

## The digital imaging system and dermatology

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### Photography in dermatology

Photography has proven to be a valuable tool in medicine.<sup>1</sup> For the dermatologist, the information contained within an image is often synonymous with diagnosis. The photographic image is an objective form of documentation,<sup>2</sup> and is more accurate than our changing memories and sketchy, hand-drawn illustrations. Images can capture fundamental morphologic and distribution patterns, as well as subtle color variation. When long periods of time elapse between patient examinations, a quick glance at photographic documentation not only provides a detailed representation of the physical findings, but may also trigger and clarify recollections.

In the areas of private practice, research, or dermatology teaching, the photograph has a wide variety of applications.<sup>3</sup> In both clinical practice and research, images are useful to monitor change.<sup>4</sup> Images can help document a changing examination, suspicious lesions can be followed for signs of change, or photographs of pretreatment findings can be used to illustrate a successful treatment option to a new patient.<sup>5</sup> In clinical research, images are the basis for assessing efficacy. Additionally, the documentation of procedures for legal (malpractice) issues has taken on a greater significance in this era of litigation, while the documentation of procedures for insurance purposes is sometimes required.

In research and publishing, images objectively illustrate treatment successes, while aiding in the evaluation of case studies where standard photographic approaches are used.<sup>6</sup> In the teaching arena, images are used to illustrate diagnostic findings and are essential for the teaching of dermatology, where the resident trainee is expected to develop a broad knowledge of multiple uncommon diagnoses, many of which reside only in film archives or in texts.

Images form the basis for telemedicine. Telemedicine is the practice of providing medical care based upon an

examination that utilizes electronically transmitted information in the form of pictures/live video, sound, and any other form which can be electronically transduced and used for diagnosis. With recent advances in the quality of digital images and the amount of available bandwidth to transfer such detailed images, telemedicine is particularly effective in dermatology where the diagnosis can often be made utilizing images and history alone.<sup>7</sup> Previous studies with off-the-shelf consumer level digital cameras have shown promise for telemedicine, and with the technology available today, teledermatology is quite practical.<sup>8</sup>

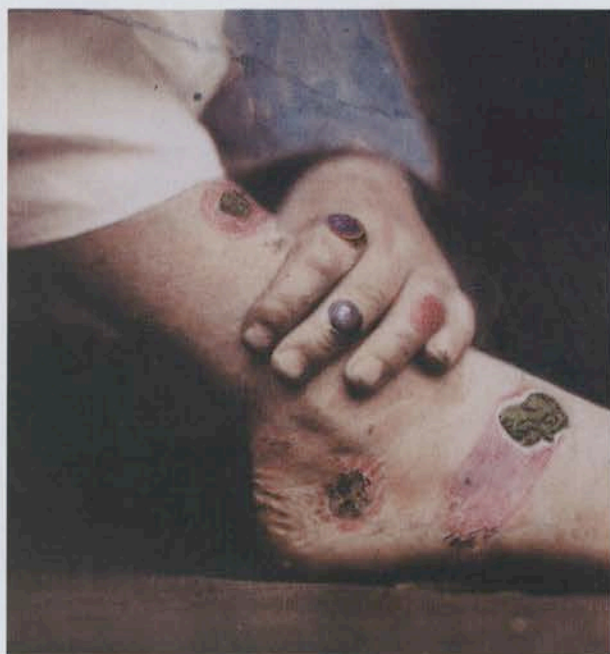
With the expanding popularity of digital imaging in dermatology,<sup>9</sup> new uses and opportunities constantly present themselves. The Internet provides a new channel for resident and continuing medical education.<sup>10</sup> It also allows for the rapid and convenient transmission of images for telemedicine purposes. As the ability to create, catalog, retrieve, print, or transmit images across private networks and the Internet continues to become faster and less expensive, we will continue to see new and creative uses for the digital image in medicine as well as in everyday life.

### Historical perspective

The first known medical image was probably made in 1845, by the Parisian Alfred Donne,<sup>11</sup> using the daguerreotype process, a direct-positive photographic method that created a highly detailed image on a sheet of copper plate that was coated with a thin coat of silver halides. During the 150-year interval since the birth of medical photography, dermatologic photography has evolved into widespread use. Images of skin disease are used to illustrate texts and journals, and have become a vital component to patient care within offices and to teaching within our residency programs. The 150-year journey has been marked by a series of technologic advances.

