) occurs **early**, (b) hits **hard**, and (c) is found even in individuals with **few or none** of the standard, traditional risk factors. In addition to its extreme prematurity, severity, and weak association with traditional risk factors, Indian heart disease clinically speaking also tends to be diffuse—spread along multiple sites throughout the length a coronary artery, making treatment more difficult. In Chapter IV, we will look at possible reasons why heart disease among Indians tends to be so malignant. ♦

1.1 ► Atherosclerosis, Heart Disease, and Heart Attack

HEART DISEASE is responsible for more deaths and disability among Americans, both male and female, than any other killer, and it is quickly establishing itself as the leading cause of death and disability among Asian Indians as well. In 2002 more than one out of every three Americans (34.2%) had some form of cardiovascular disease, and almost one million (927,4000) died from heart disease, according to the American Heart Association. The most recent estimate for the direct and indirect cost of strokes and cardiovascular disease in the United States—counting hospitalization costs, medication, home health care, and lost productivity—is \$393.5 billion a year. This is more than twice the total cost of all cancer and HIV cases combined.

Furthermore, the incidence of heart disease is spreading worldwide. For example, as Asian countries adopt a more sedentary westernized lifestyle, together with the high-fat, high-salt diet and processed foods that have come to be associated with technological affluence, researchers are noticing that “western” diseases are becoming more prevalent causes of death in Asia. In every region of the world except sub-Saharan Africa, noncommunicable diseases such as cardiovascular disease are quickly becoming the dominant causes of death and disability.

The first stages of heart disease begin in childhood, and it progresses silently for decades until, in millions of people, it results in a heart attack or even sudden death. The majority of deaths occur before the person even reaches the hospital. Most people do not worry about getting a heart attack if they do not have any chest pain. In reality, chest pain occurs only in a fraction of people who suffer a heart attack or sudden death. Managing a silent killer that often does not announce its intentions requires understanding what heart disease is, and what it does.

A Word about Terminology

Throughout this book, the term Indian refers to people, who trace their origin to the Indian subcontinent—meaning Bangladesh, India, Pakistan, and Sri Lanka—including those who now live abroad but originate from one of these four countries. “Indian” in this context is ethnically interchangeable with “South Asian,” “Indo-Asian,” or “Asian Indian.” The term thus excludes native Americans but includes more than people from the nation of India.

Measurement Units: As is conventional, blood glucose levels, triglyceride levels, and cholesterol levels are stated throughout this book in milligrams per deciliter (mg/dL). Blood pressure is stated in millimeters of mercury (mmHg).

THE VOCABULARY OF HEART DISEASE – A BASIC PRIMER

To do this, it would help if we first went over a few of the common terms doctors use to discuss it. Cardiovascular disease is really an umbrella term, a collection of interrelated disorders that affect your heart and/or your blood vessels. *Cardio* means heart; *vascular* refers to vessels. Your heart and vessels make up your **cardiovascular system**. The two are intimately connected. Heart disease is one form of cardiovascular disease, and coronary heart disease is the most frequently occurring form of serious heart disease. In fact, throughout this book, the term **heart disease** will be used to mean **coronary artery disease** (or CAD).

Affecting 13 million Americans, CAD refers to diseases that affect the handful of arteries that supply blood to the heart. Symptoms of **angina** (or chest pain) occur when these arteries become narrowed and clogged, limiting blood flow to parts of the heart muscle. A **heart attack** occurs when the blood flow in a coronary artery is completely sealed off by a massive **blood clot**, depriving that part of the heart muscle of oxygen, blood and nutrients.

Blocked arteries can also lead to strokes or other **cerebrovascular** diseases (*cerebro* refers to brain). A stroke is really a “brain attack.” Like a heart attack, it results from a major blockage of blood flow—this time, to the brain.

If CAD is the most serious kind of heart disease, **hypertension** (or high blood pressure) is the most

Although there are many kinds of heart disease—hypertension, for example—coronary artery disease is by far its most serious form.

common kind of cardiovascular disease as a whole, affecting more than 60 million Americans. Although hypertension is a disease of the blood *vessels*—it creates secondary disorders that can affect the heart or brain. It frequently leads to a stroke or to heart failure, although less often to a heart attack.

A Domino Effect

Your heart consists of three things: muscle, arteries, and valves. Each can become diseased, and the diseases of each can lead to disease in the other two. Your cardiovascular system is therefore a highly interactive system with backward and forward linkages. Disease in one part can ultimately trigger a domino effect.

Peripheral vascular disease When an artery that supplies vital nutrients to the heart is suddenly clogged, this can lead to a heart attack. If the artery is in the brain instead, a stroke may occur. If instead it is located in an arm or leg, peripheral vascular disease, or PVD, may result. Unless diagnosed early and treated, PVD can result in amputation. Other less common types of heart disease not discussed extensively in this book include valvular heart disease, congenital heart disease, and cardiomyopathy.

Now that we have developed a basic vocabulary of heart disease, it is time to open up a real heart and take a look inside. Here, then is Heart Anatomy 101.

DOWN IN THE ENGINE ROOM: THE HUMAN HEART

THE HEART is a muscular pump a little larger than your fist and weighing about half a pound. It pumps blood nonstop. Every 24 hours, an adult heart expands and contracts 100,000 times, pumping about 2,000 gallons of blood through the body's 60,000 miles of arteries and veins, the network of tubes that carry blood throughout the body. How does a vein differ from an artery? **Arteries** carry bright red, oxygen-rich blood from your heart to your body's organs. **Veins** bring dull-red, oxygen-depleted blood back to the heart. Veins, in a sense, are the giant transportation system bringing back tired workers at the end of the day to get cleaned up and revived for another day's work. But before your heart sends the blood back into your body for reuse, the right side of the heart sends it into the "workshop" for cleaning and filtration (in the lungs, kidneys, and liver) and re-oxygenation (in the lungs). This lung-kidney-liver workshop then sends the rejuvenated blood back to the heart for shipment out to the body. The entire thing works very well—so long as you do not have plaque and other diseases compromising the performance of these four vital organs: heart, lungs, kidneys, and liver.

What Factors Trigger Coronary Artery Disease?

You can develop heart disease through 1. genetic risk factors you inherited, 2. congenital defects of the heart that you were born with, or 3. unhealthy lifestyle choices that accelerate the progression of atherosclerosis and plaque formation.

You cannot do as much about the first two types of risk factors—genetic factors and congenital abnormalities—as you can about the third set, lifestyle choices, although even people with congenital abnormalities and genetically determined risk factors can now live near-normal lives for many decades, thanks to the tremendous effectiveness of the medications, medical treatments, and surgical procedures developed in the past 30 years to combat cardiovascular disease.

The most serious of the controllable (i.e., lifestyle) risks include:

- smoking
- obesity
- physical inactivity
- stressful emotions such as anger, hostility and depression
- failing to take your cholesterol-lowering and blood pressure medications
- failing to treat conditions that worsen heart disease, such as diabetes and metabolic syndrome
- eating foods high in saturated and trans fats, refined carbohydrates, cholesterol, and salt

These seven risks, taken together, constitute the most common and greatest controllable causes of coronary artery disease in all populations, including Indians.

To do this work, the heart has four chambers—two up, two down. The top two chambers, the right and left **atria**, are like your “Incoming Mail” boxes. They receive blood from the veins and send it down to the ventricles below. The lower two chambers, the right and left **ventricles**, are like “Outgoing Mail” boxes. They pump blood out. Atria above take in blood; ventricles below pump out blood.

Like a bicycle pump, each of the heart’s four chambers has a one-way-only valve that lets blood flow in one direction only, forward. In short, your heart is made up of three things:

- **Muscle**, especially the powerful left ventricle
- **Arteries**, particularly the coronary arteries that supply the heart with oxygen and nutrients
- **Valves** that keep the blood moving in one direction

Over your lifetime, any or all of these three can become diseased or begin to fail. Diseases of the heart *muscle*, of the coronary *arteries*, or of the heart *valves* together make up what physicians collectively call **heart disease**. Now that we have looked briefly at the structure of the heart, let’s look more closely at what causes it to become diseased. We will focus specifically on coronary artery disease.

The Circulatory Cycle

Tired blood carrying waste products from your body tissues enters the heart through the right atrium. It is sent down to the right ventricle, one of your heart’s two powerful pumps. The right ventricle shoots it out to the lungs, for oxygenation and refreshing. It is then sent back to the left atrium. From there, the blood is sent down into the powerful left ventricle, which pumps it out into the body through the giant artery called the aorta. And the process starts all over again.

CORONARY ARTERIES: LIFELINES OF THE HEART

THE ABBREVIATION CAD, meaning Coronary Artery Disease, is often used in books and articles to refer to heart disease in general. Why? You can develop large, unstable plaques in any artery anywhere in your body, but it is when you develop them in your coronary arteries that you are in real trouble. The study of heart disease is, in large part, the study of what is happening in your **coronary arteries**. Turn your wrist over and look at the veins running just under the skin. The coronary arteries look like that. They wrap around the surface of the heart like delicate strings, running down the front, back, and sides of the heart muscle. You need to know what they are, what they do, and why it is important to keep them plaque-free. Here are the facts.

