You hear a lot of talk these days about how digital video technology has brought video production "to the masses" both by making production more affordable, and technically easier. No doubt about it, if you want to shoot some footage of your family and then do a little editing to take out the boring parts, FireWire-based DV technology will prove to be much easier than conventional analog editing systems. However, if you're envisioning a more complex project—something longer, with sophisticated production values, and high-quality images and sound—then you're going to have to "get your hands dirty" and spend some time learning a little more about how video technology works—both analog and digital.

In this chapter, we're going to introduce you to the fundamentals of video technology. Consider this chapter a reference for the terms and concepts you will encounter on a day-to-day basis during your production process, as well as throughout the rest of this book. By the end of this chapter you should be able to make an informed decision about which video format best suits the needs of your project.

The answer to that question has become a lot more complex in recent years, but at the simplest level, video is a collection of electronic signals recorded by a camera onto a piece of magnetic media, usually videotape. But what about video for the Web, or video that's computer generated, or DVDs? Although it's true that within the next ten years videotape is likely to become obsolete, as the technology required to record directly to disk improves, at present most video footage—whether digital or analog—is still acquired through a camera that records onto videotape.

If you have any desire to deliver a project outside of your computer—using a video projector, television display, or by transferring to film and projecting in a theater—then you have to understand some fundamentals about videotape. Note that many of the terms and concepts in this chapter apply to any recorded media, whether direct-to-hard-drive recorders or optical disks such as DVDs.

Tracks

A video camera takes audio and visual information from the real world and turns it into electronic data that can be stored on a piece of magnetic tape. Videotape works by manipulating magnetic particles that are suspended in a medium applied to a thin piece of celluloid. During playback, the tape is pulled out of the tape cassette and wrapped partway around a spinning metal housing, called a *capstan*. The tape is pulled across *heads* that record and play back information to and from the tape.

Whether analog or digital, the data stored on a videotape is laid down in separate *tracks* along the tape. A track (sometimes called a *channel* or a *stream*) is a linear piece of information recorded along the tape. Wider tape has more physical space to store data, and so can yield better image quality. To maximize the space provided by any type of tape, video frames are recorded diagonally across the width of the tape, rather than straight across. This diagonal orientation yields more physical space, and so allows engineers to eke out a little more quality from the same tape width (Figure 3.1).

Usually, four tracks are recorded onto the videotape: the video track, two audio tracks, and the *control track*. Some types of videotape recorders can record four tracks of audio, usually at a lower quality level so that they take up the same physical space on the tape as two tracks. The control track is the equivalent of sprocket holes on a piece of film. It contains sync pulses that define where each frame of video starts and ends, which is crucial for stable playback. If you encounter a videotape that has an image that rolls across the monitor, the trouble is probably due to a damaged control track. Sometimes this can be fixed by dubbing the footage to a new videotape.

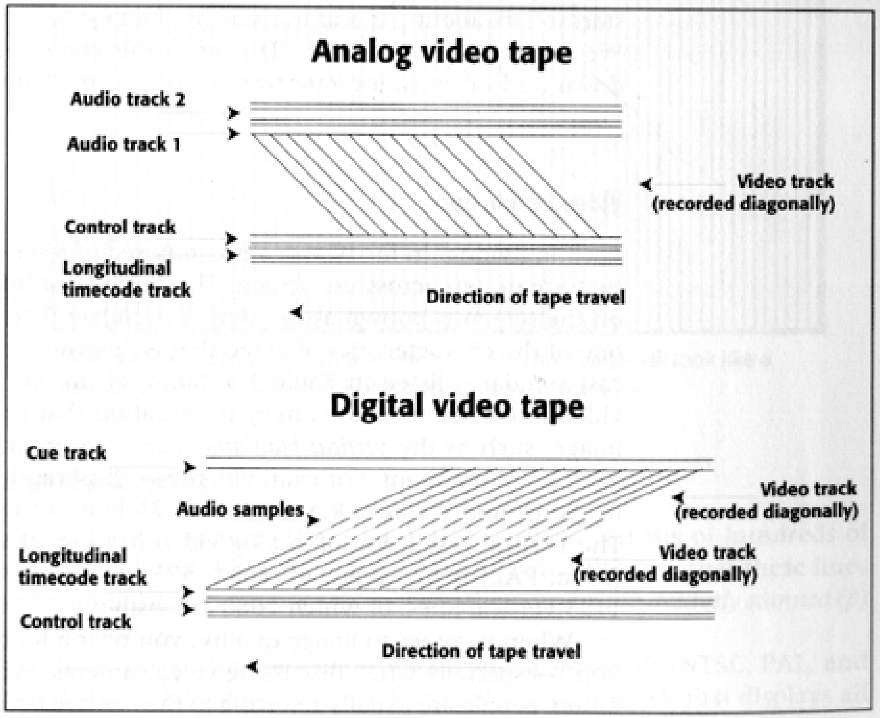

FIGURE 3.1 These two diagrams show how information is typically stored on analog and digital videotape.

Digital video files such as QuickTime movies also contain "tracks" of video, audio, timecode, and other elements. Manipulating, and sometimes even replacing, these individual tracks will be a regular part of your editing process.

Frames

The video track on a piece of videotape consists of a series of still images, or *frames*, that, when played in sequence, appear to be moving. When motion picture film was invented, it originally ran at a *frame rate* of 18 frames per second (fps). With the advent of sound, the frame rate had to be increased to 24 frames per second to get audio that sounded right. The frame rates of video vary, depending on where you live (see the following section "Video Broadcast Standards" and Table 3.3). Frames of video are similar to frames of film, except that you can't see them by holding them up to the light. Instead, you need a videotape player to decode the electronic information that constitutes each frame, and display it on a video monitor.

The frame rate of analog video in the United States is 29.97 frames per second. The frame rate of video in most of the rest of the world is 25 frames per second. Frame rate issues can get pretty complicated when you start to talk about HD and transferring footage between different formats. We discuss frame rates for HD later in this chapter and we discuss pull-down and other frame rate transfer issues in Chapter 13, "Preparing to Edit."

Video Resolution

Each individual frame of video is composed of a series of horizontal lines that are drawn across the screen. The number of horizontal lines that fit on the screen is known as the *vertical resolution*. The vertical resolution is one of the characteristics of video that is determined by the video broadcast standards listed in Table 3.3. Some of the horizontal lines in each video frame are used to convey information that isn't part of the visible image, such as the *vertical blanking interval*—something you don't really need to worry about. For example, the vertical resolution of analog video in the United States (a.k.a. NTSC) is 525 lines, of which 480 are visible. The vertical resolution of analog video in most of the rest of the world (a.k.a. PAL) is 625 lines, of which 575 are visible. HD 1080 consists of 1125 vertical lines, of which 1080 are visible.

When it comes to image quality, you hear a lot of talk about "resolution"—especially when discussing video cameras. When speaking of resolution, people are usually referring to the *horizontal resolution*—that is, how many individual pixels (or dots) there are in each one of those horizontal lines. The vertical resolution mentioned earlier is fixed, but the horizontal resolution is variable.

Due to the way in which the human eye works, a set of alternating black and white lines, like those in Figure 3.2, will look like gray mush if the lines are small enough. Horizontal line resolution measures how many alternating black and white lines can fit in a video image before turning into an indistinct gray mass. Due to its subjective nature, horizontal line resolution is not a hard-and-fast figure: it varies according to such factors as the monitor or TV, the camera hardware, how bright the room where the monitor is, how far you are from the monitor, and how good your vision is. Some cameras, lenses, and monitors have a greater capacity for displaying distinct vertical lines, and these devices are considered to have better "resolution."

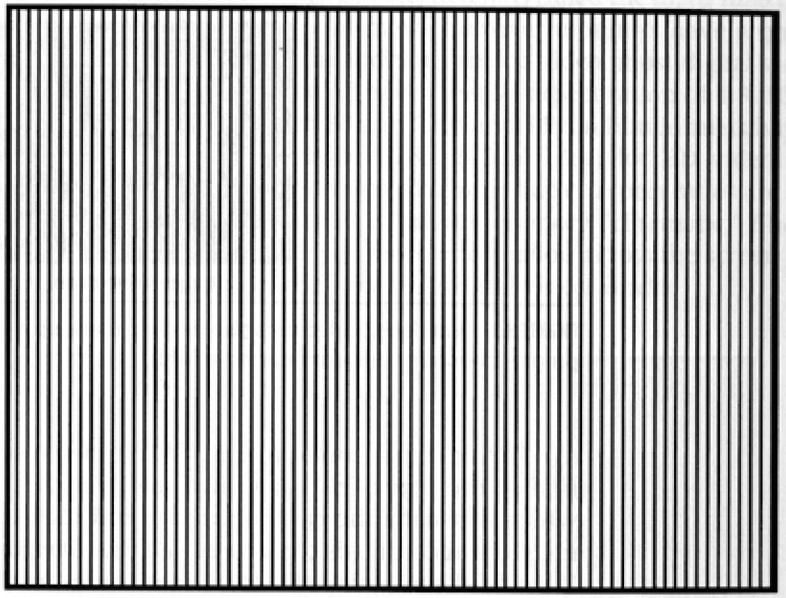

FIGURE 3.2 The black and white vertical lines in this image will look like a mass of gray if you hold the book far enough away from you.