Neuse and Wilfried<sup>12</sup> provided an excellent historical survey of these compelling transitions, beginning with Donne's first medical daguerreotype. This first application was followed by other changes in technology, such as the creation of the hand-colored photographs of the late 19th century (Fig. 1), the first medical stereoscopic photographs made in Germany, the half-tone "heliogravure" images of Fox<sup>13</sup> beginning in 1878, the first portable box camera developed by George Eastman in 1888, the introduction of true color print photography in 1914, continuing on through the introduction of modern Kodachrome<sup>®</sup><sup>14</sup> slide films, as well as the E-6 Ektachrome<sup>®</sup><sup>15</sup> film types that are still widely used.

In the evolution of photographic processes, digital imaging was the next milestone. Sony<sup>®</sup> first introduced digital photography to the world in 1981. The ProMavica, a product for the professional community, soon replaced Sony's first camera,<sup>16</sup> the Mavica, an acronym for magnetic video camera. During the time interval from 1981 to the present, digital photography has undergone astonishing growth.<sup>17</sup> Furthermore, within the past 3 years, the almost exponential reduction in equipment costs appears to be coupled to remarkable achievements in image quality and camera features, further fueling the digital image revolution.



**Figure 1** Historical photograph. Title: Photographs of the Diseases of the Skin. Author: Alexander John Balmanno Squire (d. 1908). Imprint: London: John Churchill & Sons, 1865

### Composing the digital photography system

When considering the requirements for a digital photography system, one must consider how the images will be used. The practitioner utilizing the digital system for casual documentation has different requirements from those interested in high-resolution imaging for publication and teaching purposes. To make a successful choice, one must clearly evaluate the goal of the photography *before* a digital system<sup>18</sup> is chosen, to avoid disappointments in system performance or excessive spending on unnecessary equipment.

Although the camera is usually the most carefully scrutinized element, it is only one part of the digital imaging system. Careful consideration must also go into selecting a method for digital image transfer from camera to computer, as well as to the hardware and software to be used in cataloging, storing, and printing the digital image. Table 1 shows a comparative view of the estimated time requirements inherent to capturing, storing, and printing a digital image. All of these components deserve as much scrutiny as the camera choice.

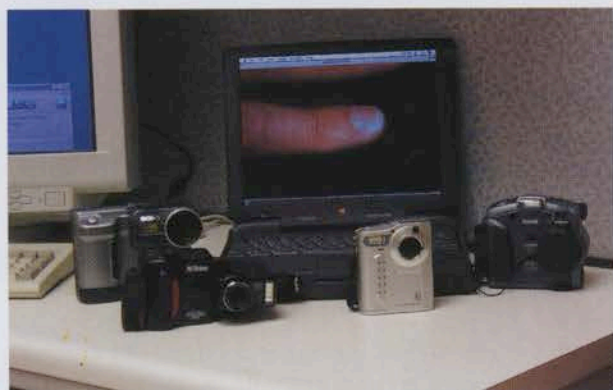
### Identifying the goals

When considering the system requirements, how images will be used determines the most appropriate digital system. For a busy cosmetic practice, there may be a need for storage of tens of thousands of patient images yearly. Fast, efficient recall of prior images, with on-screen viewing in the examination room and print capability, may be required. Close attention to the portability of the camera and ease of data entry is essential. Alternatively, digitally capturing a few images each day for teaching, publishing, and lecturing will not require as much efficiency, and emphasis on higher resolution images may be warranted. High-resolution images will necessitate more storage (larger hard drive), and an additional emphasis may be placed on high-quality print or slide production as part of the output from such an archival system.

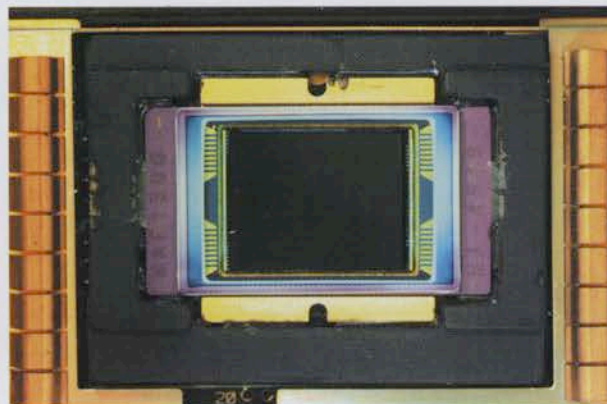
The complexity of choosing the appropriate camera is wed to the image transfer hardware choice, and a method to catalog, store, retrieve, and print the digital image. Each step and its requirements need to be considered and integrated as much as possible to provide a solution to the imaging needs. As digital images are temporarily stored within the camera, a recent computer will be necessary to provide adequate storage, run software, and drive a color printer for hardcopy