Although the heart pumps blood to the rest of the body, being an organ itself it too needs its own blood supply, just as workers in a food-processing

The left ventricle is the heart’s Main Engine Room. It makes up more than two-thirds of the heart’s entire muscle mass. Because it does so much work, it is particularly vulnerable to a heart attack.

factory need food themselves. This is the function of the coronary arteries. They supply blood and nutrients to the heart muscle itself. As the heart “exports” oxygen-rich blood to the body through the left ventricle—the heart’s main pumping engine—it reserves some of this blood for its own private use by diverting some of it into the coronary arteries. As shown in **Color Plate 1.1. Major Coronary Arteries that Supply the Heart Muscle** (page xvii), the two major coronary arteries—the left main coronary artery and the right coronary artery, colored red—branch off the aorta. The aorta, the largest blood vessel in the body, about the thickness of a garden hose, functions as the heart’s main faucet. After coming off the aorta, the two coronary arteries

ing factory need food themselves. This is the function of the coronary arteries. They supply blood and nutrients to the heart muscle itself. As the heart “exports” oxygen-rich blood to the body through the left ventricle—the heart’s main pumping engine—it reserves some of this blood for its own private use by diverting some of it into the coronary arteries. As shown in **Color Plate 1.1. Major Coronary Arteries that Supply the Heart Muscle** (page xvii), the two

Left main coronary, Left anterior descending, and Circumflex coronary.

Different segments of one coronary artery have different names. Why? After all, your body’s arteries, beginning with the aorta down to your feet, are all interconnected. There is no point where one artery abruptly becomes a completely new, independent artery. Yet we cannot just call them all the same artery. Much the way the a street name can change when it enters a new neighborhood, a coronary artery changes name depending on which portion of it we are talking about. It is simply an identification convention.

divide into smaller vessels that supply the heart muscle. When one of these huge coronary arteries becomes blocked by a very large plaque, or a plaque that ruptures and creates a large blood clot, it is not like your

What is Multi-Vessel Disease?

A person has **one-vessel coronary disease** when only one of their coronary arteries is severely narrowed or blocked. **Two-vessel** disease means two are blocked. You have **three-vessel** when all three are occluded. Generally, the larger the coronary artery, the greater its capability for triggering a heart attack, if it becomes blocked by plaque.

kitchen sink becoming clogged. It is more like an entire hydroelectric dam becoming blocked: The consequences to the heart are catastrophic. Yet in billions of people around the world, these arteries slowly start to become blocked and narrowed almost from birth. Identifying powerful but easy steps that can slow down this process is what much of this book is about.

Let's back up to the top, starting on the left side. The first inch or so of the left coronary artery is called the **left main coronary artery**. It is about as wide as a drinking straw. A heart attack resulting from a blockage of this segment of the artery is relatively rare (one out of every 50 attacks), but it carries the highest risk of death: 75% of heart attacks that result from a blockage of the left main artery are fatal. Most patients with left main coronary artery disease die suddenly without even having a heart attack.

Moving further down, the next segment of the left coronary artery is typically the **left anterior descending artery**—chillingly referred to as the “widow-maker” artery. It supplies most of the left ventricle, especially the frontal part (or anterior). When blockage of this artery results in an “anterior” heart attack, the likelihood of dying is twice as high as from heart attacks caused by blockages in other arteries.

Also branching off the left main coronary artery is the **circumflex artery**. It wraps around the left side of the heart and toward the back. It is typically small, but in a few individuals it may be as large as the left anterior descending artery. Blockage of this artery tends to result in a lateral (side) heart attack. A lateral heart attack is about half as likely to lead to death or to complications as an anterior (frontal) heart attack.

Now let's go to the right side of the heart. Like the left coronary artery, the **right coronary artery** originates from the aorta and supplies the right side of the heart muscle. Usually small, in some individuals it may be quite large. A blockage of this artery results in an inferior heart attack. (“Inferior” here does not mean worse. It just means lower. Anterior means front, posterior means back, and lateral refers to the sides of the heart).

If this sub-section has conveyed anything to you, it should be this: Do not let your coronary arteries become blocked, under any circumstances. Yet every year, tens of millions—including millions of Indians—succumb to this fate, partly because until recently we had not grasped atherosclerosis very well. In many communities around the world—even in the west—the partially erroneous traditional understanding of atherosclerosis continues to prevail. Let's see why this matters so much.

TWO VIEWS OF ATHEROSCLEROSIS

PLAQUE FORMATION, and the heart disease that results from it, is a highly deceptive process. The failure of medicine to understand it well until recently has led both doctors and their patients to underappreciate, under-diagnose, and under-treat this serious disease. A decade or two ago, doctors thought heart attacks were caused mainly by the narrowing of arteries by accumulated plaque, because they were literally looking at heart attacks through the lens of angiograms, and arterial narrowing is what an angiogram can detect. More recent research has put the spotlight on what angiograms do not detect: plaques that are about to rupture.

In fact, atherosclerosis can cause heart problems in two distinct ways: through the narrowing of an artery by a plaque that becomes too big, and through the rupture of an unstable plaque that, like an erupting volcano, bursts and releases sub-

Until recently, doctors thought heart attacks were caused mainly by narrowed arteries, because that is what angiograms detect. But arterial narrowing is not even half the story.

stances that trigger the formation of a potentially life-threatening blood clot.

The old view was not altogether wrong, just incomplete. Arteries still do get narrowed, and people come to the hospital complaining of chest pain caused by exactly that. But, in fact, the great majority of heart attacks are caused by the *second* mechanism, plaque rupture. Let's look at this more closely.

The **traditional** view of atherosclerosis was that most major cardiac events such as heart attacks resulted from the narrowing of a coronary artery by a plaque that bulges out into the open channel of the artery, reducing its diameter and limiting or cutting off blood flow to some part of the heart muscle. This presents an incomplete, and in many ways inaccurate, picture. In what ways?

An atheroma is the collective term for all the unhealthy pieces of tissue, such as fatty streaks, that grow within the wall of an artery, beginning during your childhood, and ultimately turn into either stable or vulnerable plaques.

Bulging, when it does happen, is merely the tip of an “iceberg” that has been building inside the artery wall for decades. In fact, plaque buildup does not begin to show through the lining of the artery until approximately 40% of the plaque's maximum size has already formed within the wall.

Second, the developmental timeline: The narrowing of an artery, and the bulging that some plaques show, both occur at a much later stage of atherosclerosis than was once thought. Arterial narrowing—and the chest pain that accompanies this—is actually the *very last stage* of atherosclerosis, when the disease is advanced. By the time you actually get chest pain from artery blockages, it is often already too late. We are now finding out that atherosclerosis is a slow, systematic process that *starts in childhood* and progresses silently for many decades, its pace determined by the number and severity of cardiovascular risk factors to which the person is exposed. Indeed, its foundations may even be laid during gestation: Studies show that atherosclerosis occurs more rapidly in children whose mothers had high levels of cholesterol while pregnant. Even teenagers and young adults may have varying stages of atherosclerosis, with fatty streaks

Plaque, Cholesterol, and Atherosclerosis

What causes blockages in an artery?

Blockages are caused by the buildup of plaque in the wall of an artery and along the artery's innermost lining, in a process known as atherosclerosis. Atherosclerosis, pronounced ath-ro-skluh-ROW-sis, is far and away the major (but not the only) cause of heart attack and stroke. It is a big word, but you need to know it because the chances are that it is taking place in your body even as you read this, and it often has fatal long-term consequences. From the Greek words athero (meaning paste) and sclerosis (hardness), atherosclerosis is probably as old as humankind itself and has been found even in the embalmed mummies of ancient Egyptian pharaohs. But only in the last few decades has plaque buildup established itself as the cause of more than 50% of all deaths in western countries.

What, exactly, is plaque? Plaque, which looks and feels a bit like pizza cheese, is a sticky paste made up of LDL cholesterol, lipoprotein(a), fat, blood platelets, calcium, waste products from cells, blood-clotting fibrin, and other blood substances that becomes deposited within the lining of an artery. LDL, which stands for **low-density lipoprotein**, is the bad kind of cholesterol. Atherosclerosis involves a complex interaction of processes in which LDL and lipoprotein(a) gradually oxidize—essentially, rust—to form fatty streaks, and ultimately a plaque with a cover over it. This oxidation cannot be reversed once it occurs, but having high levels of HDL (or good) cholesterol in your blood can prevent some of the oxidation of LDL into plaque. Plaque hardens and thickens the artery wall and—what is even more dangerous—leads to the possibility of the plaque bursting and causing a heart attack.

The roles of LDL and HDL cholesterol in heart disease are discussed at greater length in Chapter II. Meanwhile, here is a rule of thumb to help you remember which is good and which is bad: You want your **HDL** level to be **High**, and your **LDL** level to be **Low**.

and plaques in their arterial walls. In some people with multiple risk factors, atherosclerosis can become severe by their twenties or thirties.

Modus Operandi of a Silent Killer

If coronary arteries narrowed as soon as plaque started to build, many people would get chest pain in their 20s, call their doctor, and begin treatment and lifestyle modifications. Arterial narrowing would give them advanced warning in the form of chest pain that something was wrong.