Scanning Methods

We already mentioned that each frame of video consists of hundreds of horizontal lines. What we didn't mention is that the way that these lines are scanned across a monitor can vary: they can be *progressively scanned (p)* or *interlaced (i)*.

All of the current, analog video broadcast standards (NTSC, PAL, and SECAM) are *interlaced*. For each frame of video, your TV first displays all of the even-numbered scan lines—from top to bottom—and then goes back and fills in all the odd-numbered scan lines (Figure 3.3). Each pass across the monitor is called a *field*, and each frame of interlaced video consists of two fields. The order in which the fields are drawn can change, depending on how a videotape is recorded.

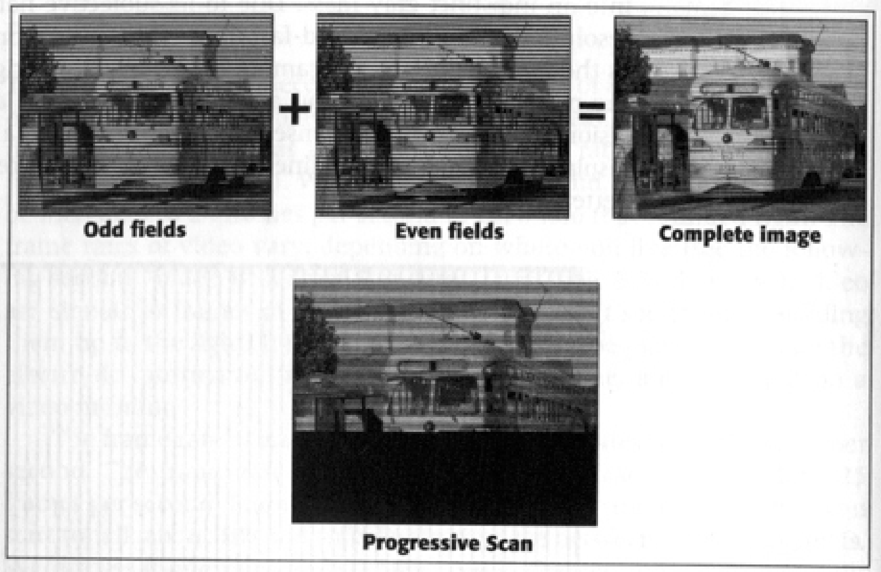

FIGURE 3.3 Interlaced video uses two fields to make up a complete frame of video; progressive scan video does not have fields.

The field that contains the odd-numbered scan lines is called the *odd field* or the *upper field* (or sometimes *field one*). If this field comes first, which is usually the case for analog and high-end digital videotape formats, the recording is considered *odd field dominant* or *upper field dominant*. If the field containing the even lines comes first, it's considered *even field dominant* or *lower field dominant* (or more rarely *field two dominant*) which is the case for the DV formats.

Know Your Field Dominance

When outputting video from rotoscoping, compositing, effects, or animation programs, you'll usually need to know which field to specify as dominant. If you're shooting with one of the DV-based formats, your footage is field two dominant.

Your computer monitor and some of the new digital television broadcast standards use *progressive scanning* to display the video image on the screen. They draw each line, in order, from top to bottom, in a single pass. Progressively scanned video has frames but no fields; the result is a cleaner-looking image. Many digital video cameras offer a progressive

scan shooting mode, which we discuss in Chapter 4, "Choosing a Camera." Digital video cameras that shoot "24p" record 24 frames per second using progressive scanning.

Digital television standards are named according to the number of lines of vertical resolution and whether they are interlaced (i) or progressively scanned (p). 1080/60i has 1080 lines of vertical resolution and uses interlaced scanning. 720/60p has 720 lines and is progressively scanned.

Native Aspect Ratio

The ratio of the width of an image to its height is called the *aspect ratio* (Figure 3.4). Television displays and most computer monitors have a native aspect ratio of 4:3, or 1.33:1. In addition, analog video, most digital video, 16mm, 8mm, and Super8 film all have a native aspect ration of 4:3. High-definition (HD) video (both 1080 and 720) and 35mm film formats have a much wider native aspect ratio, 1.78:1 (a.k.a. 16:9) for HD video and 1.85:1 for most 35mm film. Formats with wide native aspect ratios are also called *widescreen*. Typically, wider is considered more "cinematic." Shooting in a wider format lets you put more information across the screen and is a truer representation of the way our field of vision works.

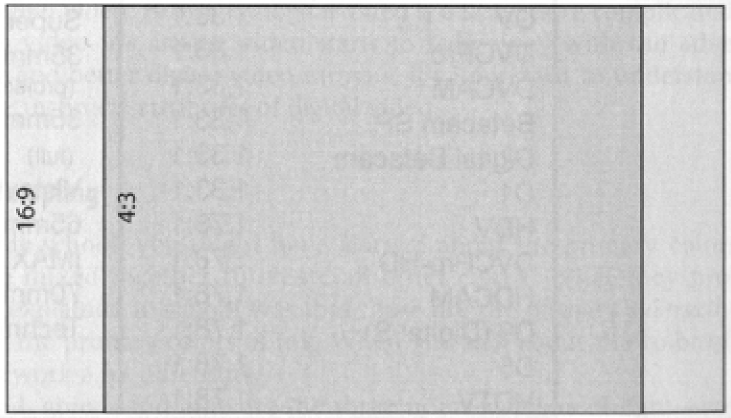

FIGURE 3.4 The larger rectangle has a 16:9 aspect ratio, while the smaller rectangle has a 4:3 aspect ratio. HD formats have a 16:9 aspect ratio, most other formats only provide a 4:3 aspect ratio.

Video and film formats that have a native aspect ratio of 4:3 can be manipulated by using special anamorphic lenses to record the image differently and then stretch it out to widescreen. It can also be manipulated by digitally cropping, or *letterboxing*, the image which makes the image look like widescreen even though it isn't *true 16:9*. We'll talk more about anamorphic lenses in Chapter 4,"Choosing a Camera," and letterboxing in Chapter 19, "Output."

Because the 1.78:1 aspect ratio of widescreen video is close to the 1.85:1 aspect ratio of 35mm film, choose an HD format with a native 1.78:1 aspect ratio or use anamorphic lenses to get a 1.78:1 aspect ratio if you're shooting video and plan to do a final transfer to 35mm film.

An Aspect Ratio by Any Other Name . . .

The 4:3 aspect ratio of television and most computer screens is sometimes referred to as a 1.33:1 ratio. This is to allow for easier comparison to other aspect ratios (Table 3.1). Similarly, 16:9 is also called 1.78:1.

TABLE 3.1 Film and Video Aspect Ratios

Video		Film	
Format	**Aspect Ratio**	**Format**	**Aspect Ratio**
Analog TV (NTSC, PAL or SECAM)	1.33:1	8mm	1.33:1
Computer screen (640 x 480 pixels)	1.33:1	Super 8mm	1.33:1
DV	1.33:1	16mm	18:13 (approx. 1.33:1)
DVCPro	1.33:1	Super 16mm	5:3
DVCAM	1.33:1	35mm (projected)	1.85:1
Betacam SP	1.33:1	35mm (full)	1.33:1
Digital Betacam	1.33:1	Vistavision	3:2
D1	1.33:1	65mm	16:7
HDV	1.78:1	IMAX	6:5
DVCPro-HD	1.78:1	70mm	2.19:1
HDCAM	1.78:1	Techniscope	2.35:1
D9 (Digital S)	1.78:1		
D5	1.78:1		
HDTV	1.78:1		

Physical Characteristics of Videotape

Videotapes themselves are limited by their physical characteristics, which include tape lengths (or run times), recording speeds, and cassette sizes.

Each videotape format has its own set of available tape lengths, although not all tape formats have tapes that are longer than 90 minutes. If

your final project is going to be more than 90 minutes, you might need to use two tapes for your master. Generally, shorter tapes are used for shooting, and longer tapes are reserved for mastering (if needed).

Just as a VHS deck supports different recording speeds to trade quality for longer recording times, many formats allow for SP or LP recording modes. For digital filmmaking purposes, always record at the highest quality mode, which is SP. Most professional cameras and decks only offer a single, high-quality recording speed.

Traditionally, professional video formats have different cassette sizes—large (therefore longer) sizes for mastering, and smaller (shorter) ones for shooting. In fact, the miniDV-size cassette is the cause of much confusion these days. All of the DV-based formats (DVCPro, DVCAM, DV, and HDV) use the small miniDV cassettes for shooting and editing. Some of these formats (DVCPro, DVCPro-HD, DVCAM, and HDCAM) also use larger tapes for shooting and editing. The consumer-oriented DV format equipment cannot use the larger-size cassettes. As a result, many people who are only familiar with the miniDV cassettes mistakenly think that "miniDV" is the tape format, when it's actually just the cassette size.

Digital Video Primer

All of the information we've discussed so far holds true for both analog and digital video. However, digital video is a little more complicated than analog video. As analog video starts to fade away with the advent of newer and better digital video formats, it's important to understand the unique technical attributes of digital video.

Color Sampling

In grade school, you might have learned about the primary colors that can be mixed together to create all other colors. What they probably never explained in school was that those are the primary *subtractive* colors, or the primary colors of ink. When you talk about the color of *light*, things work a bit differently.