The danger of atherosclerosis is that, in the first several decades of your life, plaque does not narrow your arteries and cause pain. It tries to, but for several years your arteries expand in diameter to compensate for this narrowing, until they are stretched to their limit and can expand no more.

There is worse: The large, hardened, highly visible plaques that narrow your arteries and generate chest pain are not the most dangerous plaques. The most dangerous are the soft inflamed plaques buried deep inside the artery wall that burst and trigger a heart attack, often without your feeling anything ahead of time.

age. The typical heart attack occurs in a coronary artery that had narrowed by only 20%. That means something other than arterial narrowing must be going on: that something is the rupture of an inflamed plaque that triggers the formation of a blood clot (see **Color Plate 1.4, Cross Section of a Coronary Artery Showing Plaque Rupture, page xvii**). We need to understand what this inflammation is, why inflamed plaques rupture, and how they cause heart attacks. Let's turn to that now.

As recently as 2004, most artist illustrations of plaques in arteries still showed them as little bumps bulging out into the lumen. What was missing from these portrayals was *the main story!* Meaning, the thick, lipid-rich plaques that don't bulge into the artery at all, but instead change the very size and thickness of the artery wall itself, stretching the artery lining taut like the skin of an over-grilled sausage.

In fact, a plaque can force an artery to enlarge to two or three times its usual diameter, creating weak thin walls that, like a balloon blown to its limit, may hemorrhage, quite often in the brain.

Look at the sequence of images presented in **Color Plate 1.3, Cross-section of a Coronary Artery Showing Plaque Buildup, page xvii**. A normal, healthy artery (far left), for example in a young child, has a thin, elastic, flexible wall and looks whistle-clean, like a brand-new garden hose that has no buildup of mold, grime, or leaves inside it. As coronary artery disease progresses and clumps of fat and cholesterol thicken the artery wall, the artery (stage 2) expands to maintain its internal diameter, and it succeeds in doing this for several decades. It is only after the intra-wall plaque buildup has become extensive (stage 3)—and the artery has expanded as far as it can go—that the internal diameter of its passageway has no choice but begin to shrink with further plaque buildup. Stretched to its limit, the artery does not have very many options left. At that point, narrowing often occurs quickly and severely (stage 4).

Third, causal effect: A third way in which the traditional view of atherosclerosis was wrong is causal effect. Most heart attacks are not caused by arterial narrowing at all. The severe narrowing seen in stage 4 of Figure 1.3 typically leads to a type of recurrent chest pain called stable angina, not to a heart attack. In fact, more than two out of every three heart attacks result from a sudden blockage of coronary arteries that, *before the crisis, showed only mild or moderate atherosclerotic block-*

Plaque rupture

AS WE HAVE JUST SEEN, arterial narrowing, while serious, is not as critical an issue as plaque rupture. But why do plaques rupture at all? Doctors cannot say just by looking at a plaque whether it is the kind that will rupture. But we now know that an *inflamed* plaque is the most likely kind to rupture. We have seen that the traditional view of atherosclerosis was inaccurate on several fronts:

- The shape of plaques: Many do not bulge at all; they are buried deep within the wall of the artery
- The timeline of plaque formation and artery narrowing: Plaques form much earlier than was first thought, and narrowing occurs much later than was traditionally believed
- The cause of heart attacks: Plaque rupture, not arterial narrowing, causes most heart attacks

Inflammation: There is another way in which the old view was wrong. It portrayed atherosclerosis and plaque buildup as essentially a *physical* process: Arteries, physicians believed, narrow through the sheer accumulation of cholesterol-based lipids, similar to the way dirt gathers cumulatively on a car windshield. It was seen essentially as a mechanical process that results in a “plumbing” problem, like that of a clogged kitchen drain. Fatty deposits, doctors believed, steadily accumulate in a more or less linear way, eventually narrowing the artery if given enough time. If a blood clot then comes along, it may get stuck in the small opening of this narrowed artery, and you would be in trouble. Today, we know that plaque does not merely build up, layer after layer. Atherosclerosis chronically inflames the inner lining—or endothelium—of the artery, making it unstable and vulnerable to plaque eruptions. Just as neglected teeth and gums are not simply encrusted mechanically with plaque but become chronically inflamed and diseased, so do the inner surfaces of coronary arteries when people neglect their health.

In fact, the entire atherosclerotic process is inflammatory from beginning to end. It is inflammation that allows the lining of the artery, normally impermeable, to be penetrated by cholesterol-rich fatty streaks that become plaques. It is inflammation that causes the protective cap over a plaque to rupture, creating what is essentially an open sore that begins to spill its contents directly into the blood in the artery. And it is inflammation that often creates a massive blood clot at the site of the rupture, a clot that ultimately becomes the cause of the heart attack.

In short, atherosclerosis goes far beyond the mere accumulation of a thick layer of plaque. Indeed, when you compare the cross-section of a normal, healthy artery with that of an artery thickened by plaque, the contrast looks like the difference between the midsection of a 20-year-old gymnast with virtually zero body fat, versus the midsection of a 300-pound obese person. One is completely smooth and sleek; you could drop a bead of water on it and it would simply roll off smoothly with no interruption. By contrast, the inner walls of the artery thickened by plaque are distended, misshapen, and packed with fat. Their surfaces, damaged by years of atherosclerosis triggered by hypertension, smoking and cholesterol, look uneven and pock-

All of us have had a pimple at one time in our lives. The skin covering the pimple is often red, stretched, and inflamed, and is easily broken. A similar process occurs when a fat-filled plaque stretches the lining of an artery whose walls, over many years, have become thickened and weakened by layers of plaque. Eventually, like an inflamed pimple, the layers of covering tissue that keep the atheromic plaque from coming into direct contact with the blood stream are likely to rupture. In response, your body rushes platelets to the area to try to create a blood clot to cover over the open rupture. Although this clotting response is a protective response, this is the foundation of a heart attack. If the internal diameter of the artery is already narrow where the plaque is, the blood clot can block off blood flow, and heart muscle cells begin to die. A heart attack is the death of heart muscle.

Arterial Hardening versus Plaque Rupture

The traditional view of atherosclerosis presented it simply as the physical build-up of plaque on the lining of an artery, narrowing and hardening it. The emerging view centers on the role of soft, yolk-like plaques that become inflamed and rupture, stimulating a blood clot to form that can lead to a life-threatening heart attack if it becomes big enough to cut off blood supply to a part of the heart muscle.

The traditional model, however, was not entirely inaccurate. Before age 30 or thereabouts, plaque buildup is relatively mechanical and cumulative, and inflammation and rupture are less likely. Secondly, arterial hardening is real and harmful. Rupture is not the only danger. A healthy artery has highly elastic walls that expand easily to allow more blood to flow through when you suddenly need to run upstairs. A healthy coronary artery can expand to allow **five times** its normal volume of blood when needed. Hardened arteries cannot expand easily. If a plaque blocks or ruptures in a hardened artery, it is all the more difficult for the heart to get the oxygen it needs. The same plaque in a highly expandable coronary artery may not threaten the person's life. In short, recent research has focused on the role of plaque rupture, but arterial hardening still remains a real danger.

Plaque versus Clots: What Really Causes Heart Attacks?

Forty years ago, physicians believed that heart attacks were caused primarily by blood clots. Then we learned about plaque, and plaque formation became the lens through which we came to understand heart attack. Today, we have a more integrated view: we know that heart attacks typically involve both blood clots and plaque, and that the process is driven by inflammation.

The vast majority of heart attacks occur not because plaque chokes off one of your coronary arteries but because a soft, unstable, lipid-rich plaque—sometimes quite small—bursts and releases substances that stimulate your body to begin forming a blood clot at the site of the ruptured plaque. If this clot grows quickly, often without any pain warnings, it can induce a heart attack by preventing blood flow to a portion of your heart muscle and starving it of oxygen. Hard, stable plaques, by contrast, have little risk of rupturing. They can progressively narrow the channel of a coronary artery, but this is more likely to cause chest pain well before it causes a heart attack.

Not only are far more heart attacks caused by soft plaques that rupture, but these plaques often do not show up on an angiogram because they are buried smoothly inside the wall of the artery, like a coiled snake hidden in tall grass. The large, hard, visually noticeable plaques that show up impressively on an angiogram are not your greatest worry because they give advanced warning of their danger by causing chest pain when they narrow an artery. Silent, hidden soft plaques are the real landmines of heart disease.

marked with hundreds of microscopic cracks where fat deposits hide.

Frankly, an artery with substantial atherosclerosis looks like an accident waiting to happen—which is precisely what often happens. As shown in **Color Plate 1.5**, *Cross-section of a Healthy Artery and a Diseased Artery*, page xvii, the difference between a healthy and a diseased artery is not simply that the one with a lot of plaque is narrower. More than just narrowing, the second artery's lining has been organically changed: its very biochemical structure has become less stable, more fragile, more uneven, more inflamed, and more vulnerable to harboring soft plaques that may suddenly rupture.

This is a simplified account of what cardiologists call *endothelial dysfunction*—the set of damaging changes that can occur to the artery lining (see **Color Plate 1.6**, *Atherosclerosis Timeline Showing Progression of Endothelial Dysfunction*, page xvii). Caused by atherosclerosis, endothelial dysfunction makes your arteries more vulnerable to the conditions that lead to heart attacks.

Implications of our new understanding

OUR NEW UNDERSTANDING of atherosclerosis has important implications: First, it tells us that patients and doctors should not wait until a coronary angiogram shows severe arterial narrowing before taking heart disease seriously, because narrowing already suggests that the disease is advanced. As we saw earlier, in Figure 1.3, even seemingly healthy people with a normal amount of opening in their coronary arteries, and who have never had chest pain, may still have a dangerously large amount of plaque, putting them at high risk for a heart attack.

Second, we have now learned that doctors and patients must pay much more attention to how plaques develop and ways of reducing the chances of rupture. You need to change those lifestyle habits that accelerate plaque formation and plaque inflammation, even if there is no direct evidence that you have plaque in your arteries, because by the time you get that direct evidence, the disease is already far gone.

Third, we now know that it is short-sighted to focus primarily on the large plaques that may be highly visible on an angiogram, because plaque visibility has little to do with how dangerous the plaque is. The most dangerous plaques are the soft, lipid-rich, inflamed plaques that are often buried, out of sight, inside the artery wall. The ones visible on the surface are, therefore, often just the tip of an iceberg. Most plaques are hidden deep within the artery wall, making them hard to detect even when using advanced medical equipment. This means you cannot rely on angiographic detection to tell you when to begin a preventive strategy.

Stable versus vulnerable plaques

Recent research, in short, has taught us that not all plaques are the same. Some are much more likely to rupture and lead to heart attacks, while

others are more stable. See **Color Plate 1.7**, *How stable and vulnerable plaques differ*, page xviii. The difference lies in their structure and content. These differences in structure and content have given rise to the term **vulnerable plaque**. Let's look at this a bit more closely.

Like a skin wound that forms a scab to protect it, or a corn on a toe, a plaque is covered by a hard fibrous cap which keeps its contents from coming into contact with the blood flowing through your artery. A stable plaque that is not likely to burst is one that has a thick, tough fibrous cap lying over it, and a small, relatively dry lipid (fatty) pool at its core. Inside it, there is a lot of calcium and fibrin, both of which are hard and tend not to become inflamed. Stable plaques can be large and look very impressive on a coronary angiogram, but they rarely break open and produce a heart attack. They become dangerous only when they grow large enough to restrict blood flow to the heart muscle, producing a form of chest pain called stable angina.

An unstable plaque, also called vulnerable plaque, is a totally different beast. Often smaller, this inflamed plaque has a thin, easily broken cap overlying a soft, large, yolk-like, lipid-rich pool at its core, with very few calcium deposits in the plaque to give it some firmness or toughness. In addition, it contains numerous inflamed cells, making it much more likely to rupture and release its contents directly into your bloodstream, creating a large blood clot.

Vulnerable plaques have substances in them that make your blood excessively prone to clotting when the plaque's contents contaminate your bloodstream, causing blood platelets and other substances to clump together to form a life-threatening blood clot. In almost every case, heart attacks are caused by a soft, vulnerable plaque that ruptured and formed a clot.

The difference between the content of a stable plaque and that of an unstable plaque is like the difference between the yolk of a hard-boiled egg and that of a raw egg. Guess which one is more likely to break?

While hard plaques, once formed, cannot be regressed, the more dangerous soft plaques can. Medication called statins draw cholesterol out of soft plaques, making them smaller, harder, and more stable. Hard plaques, by contrast, are like plaque that forms on teeth, which needs to be scraped off with a hard instrument. A hard plaque that becomes too large must be physically flattened through a procedure such as balloon angioplasty.

Vulnerable blood

Just as some plaques are more vulnerable to fissuring, some people's blood is also more vulnerable to clotting, and thus more likely to lead to heart attack than that of others. What creates vulnerable blood? The causes include smoking, low levels of HDL, and high levels of lipoprotein(a), homocysteine, fibrinogen and triglycerides. (We will discuss these in greater depth in later Chapters.) All of these can contribute to making your blood more likely to clot excessively.

Inflammation of the Artery is an Active Process

Atherosclerosis is not just the passive buildup of plaque, and plaque is not just grime, like dirt on your body after a game of soccer. Plaque is a sign of active damage. The fatty streaks that represent the first signs of plaque indicate that there is inflammation present in the artery wall. Without this inflammation, cholesterol-rich fat cannot breach and penetrate the inner lining of the artery wall and become buried inside it. In fact, when your body detects that plaque is starting to form in your arteries, your immune system sends white blood cells to the site where the plaque is accumulating to try and repair the damage and heal the inflammation.

In a sense, having plaque is like having a constant fever running through your arteries. It signals that atherosclerosis has damaged the inner lining of your arteries—the **endothelium**. Just as the skin of a chameleon continually adapts to light conditions and other cues in its environment, the endothelium is a sensitive, "active" layer of cells that is constantly sensing, assessing, and rapidly responding to small changes and stimuli in the blood that flows over it. Secondly, a healthy endothelium is "watertight": it is impenetrable to substances in the blood. Hypertension, diabetes, smoking, and other factors that promote atherosclerosis (a) reduce the ability of the endothelial surface to adapt to change, (b) weaken its ability to prevent unwanted blood clots, and (c) damage the endothelium by making it easy for LDL cholesterol to penetrate it and become buried within the arterial wall as plaque. In short, atherosclerosis creates a **dis-eased lining** that can no longer fight effectively to protect you from cardiovascular complications.

Plaque Remains Silent for Decades

Almost everyone knows of a friend or relative who felt a twinge of pain and went to the hospital, only to be told that their illness was so advanced that it was inoperable, or would require years of treatment. Early and mid-stage atherosclerosis falls in the category of "**silent**" disease. The human body frequently uses **pain** to signal the presence of disease, but this is not the case in early- and mid-stage atherosclerosis. Even in a modern hospital, plaque can be hard to detect unless it is advanced, because for decades it builds up without showing through the artery's lining in a distinct bulge. The artery lining looks smooth.

Yet, like a volcanic mountain rumbling far beneath the surface, soft buried plaque can be very active. It can suddenly erupt, spewing its contents directly into the artery and triggering the formation of a potentially dangerous blood clot. Researchers discovered that many people in their teens and 20s have atherosclerosis not through doctors performing diagnostic tests and finding the plaque, but through performing autopsies on young people who had died in accidents and examining their blood vessels. Pathology, not angiography, is what told doctors that millions of young people have significant atherosclerosis. But "pathology," by definition, means it is too late! You need to discover it earlier than that. How? Not by waiting for chest pain to signal its presence, but by assessing your own personal risk factors and taking aggressive, proactive, preventive action.

Consider that, for about two-thirds of men and about half of women in the US, heart disease is like high blood pressure. It is painless. The first sign they receive of their heart disease is often the last: a heart attack or sudden death. In fact, although the typical heart attack occurs in a coronary artery with only 20% narrowing, a treadmill stress test detects heart disease only when one or more of the person's arteries is narrowed by 75% or greater.

The reason aspirin can help to prevent a heart attack is that it makes blood less vulnerable. Conversely, Merck & Co.'s worldwide withdrawal in 2004 of its anti-inflammatory arthritis drug Vioxx in response to a public health advisory issued by the U.S. Food and Drug Administration was based on indications that Vioxx increases the risk of a heart attack by making blood more vulnerable.

Half a century ago, doctors considered the major cause of heart attacks to be coronary thrombosis—the simple blockage of a coronary artery by a blood clot. Today, we know that most heart attacks are caused by a combination of plaque-formation (atherosclerosis) and blood clots (thrombosis), particularly among people who have vulnerable blood along with a large number of vulnerable plaques. Plaque is the number-one enemy, but clots play a role in the final stage. The good news is that, through lifestyle choices, you can reduce the vulnerability of both your blood and your plaques, as well as keep the number of plaques you develop to a minimum.

Vulnerable heart

Just as some blood and some plaques are more vulnerable than others, some hearts are more vulnerable. A vulnerable heart is one that has been damaged by a heart attack or other causes, which render it unusually susceptible to fatal conditions such as ventricular tachycardia (a form of arrhythmia) or to ventricular fibrillation that can result in cardiac arrest or sudden death. (These conditions will be discussed shortly). A person, who has survived a heart attack or cardiac arrest, is generally considered to have a vulnerable heart. Surviving a major coronary event is clearly wonderful news, but the point is that it is far better not to have had such an event at all in the first place, because that very history places you at greater future risk. Like a bone that has been broken before, a post-coronary event heart may never quite fully regain its earlier robustness.

Vulnerable patient

We are now recognizing that there is a category of patients, who should be referred to as vulnerable patients. The combination of vulnerable plaque, vulnerable blood, endothelial dysfunction, and a vulnerable heart makes for a *vulnerable patient* who is at high risk of a heart attack or stroke. Fortunately, cardiologists recognize such patients relatively easily from their medical history and appropriate tests. Through assessing a patient's cardiovascular risk factors, physicians can identify vulnerable patients who are likely to have numerous vulnerable plaques and/or vulnerable blood. The challenge now is for doctors to be able to identify vulnerable patients earlier and more easily, and for

patients to be able to recognize the presence of hereditary and lifestyle factors that may be heightening their vulnerability to coronary artery disease, putting them at risk for a tragic event down the road.