Red, green, and blue are the three primary colors of light—you can create any other color of light by mixing those primaries together. However, whereas mixing primary colors of ink together results in a darker color, mixing light creates a lighter color. Mix enough ink and you eventually get black, but if you mix enough light, you eventually get white.

Video cameras and televisions create color by mixing the three primary colors of light. In addition to red (R), green (G), and blue (B), the video signal has another element, which is lightness, or *luminance* (Y). The camera sees each of these four elements as separate, continuous analog waves.

While analog cameras store an analog representation of these waves on videotape, digital cameras first convert the waves into numbers, through a process called *sampling*. Each wave is broken into a series of bits that can be stored on the digital tape as 0s and 1s. The denser the samples, the better the perceived quality of the image (Figure 3.5).

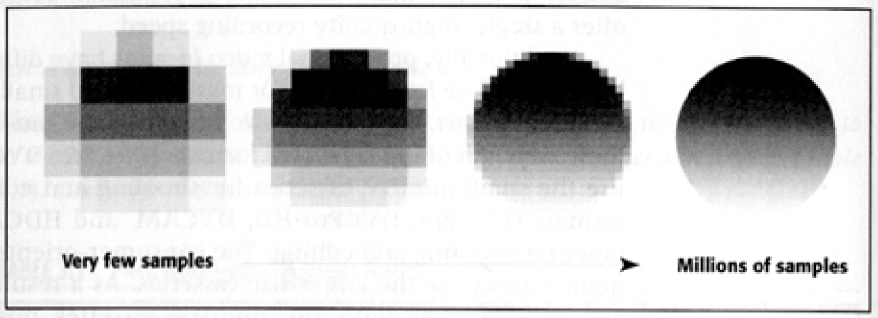

FIGURE 3.5 As the number of samples increases from left to right, the image becomes clearer.

When a digital camera samples an image, the degree to which it samples each primary color is called the *color sampling ratio*. A fully uncompressed video signal—also known as RGB color—has a color sampling ratio of 4:4:4. The first number stands for the luminance, or *luma*, signal (abbreviated y'), and the next two numbers stand for the color difference components (Cb and Cr), which together add up to the full chroma signal. 4:4:4 means that for every pixel, four samples each are taken for the luma signal and the two chroma signals.

To make the resulting data smaller, and therefore more manageable, about half of the color information is discarded. The highest quality digital video formats throw out half of the color information. These formats have a color sampling ratio of 4:2:2, which means that for every four luma samples, there are two color difference complete samples. The human eye is more sensitive to differences in light and dark (luminance) than to differences in color (chrominance). In theory, the discarded color information is detail that the human eye cannot perceive, so it's worth throwing it out for the sake of saving storage space.

The color sampling ratio of most HD formats is 4:2:2. Some HD formats, like HDV, use 4:2:0 color sampling which reduces the color information of 4:2:2 by 25 percent. Digital PAL formats also use 4:2:0 color sampling. DV formats use 4:1:1 color sampling, half the color of 4:2:2, which is an amount of color reduction that is considered visible to the viewer.

Compression

To fit more data onto a tape and to better facilitate digital post-production, most digital video formats use some type of data compression. This compression process can greatly affect the quality of your image. Uncompressed video has a compression ratio of 1:1, while compressed video can range anywhere from 1.6:1 to 10:1. Video compressed at a 10:1 ratio has 10 percent of its original data. Although throwing out 90 percent of your image data might sound a little scary, rest assured that modern compression schemes can deliver excellent results, even with very high compression ratios. In fact, video DVDs use a fairly extreme level of MPEG-2 compression, showing that heavily compressed video can still be commercially viable.

As explained earlier, a video format with a 4:2:2 color sampling ratio compresses the video signal by discarding half of the color information. However, this discarded information is not visible to the human eye, so this compression is considered *lossless*.

When the color sampling rate dips to 4:1:1 or 4:2:0, the information that has been discarded *is* visible to the eye, so this compression is considered *lossy*. However, the image quality of 4:1:1 and 4:2:0 video, such as DVCAM, DVCPro, and HDV, is still considered excellent.

Compression can also occur when you capture media through a video card (whether it was originally shot with an analog or digital camera) and when you render or output digital video files on your computer.

Bit Depth

Digital video usually has a bit depth of either 10 or 12 bits. Digital devices speak in ones and zeros (two "digits," hence the term "digital"). A single one or zero is called a *bit*, and a group of bits can be grouped together to represent a single number. When it comes time to assign a numeric value to the color of a particular pixel, then the number of bits that are used to make up that number becomes something of an issue. With more bits, you can record a greater range of numbers, which means you can represent more colors. This *bit depth* of a particular format refers to how many bits are used to represent the color of each pixel.

Basically, it's just the same as boxes of crayons. If you only have eight crayons, the pictures you draw don't have nearly as much color detail and variation as if you have a box of 64 crayons. Similarly, if you only have 8 bits available for representing the color of each pixel, you don't have nearly as much color detail and variation to work with as if you have 10 or 12 bits per pixel.

Bit depth will probably never be a make-or-break factor in your format choice, but it's still worth noting it when comparing specs. For blue screen work, or other compositing tasks, or for projects where you really want to be able to manipulate the color of your final image, a format that uses a higher-bit depth will allow higher-quality, cleaner adjustments.

CODECs

Video and audio data must be compressed before they can be played and stored by your computer (unless you have special hardware for playing uncompressed video). The software that handles this task is called a *CODEC*, short for COmpressor/DECompressor. CODECs are built into the hardware in a digital video camera or video card. In your computer they are usually software-based and managed by the video architecture—QuickTime, Windows Media, RealMedia, and so forth—or by the digital video editing application that you are using (Figure 3.6).

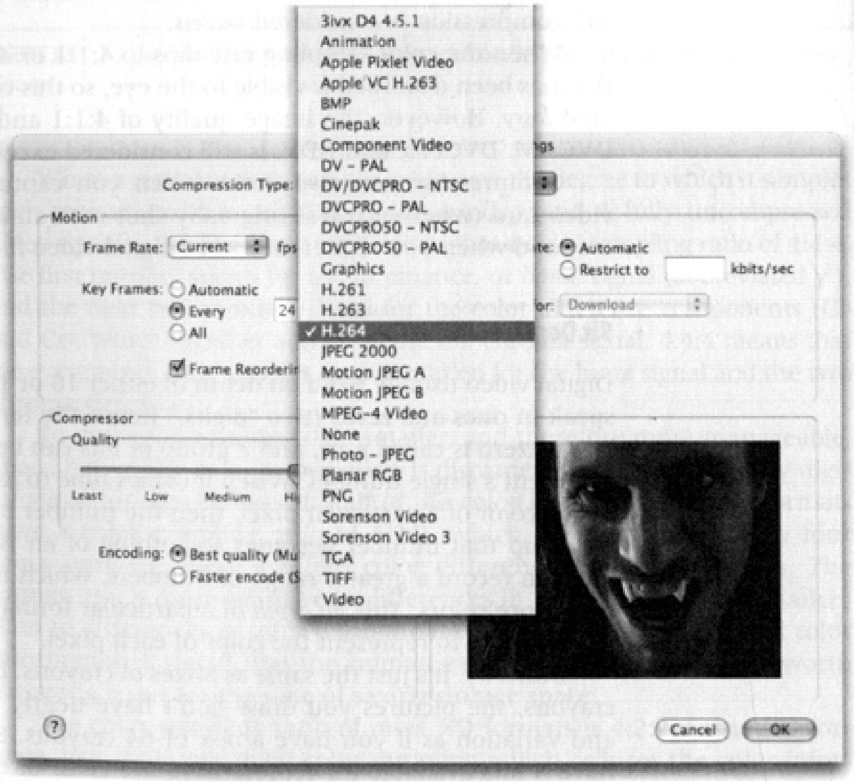

FIGURE 3.6 The standard QuickTime Export dialog presents a choice of many different CODECs, allowing you to precisely control how your video will be compressed.

If you have ever created a QuickTime movie on your computer, you have probably been presented with a choice of the different compression options that QuickTime provides. Video, Sorenson, Animation, Cinepak, MPEG-4, H.264, and many others are all CODECs that are used to compress video for storage, and then to decompress it for playback.

Different CODECs are used for different purposes. You'll use high-compression/lower-quality CODECs for Web or CD-ROM delivery, and low-compression/higher-quality CODECs for higher-quality playback. Other CODECs are used if you are using special video hardware. With newer compression technologies such as H.264 and MPEG-4, the compression/quality ratio has greatly improved. Highly-compressed Web video is increasingly indistinguishable from lower compression, high data rate video.

CODECs can be either lossy or lossless; that is, they either degrade the image quality or leave it unaffected. Many CODECs take longer to compress than they do to decompress (these are called *asymmetrical*). Most of the CODECs that ship with QuickTime are asymmetrical. For example, although it might take hours to compress a QuickTime movie using Sorenson or MPEG, the computer can decompress it and play it back in real-time. When you compress a piece of video, QuickTime hands the video stream to your chosen CODEC, which performs the compression calculations, and then writes out the compressed information to a file. Similarly, when you are ready to play back, QuickTime reads the compressed data and hands it to the appropriate CODEC, which decompresses it into video that the computer can display.

There are many different CODECs. Here are some that are important to digital filmmakers (some of which are shown in Figure 3.7):

DV-based editing applications and video boards designed to work with FireWire-based DV video (Digital8, DV, DVCAM, or DVCPro) use the hardware DV CODEC in the camera or video deck to compress and decompress the video on a videotape. After you transfer that media to your computer and use it in an editing application, a software DV CODEC is used to decompress the video for playback and to compress it when you're ready to record onto videotape. Some applications offer a proprietary software DV CODEC that offers more control and extra features than the stock DV CODEC used by your operating system.

DCT-based compression is a hardware CODEC used in some professional quality digital video cameras and digital video decks (with the exception of the DV formats mentioned earlier). Digital Betacam uses DCT-based compression. DCT-based compression is a hardware-only CODEC, so it isn't used in any editing applications.

MJPEG (Motion-JPEG) is a CODEC that provides several quality levels, ranging from very lossy to not noticeably compressed. Most high-quality video boards that offer digital and analog component I/O, such as Avid Meridien use MJPEG CODECs.

MPEG-2 is a CODEC that was originally developed for full-frame broadcast-quality video. DV video boards that offer analog composite I/O usually use MPEG-2 to compress and decompress analog video. MPEG-2 is also used for DVDs and to broadcast certain types of Digital Television (DTV). Newer digital video formats, such as D-VHS, MPEG-IMX and HDV, use MPEG-2 encoding. As DVD is now a standard delivery format, you'll probably spend a fair amount of time compressing videos as MPEG-2.

Uncompressed digital video still involves a CODEC, even though it's technically not compressed. That's because 4:2:2 digital video is still compressed down from 4:4:4 video; however, since this compression is invisible to the human eye, or "lossless," it's considered "uncompressed."

HD (High Definition) video is "uncompressed" (see above) but the files are so large that they are cumbersome to work with in post-production. As a result, many companies that make HD editing systems have special HD CODECs that make file sizes more manageable when working in HD. Avid's DNxHD is an example of one of these special proprietary HD CODECs.

HDV is the new "consumer" HD format. With its 25 Mb/sec data rate, HDV is poised to become the DV of the high-def world video. However, at the time of this writing, not all editing programs support HDV, though major applications such as Apple's Final Cut Pro HD and iMovie have been updated to work with HDV. Some applications, though, still depend on an intermediary CODEC. By the time you read this, all this might have changed. Because this is a new format, it's important to investigate your entire production workflow, to make sure that the necessary CODECs are available for your chosen software.

H.264 is just beginning to develop a presence. An extremely high-quality CODEC that has been chosen as the CODEC for HD-DVD and BluRay (the two specifications competing to become the replacement for the current DVD standard), H.264 has strong support from Apple in the form of a high-quality QuickTime implementation. For Web or final delivery, H.264 may prove to be your CODEC of choice in the near future.

Web-oriented CODECs such as *Sorenson, RealVideo 10, WMV9 (Windows media), Spark, MPEG-1,* and *MPEG-4* are designed to create very small file sizes for better distribution over the Web. For the most part, they aren't used in cameras and aren't always native to the non-linear editing systems discussed in this book. We discuss outputting video for the Web in Chapter 19, "Output."

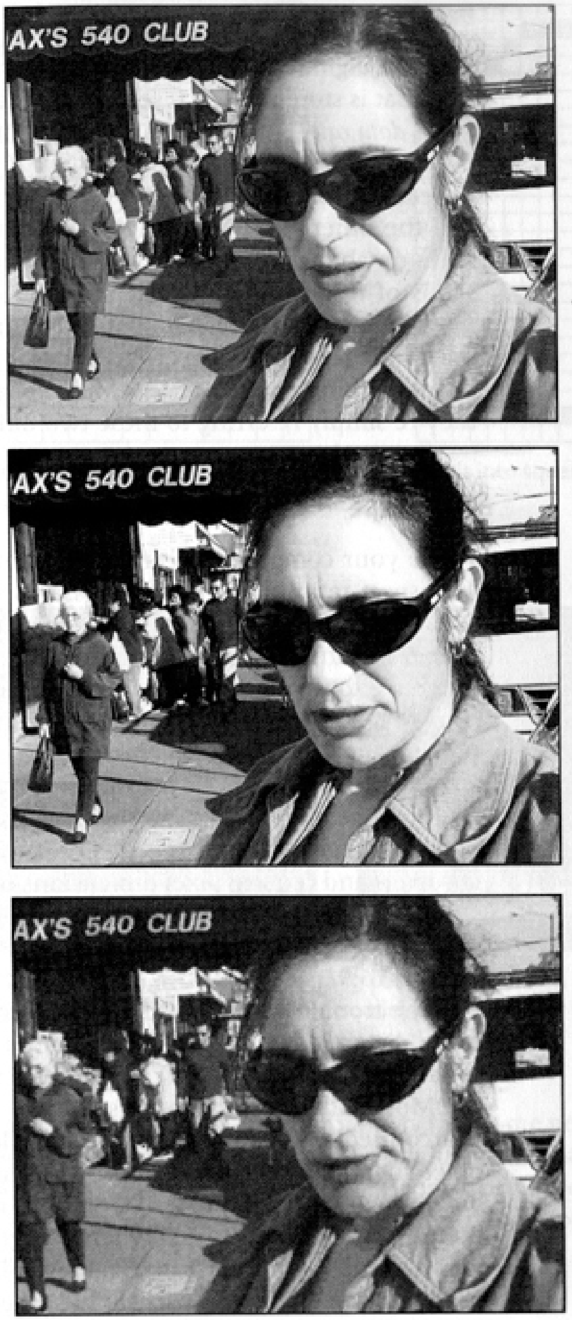

FIGURE 3.7 The same image compressed with, from left to right, DV compression, Sorenson compression, and Cinepak compression. As you can see, image quality varies a lot between different compression algorithms.

Data Rate

When a digital video camera records an image, the amount of information that is stored for each second of video is determined by the video format's *data rate*. For example, the DV format has a data rate of 25 megabits per second (Mbps). This means that 25 Mbps of information are stored for each second of video. (If you factor in audio, timecode information, and the other "housekeeping" data that needs to be stored, DV actually takes up about 36 Mbps.) DVCPro50, on the other hand, stores about 50 Mbps of information for each second of video. As one would expect, more information means a better picture, and the 50 Mbps data rate is one of the reasons that DVCPro50 has higher quality than DV. If you hear people talking about the "25 Mbps formats" or the "50 Mbps formats," they're simply referring to these two different categories of formats.

Pixel Shape

While your computer screen and a frame of video might have the same 4:3 aspect ratio, they won't necessarily have the same pixel dimensions because, unfortunately, not all video formats use pixels of the same shape. Yes, in addition to all of the other concerns and complications, you also have to think about the shape of the individual pixels! Pixel shape is primarily a concern when dealing with graphics and special effects in post-production.

Computer displays—as well as many video formats—use square pixels. This means that a screen with a resolution of 640 × 480 pixels will have an aspect ratio of 4:3. DV, DVCAM, and DVCPRO all use rectangular pixels and require pixel dimensions of 720 × 480 pixels to achieve the same 4:3 aspect ratio. But wait, there's more—the two most popular HD formats, 720 and 1080, use square pixels to create images with an aspect ratio of 16:9.

The trouble with the difference in pixel shapes is that images will become distorted when you move from a rectangular-pixel format to the square-pixel format of your computer screen (Figures 3.8a through d).

Most software applications let you specify the pixel shape of your source media. If you're planning on a lot of graphics or special effects, pixel shape can become more of a hassle. If you've already created a bunch of graphics at 640 × 480 on your computer screen and don't want them horizontally distorted when you go out to tape, you might want to pick a format with square pixels. In Chapter 17, "Titling and Simple Compositing," we discuss how to handle differing pixel shapes when working with titles and other graphic elements.

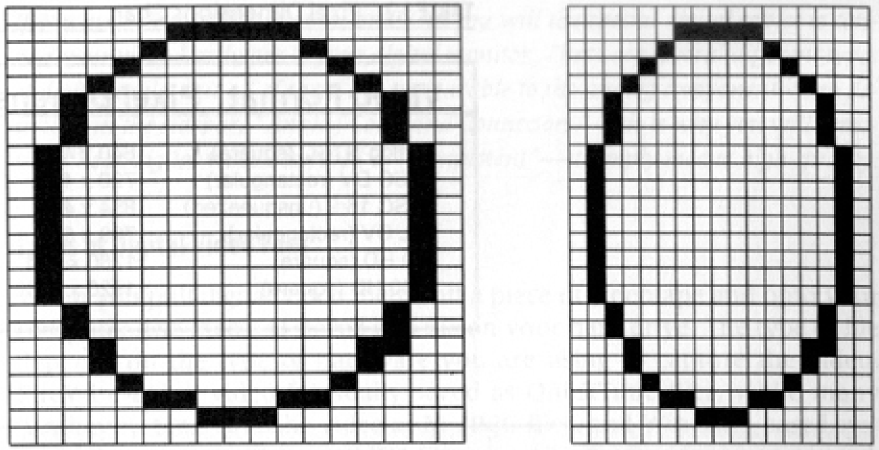

FIGURE 3.8 **(a)** Converting a circle built with rectangular pixels into square pixels. . . **(b)** results in an ellipse.