It is important to note the progressive nature of heart attacks. A heart attack tends to predispose you to sustaining another, often more severe, heart attack—partly because the underlying causes that triggered the first attack (for example, dyslipidemia) may be unchanged, and partly because the heart attack itself can weaken your heart and cause further complications, including making the patient less likely to be physically active. In addition, as mentioned, much of the plaque that is the basis of most heart attacks grows within the wall of the coronary artery itself rather than on the inside lining of the artery, especially during the early stages of atherosclerosis. Unlike large, on-the-surface plaques, this intra-wall plaque cannot be physically flattened through interventions like angioplasty. It can, therefore, lay a foundation for a series of cardiac events later in your life. Fortunately, these vulnerable plaques are the ones that respond most dramatically to cholesterol-modifying therapy.

The role of stressful emotions

What actually triggers a heart attack? Why does it occur today instead of next week? The underlying cause, of course, is heart disease. In a more immediate sense, however, heart attacks are like angina often set off by emotional stress, anger, extreme excitement, or a sudden burst of physical exertion, particularly by a normally inactive person. Emotional stress, such as heated disputes at work or at home, great fear, or mental stress generated by tight deadlines at work, increases blood pressure and releases stress hormones, particularly in women. In one heart attack study, more than half of the respondents said they had been very upset or stressed in the 24 hours preceding their attack. Anger is particularly deadly: The risk of a heart attack is particularly high up to two hours following an angry outburst. Although it is impossible to avoid all emotional stress, we can reduce our risk of heart attack by learning to better cope with stress and mastering techniques that allow it to drain away.

Sudden vigorous exercise in an inactive person also raises the risk that a plaque will burst and produce a heart attack. Inactive people concerned about heart attacks should avoid vigorous exercise until they consult

Plaque: Size is Not What Matters

In the traditional view, large plaques are the cause of both angina and heart attacks. In the contemporary view, large plaques cause a gradual onset of stable angina in a patient, for example, during exercise; but what causes heart attacks is inflamed plaques, whether large or small. Size is not the relevant factor. Inner composition is. Many dangerous, inflamed plaques are so small they do not even show up on an angiogram. A coronary angiogram cannot tell which plaques are vulnerable to rupture. They can only tell which ones are becoming so large that they may cause angina.

Is heart disease a degenerative disorder?

Quite likely your initial response to this question was yes, but the answer actually is no. Heart disease is often chronic and progressive, but it is not accurate to describe it as a degenerative disease. Here is the difference: Degenerative diseases, such as cataracts or arthritis, get worse simply as a result of the aging process. Although there may be a few things one can do to slow down their rate, on the whole, there isn't much one can do. They worsen naturally over time.

Heart disease, by contrast, does not have to get worse over time. It is not inevitable. You do not get heart disease simply because you are growing old. The fact is that you can be 90 years old and not have plaque in your coronary arteries. It does not get there simply because you became old. The process of atherosclerosis is an active, dynamic process that results in part from specific, intentional choices a person makes or fails to make. And that is the difference.

True, some of your chance of developing heart disease may depend on your ethnic group and the genetic profile you inherited. Nevertheless, like type 2 diabetes or obesity, heart disease is highly controllable, even reversible. Much depends on you. This is why it is improper to think of cardiovascular disease as a degenerative disease. It is largely a disease of choice—and choice depends on knowledge.

their physician, especially in very cold weather, which can place further stress on the heart. When you do begin to exercise, start gradually so as not to shock your system.

HEART DISEASE AND ITS CONSEQUENCES

Does Exercise Thwart or Trigger Heart Attacks?

Okay, this is a bit of a trick question. The answer is, *both*. The cardioprotective benefits of regular exercise far outweigh its risks. Among its benefits—too many to list here—it lowers blood triglyceride levels, boosts HDL levels, lowers blood pressure, helps control body weight, improves the heart's ejection fraction, keeps your coronary and other arteries elastic, and improves cardio-respiratory fitness. Those who exercise regularly at moderate intensities for long periods of time (such as marathon runners) have the lowest rate of heart disease - less than one-fourth that of sedentary individuals.

Nevertheless, there are a few cautions: A recent study suggests that people who rarely exercise are nearly seven times more likely than those who regularly exercise to have a heart attack, if they engage in sudden vigorous activity. In other words, bursts of physical activity after years of inactivity carry risks. **Second**, in rare cases—as in the famous instance of Dr. James Fixx (see *below*)—exercise may precipitate a heart attack in an athlete who already has heart disease (in Fixx's case, possibly hypertrophic cardiomyopathy) or who has several very serious risk factors for heart disease (again, like Fixx).

Finally, exercise can prevent you from realizing that you have coronary disease because, for any given level of coronary disease, angina is delayed in people who exercise, since their fit heart compensates for the blockages. None of this, however, should deter you from regular physical activity. The unfortunate Dr. Fixx, for one, may have died much earlier had he not exercised so much. Get going!

HEART DISEASE can have many consequences. We will look at seven major ones: Cardiac arrest, sudden death, stable angina, unstable angina, heart attack, heart failure, and silent ischemia.

A central question in the detection, management and treatment of heart disease is: How do you discover it when there are no obvious symptoms? A stress test on a treadmill in a cardiologist's office can be a great detection tool, but there is an erroneous impression that a stress test that turns up negative (meaning normal) means you are off the hook.

Not necessarily. It simply may be that your heart disease is not sufficiently advanced for it to have been noticeable in the test. Fairly advanced coronary disease is relatively easy to detect—either through a stress test or the chest pain that the disease itself generates. In contrast, less advanced disease—for example, 50% blockage of the artery rather than 75%—is a greater challenge. This is why it pays to understand the different forms that heart disease can take and be able to read the initial symptoms in order to distinguish them from one another. With the heart, time often is of the essence.

a. Cardiac arrest

Cardiac arrest, an abrupt loss of heart function in which the heart suddenly stops pumping, is one of the dreaded complications of heart disease. It can occur unexpectedly, with or without a heart attack. If the person is not resuscitated immediately, it can lead to sudden death within an hour of any symptoms. It is believed that Terri Schiavo, who spent the final 15 years of her life in what many experts considered a persistent vegetative state before her feeding tube was removed in March 2005, suffered severe brain damage from cerebral hypoxia caused by cardiac arrest. Cardiac arrest can have several immediate causes, including:

- ventricular tachycardia (or rapid irregular heart beat)
- ventricular fibrillation (or rapid chaotic unproductive heart beats)
- asystole (or absence of detectable electrical activity in the heart)
- or all three

Usually, cardiac arrest starts as ventricular tachycardia and quickly advances to ventricular fibrillation, which compels the heart to stop pumping blood. Ventricular fibrillation can occur in people without a heart attack, including even young athletes. Cardiac arrest caused by ventricular tachycardia and/or fibrilla-

tion can be reversed if the victim is treated with an electric shock within seven to ten minutes after onset. Every additional minute spent without defibrillation reduces a victim's survival chances by 7-10%.

Cardiac arrest caused by asystole, or complete stoppage of the heart-beat, is more serious. One's survival chances are low. All untreated ventricular tachycardia and ventricular fibrillation eventually result in asystole.

Finally, a small number of cardiac arrests are caused by extreme slowing of the heart. If you suspect a cardiac arrest, call 911 and begin cardiopulmonary resuscitation (CPR) immediately. Table 1.1 gives the warning signs of cardiac arrest and how to distinguish it from common fainting.

b. Sudden death

The most frightening of all the consequences of heart disease is the prospect of dying suddenly with no warning. This indeed is what happened to James Fixx, the famous author of the runaway bestseller *The Complete Book of Running*, who collapsed suddenly on July 21, 1984 and died, just one minute after setting a regional master's record in a 3000-meter run. His story suggests that regular exercise, although extremely important, cannot by itself guarantee you protection from serious heart disease. Fixx, it turns out, had several risk factors: He had markedly elevated cholesterol and his father had died from a heart attack at 43. A former two-packs-a-day smoker, who was 60 pounds overweight when he started exercising regularly, Fixx's autopsy showed two severely occluded coronary arteries (one at 80%, the other near-total), and also suggested that he may have had hypertrophic cardiomyopathy. He may also have had warning signs that he ignored. Had he not lost 60 pounds and become a runner, Fixx may well have died earlier.