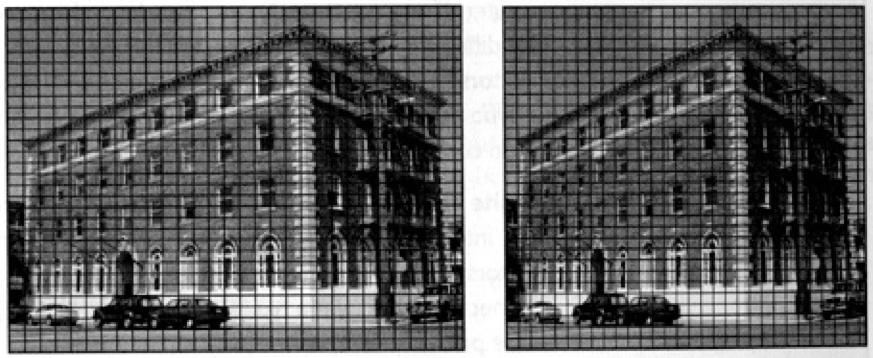

FIGURE 3.8 **(c)** Therefore, images shot with rectangular pixel cameras… **(d)** can look distorted and squished when displayed on your square-pixel computer monitor.

Incidentally, *pixel dimensions* are another way that some people describe the resolution of an image. Instead of saying the image has 480 lines, they say it has 640 × 480 pixels. (Each line of horizontal or vertical resolution has a width of one pixel.) Table 3.2 lists the pixel dimensions of various types of media.

TABLE 3.2 Pixel Dimensions Chart

Video Format	Pixel Dimensions
Analog NTSC (square)	640 x 480
NTSC DV (rectangular)	720 x 480
NTSC 16:9 (unsqueezed)	854 x 480
PAL DV (rectangular)	720 x 576
720 HD (square)	1280 x 720
1080 HD (square)	1920 x 1080

ND CONNECTORS

Even though your video hardware might be digital, many digital formats use analog connections to connect to monitors and often to other types of decks or your computer. There are three types of analog video connections, and each treats color differently. (See Chapter 12, "Editing Hardware," for more on cables and connectors.) Luckily, they are easily identified by the hardware associated with each type of analog signal. In ascending order of quality, the three types of analog video connectors are:

Composite video bundles all of the luminance and chrominance information into one signal (i.e., a composite signal). Composite video connectors typically attach to a deck or monitor through one RCA or BNC connector. If you own a typical consumer VHS deck, the connectors on it are probably composite.

S-video (a.k.a. Y/C video) breaks the video signal into two parts: luminance and chrominance. S-video yields a signal quality that is better than composite, but not as good as component video. S-video connects using a proprietary connector. Many laptops come with an S-video output to allow display on a TV monitor.

Component video divides the video signal into four different parts—YRGB—where Y = Luminance; R = Red; G = Green; and B = Blue. This results in a higher quality signal than composite or Y/C video. Component video typically connects using three separate BNC connectors.

If you are using an HD monitor or TV set you will use special digital cables to connect your video hardware to your digital monitor. There are several different types of digital cables but all of them are comparable to the analog component video described in the sidebar, "Analog Color and Connectors." This is why you will sometimes hear digital video described as "component"—it simply means high-quality.

Types of Digital Video Files

When you pull digital video media off a piece of videotape and onto your computer, the media is stored in a file on your hard drive. The type of file depends on the type of hardware you are using to capture the video. FireWire-based video is usually saved as QuickTime files, while many turnkey systems save the video as M-JPEG files, and Windows-based systems often save as AVI or WMV9 files.

If you're capturing from a FireWire-based DV camera, then your video will already be compressed using whatever CODEC your video format uses. So, if you're capturing from a DV camera or deck, then the resulting file on your computer will be DV-compressed—the camera will have performed this compression when you shot the footage.

If you're capturing using a digitizing board in your computer, then your resulting files will be compressed using whatever CODEC your digitizing hardware uses, usually Motion JPEG or MPEG-2. Although files can be converted from one format and one compressor to another (a process called *transcoding*), you must be very careful not to add extra compression during these conversions.

Video Broadcast Standards

Videotape recording was invented in the late 1950s as a way of keeping archived copies of broadcast TV shows. (Prior to that, television was "live" and simply sent straight from the studio camera into the airwaves, much like radio.) As a result, the technology of video recording is intrinsically tied to the technology of television broadcasting and this link is still evident fifty years later, even though video has diversified far beyond broadcast television.

TV broadcasting and video recording developed differently in different parts of the world. Each of the three areas that were early adopters of television—North America, France, and the rest of western Europe—came to have a different set of rules that defined the qualities of a broadcast television signal. These *video broadcast standards* were designed to regulate and standardize the quality of a television broadcast. Other parts of the globe soon took on one of the three broadcast video standards based on which area they were politically, culturally, or geographically aligned with at the time. The different video standards have different frame rates, color characteristics, aspect ratios, and image resolutions, among other things (Table 3.3).

Fifty years ago, everything was analog, including the technology described by each of the three video standards. The analog broadcast standard in North America and Japan is called *NTSC* and has a frame rate of 29.97 fps. The analog broadcast standard in most of Europe, South America, and Asia is called *PAL* and has a frame rate of 25 fps. The rest of the world, which includes France, Russia, parts of Asia, Africa, and the Middle East uses a standard called *SECAM*, which also has a frame rate of 25 fps. Recently, a digital standard has been added to the list, DTV (Digital Television). DTV is meant to eventually replace NTSC, PAL, and SECAM.

Just as digital media is more flexible than analog media, the DTV standard is much more flexible than the three analog standards. There are eighteen variations of the DTV standard and they fall into three subcategories based on resolution:

- **480** (a.k.a. Standard Definition Television or SDTV) is the digital upgrade of the analog NTSC standard.
- **720** is true High Definition Television (HDTV) standards, offering very high-quality digital signals.
- **1080** is also true HDTV, offering higher image resolution than 720.

Just to make things a little more complicated, each subset of the DTV standard has several different possible frame rates (Table 3.3). (Unlike the analog video broadcast standards, which each have only one frame rate.) These multiple frame rates allow the DTV standard to encompass both analog NTSC video and analog PAL video and allow for better playback of film (which has a native frame rate of 24 fps). We'll talk in depth about these different HD standards and their frame rates in the HD section later in this chapter.

Video standards are intrinsically tied to television and the type of TV sets (or video monitors) that are sold in a particular country. Computer monitors are not limited by the same technical constraints and can handle any of the standards listed in Table 3.3. If you have, for example, a PAL project and you want a distributor in New York City to watch it, you can make a DVD (avoiding any regional encoding) and they'll be able to watch it on their computer.

35mm film has an aspect ratio of 1.85:1 when projected.

TABLE 3.3 Changing Your Video Standard

Standard	NTSC	PAL/SECAM	480 SD	720 HD	1080 HD	Film
Frame rate(s)	29.97	25	23.976/24 25 29.97/30	23.976/24 25 29.97/30 59.97/60	23.976/24 25 29.97/30	24
Fields	2	2	0 or 2	0 or 2	0 or 2	0
Vertical res.	480	576	480	720	1080	n/a
Scanning	Interlaced	Interlaced	Interlaced or Progressive	Interlaced or Progressive	Interlaced or Progressive	n/a
Aspect ratio	1.33:1	1.33:1	1.33:1	1.78:1	1.78:1	1.85:1

It is possible to convert from one standard to another through expensive tape-to-tape conversions, cheap but shoddy-looking tape-to-tape conversions, or time-consuming software-based conversions. In other words, it's something you'll wish to avoid.

Why should you care about standards? It used to be that you would simply choose the standard that's right for the geographic region in which you live. But now you need to choose between the analog standard for your geographic region and DTV. DTV is a better choice if you are shooting on video and plan to later transfer your footage to film.

24p is used when shooting video footage that will eventually be transferred to film. It is also used when transferring projects shot on film to HD for broadcast. Some argue that shooting 24p results in more film-like footage even if it is never transferred to film. Before the advent of 24p, the PAL standard (at 25 frames per second) was a popular choice for video footage that would eventually be transferred to film.

Audio Basics

There's a saying that sound is 50 percent of a movie. Luckily, it's not nearly as complicated as video.

Mono, Stereo, and Surround Sound

Mono sound consists of one channel (or track) of audio. Almost all production sound is mono. If you record a line from a microphone into a MiniDisc recorder, you are recording mono sound because most microphones are not stereo microphones. Even if you record onto both channels of the MiniDisc recorder, you're still not recording separate left and right channels. Instead, you're simply recording the same mono signal on the recorder's two channels.

If you patch a lavalier mic into channel one and let the camera's built-in mic record to channel two, you are still recording in mono. Granted, you are creating two different mono recordings of the same thing, but the two different channels will sound very different due to the quality of the microphones, and their positioning. In no way do they add up to a stereo recording.

Stereo sound consists of two channels of audio mixed together in a special way: one channel is balanced somewhat to the left, and the other is balanced somewhat to the right. When added together, stereo tracks give a more three-dimensional feeling to the recording.

The only type of production sound that is typically recorded in stereo is music. Stereo sound is usually reserved for the final mix of a soundtrack for a film or TV show. The built-in microphones on most camcorders are stereo, but these mics are usually not suitable for serious production work. You can, of course, buy or rent stereo mics to attach to your camera, and these units will record separate left and right channels directly to tape, however this is not necessary if you are primarily recording dialog.

For theatrical release films, DVDs, and HD television, surround sound mixes are the norm. Surround sound mixes generally consist of 5.1 or 7.1 channels of sound that correspond to the position of speakers in the theatre. They give an even more intense three-dimensional feeling to the environment than do stereo mixes. Mixes and surround sound are discussed more thoroughly in Chapter 15, "Sound Editing" and also in Chapter 19, "Output."

Audio Sampling

Just as waves of light are sampled to create digital video, waves of sound are sampled to create digital audio (Figure 3.9). The rate at which the audio is sampled can vary, and, as with a video or still image, the higher the sampling rate, the better. Professional digital audio is sampled at either 44.1 kHz (CD quality) or 48 kHz (DAT quality), although there is little appreciable quality difference to the listener. Many lower-end cameras offer the option to record audio at 32 kHz, which sometimes allows you to record four channels of sound instead of two. However, if you're serious about your production, it's better to have two good channels of audio than four mediocre channels. As a rule, never record at less than 44.1 kHz—audio files aren't that big so you won't save much space by skimping during production. If you're working with one of the digital video formats, including DV, stick to the native 48 kHz sampling rate.

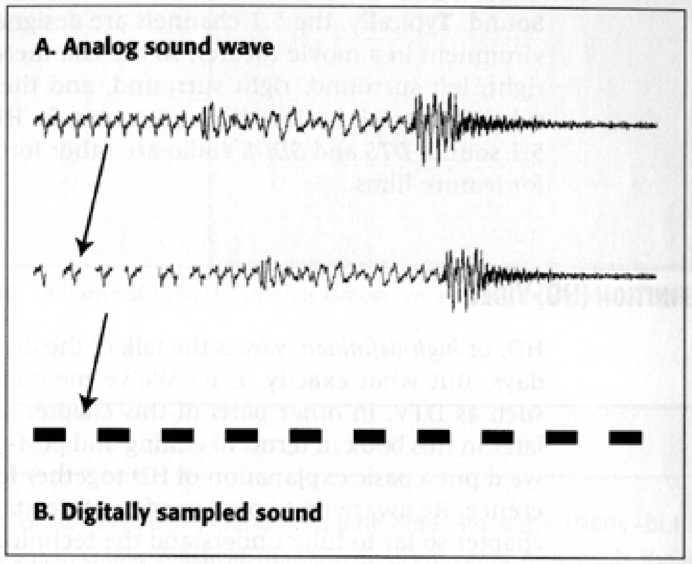

FIGURE 3.9 An analog sound wave (a) is broken into small samples, resulting in a digital audio file (b).

Types of Digital Audio Files

Once you capture audio onto your computer's hard drive, it is stored in a file. Audio is usually stored in one of several standard formats: *WAV, AIFF*, or *SDII*. These are all uncompressed formats, and all fall under the category of *PCM* audio. (You might not ever encounter the term PCM, but if you do, just think "uncompressed, high-quality audio.")

Most likely, when you're working with digital audio on your computer, you'll be using WAV files (for Windows computers) or AIFF files (for Macs). As long as you maintain the same sampling rate, conversions between different PCM audio file types are lossless. *MP3* is a highly compressed audio format that offers very small file sizes and good sound quality, despite the compression. When compressed at 192K or better, MP3 files are indistinguishable from CD audio. *MP4* (sometimes called *MPEG-4* because both MP3 and MP4 are part of the MPEG video specification) is a successor to MP3 that offers better compression without degrading quality. A 128K MP4 file delivers 160K MP3 quality in a much smaller space. AAC format (which you might have encountered in downloads from the iTunes Music Store) is just an MP4 audio file with a special digital-rights-management (DRM) "wrapper." (For more information about editing with MP3 and MP4 files, see Chapter 13, "Preparing to Edit.")

Dolby AC-3 audio consists of 5.1 channels of Dolby Digital Surround Sound. Typically, the 5.1 channels are designed to create a surround environment in a movie theater, so the channels are laid out as left, center, right, left surround, right surround, and the .1 channel is an optional subwoofer track for low-frequency sounds. HD video formats offer AC-3 5.1 sound. *DTS* and *SDDS* audio are other forms of surround sound used for feature films.

l (HD) Video

HD, or *high-definition video* is the talk of the digital filmmaking world these days. But what exactly, is it? We've mentioned HD and related topics, such as DTV, in other parts of this chapter, and we also talk about HD later in this book in terms of editing and post-production, but we thought we'd put a basic explanation of HD together for you in one place as a reference. Be aware that you'll need to understand all of the content of this chapter so far to fully understand the technical aspects of HD.

HD is a tricky thing to discuss because the term itself does not actually reference any particular format. There are loads of formats that can sport the HD moniker because, in the end, anything with higher-resolution than standard definition PAL video can be considered HD. Therefore, HD runs the gamut from affordable systems that record to inexpensive miniDV tapes to extremely expensive systems that record directly to hard drives.

However, when digital filmmakers talk about shooting HD, they're talking about one of the two DTV subsets: *720* and *1080*.

- **720** has a resolution of 1280 × 720 (Figure 3.10) and is always scanned progressively. It supports the following frame rates: 23.976p, 24p, 25p, 29.97p, 30p, 59.94p, and 60p. It has a native aspect ratio of 16:9 or 1.78:1.
- **1080** has a resolution of 1920 × 1080 (Figure 3.10) and can be scanned progressively or interlaced. It supports the following frame rates: 23.976p, 24p, 29.97p, 30p, 50i, 59.94i, and 60i. It has a native aspect ratio of 16:9 or 1.78:1.

720 and 1080 both have advantages and disadvantages. Each frame of 1080 is more than double the size of a frame of 720. However 720 offers the option of 60 frames per second, which doubles the information of the highest 1080 frame rate, 60 fields per second (or 30 fps).

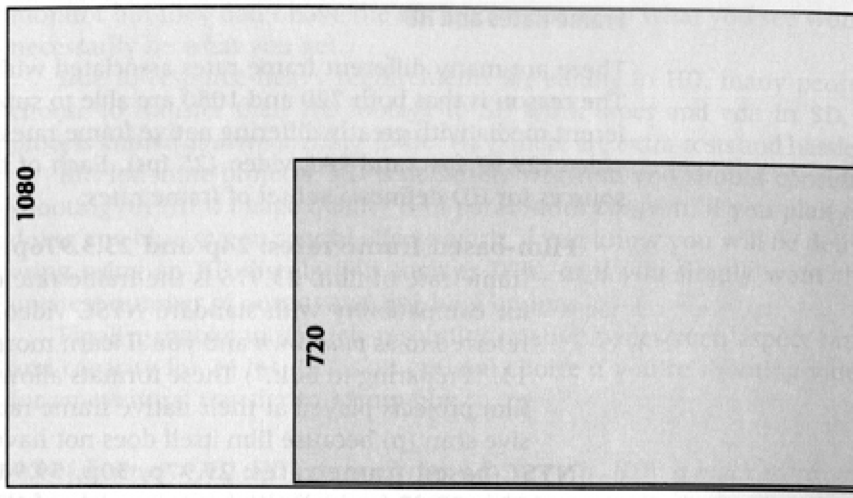

FIGURE 3.10 A frame of 1080 HD video is almost twice as big as a frame of 720 HD video.

HD TERMINOLOGY

The idea of HD has been around for a long time—since the 1960s—but it has only become a viable, practical, medium in recent years. As a result, the terminology is quite new and still in the process of refinement. Here is a guide to the way people are talking about HD.

The various types of HD video are usually described by three things: their resolution, whether they are interlaced or progressively scanned, and their frame rate. *720/24p* (or sometimes *720p24*) is HD video with a resolution of 1280 x 720 and a frame rate of 24 progressively scanned frames per second. *1080/60i* (or *1080i60*) is HD with a vertical resolution of 1920 x 1080 and a frame rate of 60 interlaced fields per second. Because 1080/60i is probably the most widely used of the 1080 HD configurations, it is often simply called *1080i*. Similarly, 720/60p is often referred to as *720p*. In this book, we use the full description (1080/60i) in order to avoid confusion. We use *720* and *1080* to refer to the entire range of frame rates sharing those resolutions respectively.

With HD video, interlaced video is described by the number of fields instead of frames. 1080/60i has 60 *fields per second*. Since two interlaced fields of video add up to one frame of video, the frame rate is still 30 frames per second—60i is just a different way of describing the same thing and letting you know that it's interlaced.

Frame Rates and HD

There are many different frame rates associated with 720 and 1080 HD. The reason is that both 720 and 1080 are able to support a variety of different media with greatly differing native frame rates: film (24 fps), NTSC video (29.97 fps), and PAL video (25 fps). Each of these three potential sources for HD defines a subset of frame rates:

Film-based frame rates: 24p and 23.3.976p. 24 fps is the native frame rate of film. 23.976 is the frame rate of film compensated for compatibility with standard NTSC video. (This translation is referred to as *pull-down* and you'll learn more about it in Chapter 13, "Preparing to Edit.") These formats allow for the broadcast of film projects played at their native frame rate. Both are progressive scan (p) because film itself does not have fields.