Table 1.1. Signs of Cardiac Arrest

Signs	Actions to confirm cardiac arrest
Sudden loss of responsiveness; no spontaneous movement	No response to gentle shaking
No normal breathing	The victim does not take a normal breath when you check for several seconds
No circulation	No palpable pulse

The important thing to bear in mind is that heart disease often kills without giving any advance warning symptoms at all. That is why aggressive prevention is so important. For about 30% of people with heart disease, sudden death with no chest pain whatsoever is the first and last symptom of heart disease they ever face. Sudden death is nevertheless extremely uncommon in people with relatively normal-functioning hearts. As in the case of James Fixx, it is generally the result of disease accelerated by risk factors such as smoking, family history, and abdominal obesity, which is a risk factor even in someone whose body weight and BMI (or body mass index) are normal. Every year, some 250,000 Americans die from sudden death without ever being hospitalized for heart disease, and about two-thirds of all deaths from heart disease occur before the person reaches the hospital, even in major metropolitan centers. Owing to advances in nationwide efforts at prevention and treatment of heart disease in the US, the rates of sudden and non-sudden deaths have decreased more than 50% over the past half century, but there is as yet no evident decline among people living on the Indian subcontinent.

c. Stable angina

Angina pectoris, often simply called angina, refers to pain or discomfort in the chest that may radiate down your arm or into your jaw and typically lasts 2-15 minutes. Angina occurs when one or more of the

Consequences of Heart Disease

Heart diseases such as atherosclerosis can lead to

- Cardiac arrest
- Sudden death
- Stable angina
- Acute coronary syndrome (unstable angina)
- Heart attack
- Silent heart disease and silent ischemia
- Heart failure

Think Prevention, not Treatment

While many more Americans could benefit from a heart transplant than currently do, only about 2,000 hearts become available each year and there are long waiting lines. Bypass surgeries, stents, and coronary angioplasties, though less rare than transplants, are also very expensive. This means keeping your heart healthy rather than replacing it or repairing it is the real answer. Prevention rather than treatment is the key to cardiovascular health.

coronary arteries that supply the heart muscle with blood and oxygen becomes severely narrowed through plaque buildup (atherosclerosis), depriving the heart muscle of oxygen-rich blood. The result is pain. It is important not to rely on the onset of angina as the first warning sign to adopt a heart-healthy lifestyle.

Rather, it indicates the presence of a disease that is already advanced and the evident failure of whatever medical treatment you were receiving.

Health Smart Tips

It is important not to see angina as the first warning to begin making heart-healthy choices. Rather, it usually represents the failure of medical therapy to prevent and detect disease that is now already quite advanced.

In contrast to unstable angina, which is worse, stable angina is a chronic condition; unstable angina is an acute condition that is closer to a full-blown heart attack. Stable angina is usually brought on by the physical stress of exercise (fast walking, climbing stairs, mowing lawn, sex) or by emotional stress (anger, excitement, fright), and stops with rest. Pain occurs when the heart needs more oxygen than your clogged coronary arteries can supply. This temporary imbalance between supply and demand, which can be seen on an electrocardiogram (ECG or EKG), is called **ischemia** (pronounced *is-KEEM-yuh*). Angina is your body alerting you that ischemia is occurring.

If your coronary artery disease worsens, then as time goes by your angina will occur with less and less physical exertion because your heart's ability to receive oxygen through your narrowed coronary arteries is decreasing.

What are the signs of stable angina? Most people describe the discomfort as a feeling of pressure, tightness, or heaviness in the center or left side of their chest area. Some describe it as a “crushing of the chest,” “as if an elephant stepped on my chest,” or “a truck sitting on my chest.” The discomfort often radiates into the left arm, jaw, or upper back. Occasionally, and particularly in women, the discomfort is felt only in one of these other areas, without any discomfort in the chest. Chest discomfort is usually accompanied by shortness of breath or sweating and is typically brought on by moderate-to-severe physical activity.

What should you do? Resting relieves the pain by decreasing the heart's oxygen demand; taking **nitroglycerine** also relieves the pain, by dilating the coronary arteries and thereby increasing oxygen supply (see Chapter VIII, Section 3).

Note, however, that although chest pain has become one of the most common reasons for emergency room visits among middle-aged men and women in the US, *not all chest pain is angina*. Diseases of the lung, stomach, esophagus, and chest wall muscle can all cause chest pain. For example, a “pins and needles” type of chest pain is usually not due to heart disease. Cardiologists use the presence or absence of risk factors to differentiate cardiac chest pain from non-cardiac. It is, nevertheless, better to be over-cautious than under-cautious, and take all chest pain seriously.

From the earlier discussion of the stages of atherosclerosis, it should be clear that, although angina may be your first clue that you have heart disease, developing angina actually signifies a state of atherosclerosis that is already advanced, because the kind of significant artery narrowing that causes chest pain does not typically occur until decades of heart disease. Chest pain that is caused by CAD should, therefore, be considered a very loud—and belated—cry for help from your coronary arteries.

d. Unstable angina (Acute Coronary Syndrome)

Like stable angina, unstable anginal pain is caused by partially blocked coronary arteries, but it is more severe and occurs at random and without warning, often when you are merely resting. It lasts longer than stable angina, is less responsive to medication, and happens more often. Unstable angina usually advances to a heart attack unless the person receives appropriate treatment. Unlike in a full-blown heart attack, however, blood tests after unstable angina typically show no evidence of actual heart muscle damage. Occasionally, a coronary spasm, in which the arterial walls temporarily contract, can lead to unstable angina. This is particularly common at rest but it can also be brought on by exposure to cold weather.

Unstable angina is one *type* of Acute Coronary Syndrome (or ACS, for short). The other is heart attack. In fact, the term “unstable angina” is rapidly disappearing in favor of ACS. The diagnosis of ACS, and

which type you have, is decided only after several days of monitoring, blood tests, and ECGs. Because a heart attack often passes through several different phases in a 24- to 48-hour period, it can take two to three days of looking at your ECG wave tracings to be able to tell what kind of ACS you may be having.

e. Heart attack (myocardial infarction)

If unstable angina is more serious than stable angina, heart attack is worse still. The medical term for a heart attack is myocardial infarction, or MI. An MI occurs (usually in the left ventricle) when one of the coronary arteries that supply the heart muscle with blood and oxygen becomes completely blocked with a blood clot, usually one that formed after the rupture of a soft, fatty plaque. In much the way that brain damage often occurs, this prolonged deprivation of oxygen causes permanent, irreversible damage to the heart muscle, resulting in scar tissue and compromising the heart's ability to contract. By contrast, stable angina (unlike heart attack) is caused not by a blood clot following plaque rupture but by the gradual narrowing of the coronary artery as a result of increasing plaque buildup.

Unlike stable angina, and even more than unstable angina, the pain of a heart attack usually lasts more than 15 minutes and does not go away with rest. Immediate treatment—for example, when the attack occurs at a hospital—can often stop it from continuing to develop, thereby minimizing heart muscle damage in patients in the middle of an acute heart attack. Immediate treatment usually involves emergency angioplasty and/or clot-busting therapy, but heart muscle cannot be salvaged if the person *reaches the hospital too late* or the hospital does not have the right facilities.

f. Heart failure

The term “heart failure” can be misleading: it does not mean your heart has stopped. It means it can no longer pump effectively. It has varying degrees of severity. Heart failure may result from several things: a large heart attack, several minor and often unrecognized heart attacks, or other causes such as high blood pressure, obesity, diabetes, and viral infection. While a heart attack develops suddenly and dramatically, over a matter of a few minutes, heart failure develops gradually over years.

The most common symptoms of heart failure are shortness of breath, swollen feet and legs, a buildup of fluid in the lungs, and fatigue. Those with advanced heart failure are often bedridden and get short of breath even walking to the bathroom. The outlook for people with severe heart failure is no better than those with cancer: 50% die within five years. The incidence of heart failure in the US has risen dramatically. Currently, five million Americans have heart failure, and one million new cases are added every year. It is now the most common cause of hospitalization in elderly patients because many more people are surviving their heart attacks through medical intervention, but are not recovering fully. Fortunately, heart failure is often a treatable and thus reversible condition.

How does a heart attack lead to heart failure? Although former president Bill Clinton had scar tissue successfully removed from his lung and chest cavity in March 2005, removing scar tissue from the heart itself cannot be done. For the millions who suffer heart attacks every year, the cells in the oxygen-starved part of the heart muscle die and form tough scar tissue that can no longer work like healthy heart cells. This scar tissue gets incorporated into the heart itself. Many heart attack survivors, therefore, develop heart failure. Over time, the heart's walls grow thin and floppy, and the heart ceases to pump effectively.

Angina's Loud Cry

In September 2004, former US president Bill Clinton, then 58, underwent a four-hour quadruple coronary artery bypass surgery at New York—Presbyterian Hospital. Happily, the surgery was successful and uneventful. Recall, however, that six months earlier, Clinton had started experiencing chest pain typical of stable angina, but this was somehow ignored, as is often the case with most of us. Angina's loud cry needs to be headed with great urgency, because once you “hear” it, it is almost beginning to get too late.

What Exactly is an ECG, and What Do Those Spikes Mean?

An electrocardiogram, or EKG or ECG for short, is a recording of the tiny electric current produced by the heart. An ECG is the line that goes "flat" when someone dies on a TV program like ER. The test is done using electrodes attached to your chest and plugged into an ECG machine that translates your heart's electric impulses into line tracings on paper. By analyzing the pattern of spikes and dips (called waves) produced by your heart, a doctor can tell if there is any damage as a result of a heart attack, if your heart is beating abnormally (arrhythmia), or if there is any disease in the heart muscle. Cardiologists use the letters P-Q-R-S-T to describe the different parts of an ECG tracing. Each spike or dip has its own letter. So you might hear your cardiologist talking about the "ST segment," or "the QRS complex," or the P wave. Each has a meaning. For example, the P wave represents the electrical activity in your two atria. The Q, R, and S waves display the electrical activity in your ventricles. A heart attack will often produce an elevation of the **ST segment**.

g. Silent heart disease and silent ischemia

Not only can a heart attack be silent (meaning painless), but the heart disease that leads to it also usually progresses silently for several decades. Chest pain develops only when heart disease is far advanced. This means that waiting for chest pain before one begins to take a proactive approach to heart disease is as flawed a strategy as waiting for labor pain to discover that you are pregnant and need to begin prenatal care.

In addition, there is no clear correlation between severity of heart disease and its symptoms. You may have severe heart disease that is depriving your heart muscle of oxygen, yet experience few or no symptoms. This is called **silent ischemia**, which, as we saw in the paragraphs on angina, means the insufficient supply of blood to a bodily organ. Even though it may go away after exercise, ischemia indicates that some of the living muscle tissue of your heart is highly vulnerable to a heart attack in the not-too-distant future because one or more of your arteries has narrowed severely. The risk of having a heart attack when you have silent ischemia is as high as when you have symptoms of angina. In fact, silent ischemia accounts for more than half of all coronary angioplasties and bypass surgeries done in the US.

How do you know if you have silent ischemia? Silent ischemia can be detected from the way your ECG (or EKG) readout looks during an exercise treadmill stress test, commonly done in the offices of most cardiologists and many physicians in the US. It can also be detected by your wearing a 24-hour heart ECG monitor called a Holter monitor, which looks like a large Walkman. These diagnostic techniques are discussed more extensively in Section 3 of Chapter VII, but let's look briefly at what an ECG, or electrocardiogram, is.

Electrocardiograms (ECGs)

The death of heart muscle cells caused by a heart attack or by ischemia releases high levels of certain enzymes and proteins, such as troponin, which can be detected by testing the person's blood. The greater the damage, the higher the troponin levels. Depending on the shape of your **ECG tracings**, cardiologists classify heart attacks as:

- Heart attacks with ST-segment elevation, or
- Heart attacks without ST-segment elevation

The first results in much greater damage to the heart. (Cardiologists once distinguished the two kinds as Q-wave heart attacks and non-Q-wave.) All these special words—Q-wave, ST-segment—refer to particular telltale changes that show up on your ECG tracing if you have a heart attack. Typically, elderly people have a non-ST-segment elevation (mild) heart attack, often followed by an ST-segment elevation (major) heart attack within a few weeks or months. By contrast, younger and middle-aged people typically have ST-segment elevation (major) heart attacks when they do have an attack.

MORE ON HEART ATTACKS

The warning signs of a heart attack

BECAUSE WE LIKE TO LOOK on the bright side, we often play down the warning signs of an impending heart attack. Yet each year 1.1 million Americans suffer a heart attack; one-third do not survive. What are the signs of a heart attack? It is not always easy to know if you are having one. Typically, however, as with angina, you may experience heavy pressure or pain in the chest, with the discomfort possibly radiating down your left arm or up toward your jaw. Sometimes the discomfort may be confined to these regions only without accompanying chest pain. Unlike angina, the symptoms tend to be more severe, last longer, and resist improvement even with rest. You may experience nausea, vomiting, shortness of breath, weakness, dizziness, fainting, or profuse sweating. Victims often get a sense of impending doom.

Monday mornings and heart attack

Heart attacks are more likely between 6:00 a.m. and 10:00 a.m., when your blood pressure is the highest, and more common on Mondays, possibly because of the stress of returning to work.

Never dismiss heart attack symptoms as “probably just some indigestion or heartburn.” It is far better to raise a false alarm than to succumb to a real one. If you suspect that you or someone near you is having a heart attack, take immediate action. Chew or crush and swallow a regular 325mg dose of aspirin and call 911 and your doctor. Even though early arrival to the emergency room markedly increases your chances of survival, you are nevertheless strongly advised *not to drive yourself* to the hospital, nor allow anyone other than a trained medic team to drive you to the hospital. A cardiac arrest in the car may be more than the unprepared driver can handle, and could reduce his as well as your chances of survival.

Another factor that makes the detection of heart attacks tricky especially among Indians is that many Indian heart attack victims have **atypical symptoms** that are hard to recognize and thus can lead to critical lost time in obtaining treatment. If mortality rates among Indians are to fall, emergency staff and physicians must more easily recognize the atypical symptoms Indians often have.

The severity of a heart attack

Because the major coronary arteries supply so much of the heart muscle, a blockage of one or more of these arteries can wreak havoc. It is, therefore, critical to do everything you can to keep your coronary arteries healthy and in full flow. Nevertheless, when a critical artery is blocked, other arteries can often pick up the slack and do double-duty, preventing serious consequences, at least for a while. More muscle is damaged when these collateral arteries, the ones that could have provided alternate blood routes, are also diseased and blocked, as often occurs in patients, who are having a second or a third heart attack. Put simply, when the “reserve team” is also sick, your chances of survival are lessened and complications tend to be more numerous.

Surviving a heart attack, therefore, depends not only on how diseased the blocked artery is, but also how many arteries in total are blocked, and the severity of the blockages. Usually your prognosis (the medical term for your chances of getting better) is good when only one coronary artery is involved, bad with two, and worst when all three major coronary arteries are severely narrowed.

Silent heart attack

Although severe chest pain is the hallmark of a heart attack, an attack can also occur with little or no chest pain. As stated earlier, in 20-30% of all heart attacks, there is no serious chest pain. These patients may often mistake their mild discomfort for an upset stomach, heartburn, or indigestion and take a couple of antacid tablets. Others who have a high threshold for pain may not realize that their

Ignorance Is Not Always Bliss

One in four heart attack victims, it is estimated, do not realize they have had an attack until later, when they have an electrocardiogram for unrelated reasons and discover it. Despite the lack of pain, the damage produced by a silent heart attack is still very real, and can predispose you to further heart attacks.

pain is particularly serious. It is estimated that as many as one in four heart attack victims did not know they have had a heart attack until they go in for an ECG for unrelated reasons. Almost half of diabetic patients, and many women, do not get typical chest pains while having a heart attack. Some may have atypical symptoms such as shortness of breath, abnormal heart beat, nausea, extreme fatigue, or profuse sweating. Many diabetics have nerve damage that reduces their sense of pain in the chest and heart. A patient's long-term outlook after a silent heart attack is no different than that of someone who has had typical chest pain.

Some Warning Signs of a Stroke

- Sudden numbness or weakness felt in the face, arm, or leg, especially on one side of the body
- Sudden confusion, trouble speaking, or understanding speech
- Sudden trouble seeing in one or both eyes
- Sudden trouble walking, dizziness, or loss of balance or coordination
- Sudden severe headache with no obvious cause

cholesterol and plaque. Yet the similarities are also distinct: In a heart attack, clogged coronary arteries choke off the supply of oxygen and blood to the heart muscle, and the affected heart muscle dies. In a stroke, the same process occurs in the brain. In fact, many cardiologists have begun to refer to strokes as **brain attacks** because of the similarity in terms of oxygen deprivation.

The *symptoms* of a stroke, however, are quite different. Most heart attacks are accompanied by severe crushing chest pain (although a minority of them are painless). In contrast, the majority of strokes cause no pain. Some strokes can be quite small. Multiple small strokes can lead to dementia, which expresses itself as forgetfulness and difficulty engaging in basic thinking.

The risk of having a stroke doubles during each decade of life after age 55, and two-thirds of all strokes

occur in people over age 65. A stroke is often preceded by a Transient Ischemic Attack (TIA) or a **mini-stroke**. The main difference between a mini-stroke and a stroke is that the symptoms of a mini-stroke disappear within a few minutes to a few hours, whereas in a stroke they persist and are often accompanied by disability. Three out of 100 mini-strokes will lead to a major stroke within 30 days, and seven out of 100 mini-strokes will lead to a stroke within a year.

What exactly causes a stroke? There are two major causes, and in each case, part of your brain tissue dies:

i. Ischemic strokes (80% of all strokes) are caused by inadequate blood supply to the brain, and are more common among whites

ii. Hemorrhagic strokes (20% of all strokes) are caused by an artery in the brain bursting and leaking blood uncontrollably. They are more common among blacks and Asians, and more lethal than ischemic strokes

Ischemic strokes occur when a blood clot blocks an artery and chokes off blood supply, as in a heart attack. Hemorrhagic strokes occur when an artery supplying the brain ruptures, like a water pipe, usually because of excessively high blood pressure inside it. Blood then leaks uncontrollably into the brain tissue, going where it should

Heart Attack and Stroke

Many people believe heart attacks are less disabling than strokes, but one often leads to the other. About 40% of people who survive a heart attack eventually develop a stroke, resulting in paralysis and disability; and about 80% of people who get a stroke do not die from it instead they die from a heart attack later on. The links between the two diseases underscore their common foundation: both heart attacks and strokes are cardiovascular diseases, although strokes are triggered more by high blood pressure, and heart attacks are triggered more by cholesterol-based atherosclerosis. In both cases, a healthy diet, weight control, and daily physical activity greatly reduce the probability.

STROKES VERSUS HEART ATTACKS

IT HAS BEEN SAID that stroke and heart disease are “first cousins with common grandparents.” Those common grandparents are their risk factors. Nevertheless, risk factors affect the two slightly differently. In contrast to a heart attack, uncontrolled high blood pressure is by far the strongest predictor of stroke. For heart attack, it is

not. One might loosely say that, hemorrhagic strokes are caused by *too much* blood, while ischemic strokes are caused by *not enough* blood and oxygen getting to the brain. Of note, a hemorrhagic stroke is believed to have claimed the life of the Franklin Delano Roosevelt, the 32nd president of the United States. Although strokes more often lead to disability than death, for many patients, living with a severe stroke is worse than death.