NTSC-based frame rates: 29.97p, 30p, 59.94i, 60i, 59.94p, and 60p. 29.97 fps is the native frame rate of NTSC video. With native HD video, the NTSC frame rate can be rounded up to an even 30 fps. As a result, there are three pairs of frame rates: 29.97p and 30p are the progressively scanned versions of standard NTSC and 59.94i and 60i are the interlaced versions. 59.94p and 60p provide higher-quality video by doubling the number of frames in a second of video. They are only available in 720 HD.

PAL-based frame rates: 25p and 50i. The native frame rate of PAL is 25 frames per second. 25p is the progressively scanned HD frame rate for PAL material and 50i is the interlaced version.

Why 29.97? When NTSC video was first standardized, all television was black and white (or more correctly, monochrome, a "black and white" TV can display far more tones than just black or white) and had a frame rate of 30 fps. When color technology was added, broadcasters and the FCC needed to figure out a way to differentiate color video from black and white. The solution? Slow the frame rate of color video down by 1/1000th of a percent (.001). That way, existing monochrome TV sets could continue to pick up the monochrome 30 fps signal and new color TV sets could pick up the 29.97 fps color signal.

HD Pros and Cons

A frame of HD video contains more pixels than a frame of analog video. As a result it requires more disk space, as well as hard drives and cabling that are capable of handling very high data rates (sometimes over 1000 Mbps), and lots of computer processing power. In addition, to view true HD footage, you need an HD display, which can cost several thousand dollars. Computer monitors (CRT or LCD) can substitute for a real HD

monitor but they don't have the same color space, so what you see won't necessarily be what you get.

Due to resource-heavy requirements for editing in HD, many people choose to transfer their HD footage to SD work tapes and edit in SD, a process known as *downcoverting*. Either way, there are extra costs and hassles.

But for some projects, HD is definitely worth it: you should consider shooting on HD if image quality is of paramount concern, if you plan on doing any blue screen special effects work, if you know you will be delivering using an HD distribution such as DTV, or if you simply want the greatest number of output and finishing options.

Finally, thanks to its high-resolution, native widescreen aspect ratio and capacity for 24 fps, HD is an optimal choice if you're shooting video for an eventual transfer to 35mm film.

When it comes to HD, HDV is the exception to the rules. HDV is much more compressed than the other HD formats, resulting in a lower quality image. As a result, it also has a low bit-rate (about 25 Mbps) which means it can be transferred or captured via FireWire. HDV uses the same color space as SD video (ITU-R BT.601), as opposed to the color space of the other HD formats (ITU-R BT.709).

Choosing a Format

Now that you're informed about video and audio technology, it's time to decide on a videotape *format* for your project.

The way in which the signal is recorded on a piece of video can vary greatly, and each of these variations is called a *format*. VHS is a consumer-grade videotape format, as are DV and Digital8. Professional videotape formats include DVCAM, DVCPro, Betacam SP, Digital Betacam, MPEG-IMX, and the HD (high-definition) formats: HDV, HDCAM, DVCPro-HD, D5-HD, and D9-HD.

Formats exist independently of the broadcast standards mentioned earlier; in other words, you can shoot PAL DVCAM or NTSC DVCAM. However, only HD format cameras can shoot 1080 or 720 DTV. The difference between the formats lies in the hardware in the camera (or video deck), and the videotape stock. HD cameras typically shoot 1080 or 720 but not both. In addition, they may not offer all the possible frame rates defined by the DTV specs for 720 and 1080. For a detailed list of the different existing videotape formats and their technical specifications, see videotape formats.pdf in the Chapter 3 folder on the companion DVD.

ON THE DVD

The digital video world has become increasingly complicated over the last few years as more and more hardware companies have released more and more formats (Figure 3.11). Luckily, manufacturers often make the new formats backward compatible with the older formats that they are based on: MPEG-IMX is a newer digital version of Betacam SP that is backward compatible with both Betacam SP and Digital Betacam. You can expect the number of formats to continue to grow as digital video technology continues to improve. Although the selection might be confusing, the great variety of formats provides an advantage to the digital filmmaker: As you balance costs against image quality, you're likely to find that you have several format options that are appropriate for your project.

FIGURE 3.11 A quick look at the Sony family of tape stock gives you a good idea about the number of different recording formats on the market today.

RECORDING WITH P2

In addition to all of these tape formats, Panasonic's P2 tapeless, direct-to-disc format is beginning to get some traction. Though tape is relatively inexpensive, easy to find, and portable, it's also fairly fragile and is somewhat inconvenient to work with—you must digitize or capture all of your tape before you can start editing. P2 is a variant of Panasonic's DVCPro specification that records directly to tiny hard drives that can be inserted in P2-compatible cameras (Figure 3.12), similar to the flash media cards that are used with digital still cameras. With P2, you don't have to hassle with capturing and because hard drives are a little more weather-resistant than tapes, you don't have to worry as much about shooting in extreme conditions.

Like DVCPro, P2 is primarily aimed at electronic newsgathering, where production deadlines are tight and having to digitize or capture footage is not always possible. Such short deadlines are usually not an issue with feature film production, but if you've decided to shoot DVCPro format for quality or compatibility reasons, then P2 might be a convenient option to consider.

FIGURE 3.12 The Panasonic AJ-SPX800 camcorder records directly to a P2 disk.

If you already own—or have access to—equipment that you plan to use for your production, then your format choice has been made by default. However, it's still important to understand the workings of each format so that you're aware of any limitations. Also, just because you've decided to shoot on one format, doesn't mean you won't use other formats during production. From creating VHS copies for test screenings and promotion, to dubbing high-end HD camera masters to lower-end DVCAM worktapes, you may end up using two or three formats before your final project is completed.

Delivery Is Everything

The delivery medium is one of the most important considerations when choosing a format for shooting. Before you decide on a format, it's crucial to know what your end product is going to be. A projected feature film? A corporate presentation on videotape? A Webcast? Choosing the right format now can save you time and lots of money in tape stock and transfers later on.

Web/Multimedia

The compressed video that is used for Web and multimedia projects may be of lesser quality, but this doesn't mean that you should just get that old

VHS camcorder out of the closet and start shooting. These days, Web video is good enough to reveal many of the artifacts that low-quality formats like VHS suffer from. Similarly, if you're planning on night shoots or special effects such as blue-screen compositing, you will need a higher-quality format. And, shooting better quality affords you the option of repurposing your footage later. Even though the low-quality of streaming Web video means you could get away with consumer VHS or Hi8, go ahead and spend a little extra money and shoot DV. The higher quality will yield a better image and provide more shooting and effects flexibility, while the camera's FireWire interface will make for an easier post-production workflow.

Video

If you're planning a "straight-to-video" release such as a corporate presentation, trade show video, or home movie then your project will eventually end up on either VHS or DVD (or both). There's a substantial quality difference between VHS and DVD but even low-quality VHS is capable of displaying good-looking video if it was shot on a high-quality format. Think about how movies you've rented on VHS that were shot on film still look pretty good, especially when compared to something that was shot on a poor-quality format like home movies or surveillance footage. Today, there's really no good reason today to shoot on any format with lower quality than DV. DV cameras can be very cheap to purchase or rent and since most have FireWire interfaces, your editing workflow will be simpler than if you use an analog format and analog capture hardware.

Broadcast Television

Almost any of today's digital formats pass the muster for being broadcast, though broadcasters all have different criteria for what they will accept. In general, if you ultimately want your project to be suitable for broadcast television then you should aim to shoot at the highest quality that you can afford. Also, you'll have to master your final project according to very exacting specifications. We'll talk more about this process in Chapter 19, "Output."

Shooting for broadcast now means making the decision between an SD (Standard Definition) shoot, and an HD (High Definition) shoot. A few years ago, this was a very simple decision: if you didn't have tons of money, you were shooting SD (i.e., DV, DVCAM, DVCPro, Digital Betacam). Nowadays, thanks to inexpensive formats like HDV, it's possible for even low-budget producers to consider HD. At present in the United States CBS and NBC broadcast 1080 DTV while ABC broadcasts 720 DTV.

Projection

Any format can be used for projection, but there is one important thing to keep in mind: People will be seeing your video footage at 10 to 50 times the size of a video monitor. Noise and digital compression artifacts can be enlarged to the size of someone's head. Consequently, you should try to work at the highest quality possible.

If you ultimately want your project to be projected on 35mm film—in a movie theater, ideally—your final video will have to be transferred to film. In theory, you can shoot any video format for eventual film transfer. However, if quality is your primary concern, you should choose a higher-end digital format or shoot on film itself.

HD projection has come a long way in the last couple years. Although only a few theatres use digital projection, it's common to see digital projection—or even just a normal, high-quality video projector—in film festivals for projects that haven't been transferred to film.