In 1990 half a million people in India died from stroke, a number projected to more than double by 2020. Alarmingly, approximately 12% of these strokes occurred in people younger than 40. Yet a 2005 hospital-based study of 942 subjects at Christian Medical College in India, a major medical center located in the Punjab region, found that 45% of them did not know the brain was the organ affected in a stroke, and 33% were unable to describe a single warning symptom of stroke.

THREE OTHER CARDIAC CONDITIONS

■ **Arrhythmia:** Arrhythmia is a disturbance in the electrical activity of the heart that creates abnormalities in heart rate and rhythm. During arrhythmia, the heart may beat too slowly, too rapidly, or both, meaning irregularly. Some arrhythmias like ventricular fibrillation and tachycardia can be life-threatening. Some experience arrhythmia as a skipping or fluttering sensation in the chest; others complain of “racing” of the heart. It can cause chest pain, shortness of breath, light-headedness, or no symptoms. Let’s look at one particular type of arrhythmia.

■ **Atrial fibrillation:** The most common arrhythmia is atrial fibrillation, a condition that afflicts more than six million mainly elderly Americans. In atrial fibrillation, the upper chambers of the heart (the atria, singular: atrium) fail to contract effectively or in coordination with each other. They are out of sync with each other. The condition is usually treated with medications. Left untreated, this arrhythmia can lead to heart failure or stroke. Patients with atrial fibrillation are five times more likely to get a stroke. The prevalence of atrial fibrillation doubles every 10 years starting at age 65. That means, for example, that 75-year-olds are twice as likely to have atrial fibrillation as 65-year-olds. Atrial fibrillation often has no symptoms, but other people experience very high heart rates. They may express it in phrases like “My heart was beating out of my chest.”

A typical adult’s resting heart rate falls somewhere between 50 and 75. In very challenging atrial fibrillation patients whose heart rates exceed 200 beats a minute and who are not responding to medication, surgery may be performed. In a novel procedure, surgeons cut a shallow maze-like pattern into the surface of the heart’s upper chambers, the atria, forcing the heart muscle to develop scar tissue. Since scar tissue does not carry electrical impulses, this prevents the erratic electrical signaling that produces atrial fibrillation. A recent approach that is non-invasive yet yields similar results uses high-intensity ultrasound to create the same kind of non-electrical scar tissue.

■ **Cardiomyopathy:** So far, we have looked primarily at coronary heart disease—which refers to conditions caused mainly by plaque in coronary arteries blocking the flow of blood to the heart. Cardiomyopathy, by contrast, refers to the severe weakening of the heart muscle itself, not the coronary vessels, so that the heart can no longer pump strongly. The most common type is dilated cardiomyopathy

Automatic External Defibrillators

The benefit of placing automatic external defibrillators (AEDs) in stressful public places such as airports and offices, where cardiac arrests are frequent, has been documented. Easy to use, they have saved lives even when used by persons with no prior experience. AEDs are now FDA-approved for home use, and you can buy one, such as the Philips HeartStart Home Defibrillator, for about \$1,500. However, because it is less likely that a cardiac arrest will be witnessed at home, you should consider whether that money may be better spent on other preventive and therapeutic strategies.

(DCM), typically caused by end-stage heart disease that enlarges the heart, making it unable to pump well. Sudden death is common among cardiomyopathy patients, and some of them benefit from an implanted cardioverter defibrillator (see Chapter VIII, Section 3). Unlike most coronary heart disease, cardiomyopathy is inoperable. Unlike other muscles in the body, heart muscle tends not to heal itself. Cardiomyopathy, therefore, almost always leads to heart failure.

COMMONLY USED TERMS IN HEART DISEASE

- **Cardiac catheterization:** A catheter is a very thin, long, flexible tube. In a cardiac catheterization, a catheter is inserted into a blood vessel and slowly advanced, like a feeding tube, toward the heart from the surface of the patient's skin. It is done for both diagnostic and treatment purposes. General anesthesia is not needed, but the physician typically numbs the area before inserting the catheter and gives the patient a mild sedative. The patient does not ordinarily feel the movement of the catheter within his or her blood vessels.
- **Coronary angiogram:** A coronary angiogram is essentially an x-ray of a coronary artery to check for any plaque that may have narrowed or blocked the vessel. Angiograms have been the gold standard for the diagnosis of heart disease for decades. An easily detectable dye is injected into the artery through a catheter, and the physician uses x-ray equipment to follow the dye as it flows through the artery.
- **Coronary angioplasty:** Often, a coronary angioplasty (or simply, balloon angioplasty) is done on a patient who has substantial blockage of his or her coronary arteries but whose heart disease is not so severe as to require full-scale bypass surgery. A special catheter with a small balloon at the tip is used to open up the diseased artery without entailing actual surgery. The catheter is pushed into the artery and the balloon is then inflated. This stretches the artery and flattens and often ruptures the plaque that was preventing the blood from flowing.
- **Coronary atherectomy:** Atherectomy is a procedure in which a catheter that has a special grinding device at one end is used to clear away plaque in a blocked artery, much like a chain might be used to unclog a blocked kitchen drain. It is done to improve blood supply to the heart without surgery.
- **Coronary stent:** A stent (see **Color Plate 1.8**, *Methods of Opening Up and Re-establishing Blood Flow in coronary arteries following a Heart Attack*, page xviii) is a small tubular device that is permanently placed in an artery to keep it propped open, often following an angioplasty. The major advantage of a stent over just simple balloon angioplasty is that a stent can reduce the rate of restenosis (re-blockage of arteries caused by the buildup of new tissue) by up to 50%. Drug-eluting (meaning drug-releasing) stents are a new advance that have now reduced the restenosis rate by more than 90% (see Chapter VII, Section 6).
- **Coronary artery bypass surgery:** Coronary artery bypass graft surgery, often rather irreverently referred to as CABG (pronounced "cabbage"), is a life-saving procedure in many patients with severe heart disease such as left main coronary artery disease or triple-vessel disease (**Color Plate 1.9**, page xviii), *A Coronary Artery Bypass Operation*). It is called a bypass because, just as in road construction work when traffic has to be rerouted, the surgeon reroutes or "bypasses" blood flow *around* the clogged portion of the artery to restore supply to areas of heart muscle that were in danger of starving from lack of oxygen (see Chapter VII, Section 5).

● **Coronary event:** In principle, a coronary event (or cardiac event) can be any episode that declares the presence of complications from heart disease. In practice, the term is reserved for major episodes. This could be acute stable or unstable angina, or the onset of a clinical crisis such as a heart attack, or sudden cardiac death, or a medical intervention such as angioplasty, stenting, or bypass surgery. As discussed earlier, heart disease progresses silently for many decades before announcing itself in a major coronary event.

● **Coronary interventions:** A coronary intervention is any procedure performed on a severely narrowed coronary artery to improve blood supply. This includes Coronary Artery Bypass Grafting (CABG) surgery, coronary angioplasty and coronary stenting. **Color Plate 1.10.** *page xviii* shows the placement of a coronary stent in the left coronary artery, **Color Plate 1.11.** *page xviii* shows restenosis of the arteries through the metallic stent. Patients with diffuse disease, where there is plaque buildup on the entire artery are not suitable for coronary interventions (**Color Plate 1.12.** *page xviii*). These topics are discussed in detail in subsequent Chapters.

KEY • POINTS • IN • A • NUTSHELL

- ♥ Cardiovascular disease begins in childhood and progresses silently for many decades.
- ♥ Atherosclerosis (or plaque buildup) does not result in narrowing of the artery until very late in the disease process.
- ♥ Heart disease is not an unavoidable degenerative disease that is found in all elderly people; it is actively promoted by a combination of genetic factors and lifestyle choices.
- ♥ The various risk factors such as smoking and high cholesterol damage the artery lining in a process called endothelial dysfunction. This lays a foundation for future heart attacks or other cardiac complications.
- ♥ The mechanical view of plaque formation as a kind of "junk" that builds up layer after layer and clogs up an artery like a kitchen drain distorts the truth. The current view is that the composition of the plaque is more important than size of the plaque.
- ♥ Most heart attacks are caused not by an artery narrowing due to the buildup of hard, large plaques detectable on an angiogram, but by a blood clot that forms after the rupture of a soft, inflamed, lipid-rich plaque, often quite small.
- ♥ No correlation exists between the severity of heart disease and its symptoms. Very severe heart disease may have few or no readily identifiable symptoms.
- ♥ Heart disease gives advanced warning in the form of chest pain (angina) only one-third of the time. Most of the time, it manifests as a heart attack or sudden death without warning.
- ♥ Don't wait for the onset of chest pain to begin a heart-healthy lifestyle. Angina rather indicates that your heart disease is already far along, because arterial narrowing does not begin until atherosclerosis is advanced.
- ♥ Half of all sudden deaths occur in people with no known heart disease history, and two-thirds occur before the person reaches the hospital, even in major metropolitan centers.