Videotape Formats

In the following list, we've summarized the pros and cons of many different video formats. This should provide an idea of how you can use each format. Some of the higher-end formats may require cameras that are more expensive than you can afford. However, because these cameras are readily available for rental, and because such formats are required for very high-quality work, we've chosen to include them. It's important to be aware that the cameras designed for lower-end formats do not have the same set of features that the higher-end format cameras offer. If you're planning a complicated shoot that requires precise control of the camera, you may need a higher-end format for your shoot.

Analog consumer formats. Most people are familiar with VHS, S-VHS, Betamax, 8mm, and Hi8, all of which were developed for home video. These formats are very inexpensive, but their lack of image quality should deter most serious video producers. In addition, because they require a separate digitizing step, your post-production workflow will be more complex, and more expensive. With DV cameras so inexpensive, there's really no reason to consider these formats. If you plan on using lots of archival and found footage that's stored on these formats, then you'll need to choose between buying and renting the requisite hardware to digitize your old footage or transferring the old footage to DV tape. For new material, though, stick with a digital format.

Digital 8. Digital 8 is an 8mm consumer format intended to replace analog Hi8. It can use Hi8 or its own Digital 8 tapes. It has a 25 Mbps data rate, a 4:1:1 color sampling ratio, and 5:1 DV-based compression, but is slightly lower-resolution than DV. Again, this format is really only useful if you need to access older material.

DV. Intended as a digital replacement for the home video formats mentioned previously, DV has far surpassed the manufacturers' expectations. It has a 25 Mbps data rate, a 4:1:1 color sampling ratio, and a 5:1 compression ratio. The image quality is frequently rated higher than Betacam SP and has the advantage of being less subject to generation-loss.

DVCAM. DVCAM by Sony offers a higher tape speed than DV, but not quite as high as DVCPro, and it uses the same metal tapes as DV. The resulting higher-quality image is aimed at industrial users, but appears to be quickly becoming the low-end format of choice for broadcast.

DVCPro. With a faster tape speed than DV and DVCAM JVC's DVCPro sports a more stable image that is less prone to drop-outs but is otherwise similar to DVCAM.

The Right Format for the Job

All of the 25 Mbps formats—Digital 8, DV, DVCPro, and DVCAM—use the same CODEC. Therefore, any differences in image quality are hardware dependent; i.e., due to camera technology, lenses, tape transport speed, etc. The reason DVCPro and DVCAM are considered superior formats is due to their reliability in editing-intensive applications such as newsgathering, and due to the higher quality cameras and lenses available for these formats and also the availability of larger (and more durable) cassettes.

Betacam SP (BetaSP). Developed by Sony in the 1980s, Betacam SP was once the most popular format for broadcast television.

Digital Betacam (DigiBeta). Sony introduced Digital Betacam in 1993 as a digital upgrade of Betacam SP. Its extremely high quality has made it the broadcast mastering format of choice. Digital Betacam decks can also play (but not record) analog Betacam SP tapes.

MPEG-IMX. A 4:2:2 component, digital 50 Mbps format that uses MPEG-2 encoding and is backward compatible with Digital Betacam and Betacam SP.

D-VHS. Using the same tape shell as standard VHS, D-VHS offers digital MPEG-2 encoded video. D-VHS tapes are not compatible with standard VHS players and there are no D-VHS cameras. Rather, D-VHS is mostly intended for recording high-quality video from satellite or digital television. They are also frequently used to output viewing copies of HD projects before the final output.

D1. The first digital mastering format, D1 has until recently set the standard for high-quality digital video. The specifications that define D1 are known as ITU-R BT. 601, which consists of 4:2:2 color and a 4:3 aspect ratio. D1 has been superceded by the HD formats but it still used as a quality reference for non-HD video formats.

HDV. Newest on this list is the HDV format, which records HD footage on miniDV tapes. The low data rata (about 19 Mbps for 720 and 25 Mbps for 1080) allows for data transfer using FireWire technology. Interframe MPEG-2 compression keeps the data stream small but requires special CODECs for editing.

HDCAM. Perhaps the most popular of the HD acquisition formats, Sony's HDCAM offers a resolution of 1080.

D5-HD. Panasonic's D5-HD format can handle both 720 and 1080 DTV resolutions.

DVCPro-HD (D7-HD). Panasonic's other popular HD format, DVCPro-HD uses the same large-size DV tapes as DVCAM and DVCPro. It supports both 720 and 1080 DTV formats.

D9-HD. JVC's D9-HD is a high-end HD format based on their Digital S format. It supports both 720 and 1080 resolutions.

Film. This may be the *digital* filmmaking handbook, but that doesn't mean that there isn't a place for film in your production workflow. Even though they may be editing and posting digitally, many filmmakers still choose to shoot on actual film. In addition to the quality, unique look and flexibility of film, if you already own film gear, or are experienced and comfortable with shooting film (and assuming you have the budget) then shooting in traditional 16mm or 35mm might be the best way to go. Super8 film is a popular choice for music videos and other projects that don't require synchronized sound. Obviously, choosing to shoot film completely changes the discussion of what gear you need, and we won't be covering those issues. However, if you're an experienced film shooter, but are new to digital workflow, then you need to know that shooting film will introduce some new wrinkles into the post-production workflow. You'll have to pay for transfers of your film to video, and plan for a more complex editing workflow that involves matching back to film.

Finally, there are other parameters that might affect your format decision. Perhaps you've got access to free, or loaner gear—if you've got a friend with a nice DVCAM setup, there's no reason to invest in new gear. Or, maybe you have very particular output needs. Many film transfer houses prefer video shot in 24 frame-per-second progressive scan, while some "film look" software is designed for 30 frame-per-second interlaced video. These issues might constrain your format decision.

Choose Carefully

The movie The Cruise *was shot on NTSC using a Sony VX1000 DV format camera, but the director was so unhappy with the frame rate issues that resulted from the transfer to film that he ended up going back to his sources and remastering onto a Sony uncompressed HD format and then going to film. The process of changing from one digital video format to another is called "transcoding." It is not a lossless process and can be expensive so it should be avoided, if possible.*

YTHING

In the 1980s, video artists scrambled to buy Fisher-Price Pixelvision cameras that were intended as toys for children. These cameras recorded video onto standard audio cassettes, and the resulting extremely grainy, low-resolution, black-and-white images were (and still are) considered fascinating in ways that perfectly clear HD video could never be. You don't need 4:2:2 video to make an interesting project. If the content is compelling, no one is going to complain about the compression artifacts dancing around in the darker parts of your image. However, you do need to decide early on what's right for your project and your intended workflow, as that decision will influence your equipment choices and have a profound effect on how you shoot.

SOME VIDEO QUALITY EXAMPLES

In this chapter, you read about many of the technical concerns that affect video quality. Although it's very easy to debate the finer points of different compression ratios or CODECs, in the end, such debate might not tell you much about how good (or bad) a particular format looks. The only way to really determine if a particular video format is good enough for your needs is to see some examples.

The best way to get examples is to buy, rent, or borrow some equipment and shoot some samples under the conditions in which you expect to be working. While this might be practical for inexpensive DV gear, for more expensive DVCAM, or Digital Betacam, such expense might not be feasible. Fortunately, with so many movies being shot digitally now, you can find a number of examples of digital movies at your local video store. Check out the following movies for real-world examples of particular video formats:

Collateral: This big budget film was shot primarily on HD in order to take advantage of high-end digital video's ability to capture lots of detail in extremely low light situations. Although an experienced filmmaker might notice the appearance of *noise* on the big screen (as opposed to *film grain)* a difference in quality isn't noticeable to the average viewer.

Buena Vista Social Club: This documentary about the now-famous Cuban music "club" was shot using a combination of Digital Betacam and DV (using a Sony VX-1000). It's a fine example of the excellent level of quality that can be achieved with high-end gear. It's also an interesting opportunity to compare DigiBeta and DV side by side.

The Celebration: Shot entirely with a Sony DCR-PC7, an under-$1,000, single-chip DV camera, this intense film is a good example of what can be achieved with a cheap camera and ambient lighting.

Hands on a Hard Body: This excellent, hilarious documentary was shot on Hi-8 under very difficult lighting conditions. A good sample of analog video quality, and excellent proof that no matter how "inferior" your gear might be, if you've got a good story, and you know how to tell it well, everything will be fine.

Bamboozled: Spike Lee's second digital video feature (after the concert movie *The Original Kings of Comedy*) was shot using several Sony VX-1000s. This movie is a good example of "playing to the strengths" of DV. Rather than trying to mimic the look of a film camera, the filmmakers accepted the "video" look and used it to their advantage. Because the movie is about the TV industry, the DV quality supported their story.

Nadja: This cult-favorite vampire film set in New York City was shot partially with a Fisher-Price Pixelvision camera. The resulting grainy, black and white footage gives the film a mysterious quality reminiscent of the famous silent vampire film, *Nosferatu*.

Note that all of these features underwent a transfer to film at some point, so these are not examples of the type of quality that you get straight out of the camera. If your ultimate goal is a feature release, though, these movies show the range of quality that is possible.

SUMMARY

The information in this chapter is designed to provide a strong technical foundation before delving into the specifics of shooting, editing, sound, and special effects. You might not retain this information until you find use for it in the real world, during the production or post-production of your project. However, when you get to that stage, you'll be able to refer back to this chapter as a technical reference. Now it's time to put some of it to practical use in the next chapter, "Choosing a Camera."