**Table 1** Digital photography time requirements

Capture image	30 s
Move images to computer via memory card	2 min
Label image	30 s
Enter into database, three fields	45 s



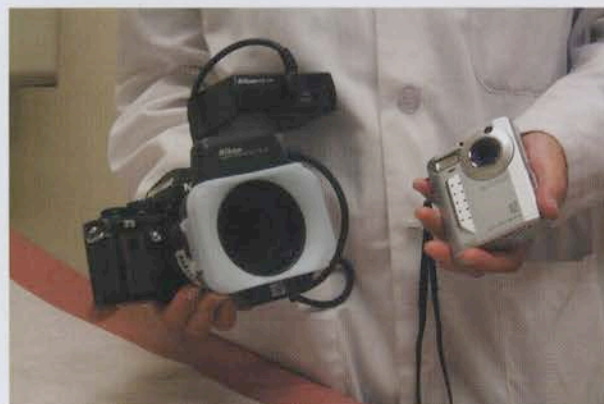
**Figure 2** Digital cameras. This picture shows the various designs and sizes of four common models of digital cameras that sell for a price of \$950 (US) or less.



**Figure 3** CCD. The heart of a digital camera is its CCD, or charged couple device. The chip is located in a camera where the film normally would reside and contains the pixels themselves.

**Table 2** Issues to be considered in digital and traditional photography

	Traditional 35-mm film photography	Digital imaging systems
Optical issues	Yes	Yes
Focal length		
Focusing parameters		
Shutter speed		
Ergonomic issues	Yes	Yes
CCD technology		Yes
LCDs		Yes
Image resolution		Yes
Image compression		Yes
Hardware processing speed		Yes
Color balance algorithms		Yes
Internal and external memory		Yes
Transfer of images from camera to storage on computer		Yes
Image integrity/security		Yes
Cataloging of images		Yes
Printing images	Yes	Yes



**Figure 4** Digital and film cameras. Film photography has been a valuable tool in dermatology; however, the cameras and flash can be rather large and heavy. Digital cameras evaluated in this article were typically much smaller and compact than their film counterparts.

storage, run software, and drive a color printer for hardcopy printing. In addition, removable media, such as a Compact Disk Writer (CD-R) and optical or removable hard drive, are required for data backup and transport.

**The digital camera**

Similar to the marketplace confusion associated with computer purchases, there also exists an equipment decision-making conundrum in the digital imaging environment. Like computers, digital cameras are constantly becoming “cheaper, faster, and better.” The often heard statement that one will delay the purchase of equipment until costs have stabilized means that a fundamental

equation is not understood: the price of equipment reaching an imaginary “bottom” level will simply not occur well into the foreseeable future. Gordon Moore, one of the founders of the Intel Corporation, observed this phenomenon of rapidly improving technology many years ago. In 1965, he was reviewing the history of the microchip. He observed the fact that, every 18–24 months, a new microprocessor would be created which would have approximately twice the number of transistors as its predecessor. He accurately predicted that this trend would continue into the future. Since Moore’s law drives innovation forward at an exponential rate, most people believe that they should wait 6 months or a year to buy their next digital device because they will get more for their money. This is absolutely correct. By utilizing this theory,

however, one might end up waiting a lifetime to make that first digital purchase.

Like their analog counterparts, digital cameras come in all shapes and sizes with a variety of feature sets and price ranges (Fig. 2). Unlike the traditional camera, these systems are governed by several digitally specific criteria that affect the image quality and the ability to take dermatologically specific images. While both film and digital media share similar issues of focal length, shutter speed, and focusing parameters, when considering the digital medium, there are a few additional aspects which must be taken into account (Table 2).

#### Digital "film": the charged couple device

The CCD (Fig. 3) or "charged couple device" is the "film" of the digital camera. It is actually a chip with an array of photosensors. When light strikes an individual sensor, the sensor produces an electronic signal. Higher resolution CCDs have more sensors per unit area, and can record more detail from the incoming light focused by the lens. The higher the resolution, the more detailed the recorded image. Chips, like film, have intrinsic characteristics. These include: ISO (sensitivity), color response, and resolution. ISO describes the chip's minimum requirements for light. Current cameras exhibit sensitivities (ISO) of 80 at the low end, ranging up to 3200 at the high end.

When using traditional film photography, it is possible to choose from many different emulsions based on the project requirements. Examples of emulsions include daylight, tungsten, or B & W type films. The CCD can only respond to differences in brightness, not to differences in color. To record color with CCDs, the architecture of the CCD must be modified. Colored filters are placed over adjacent sensors, which allow a group of very close sensors to record the intensity of the filtered light. Software is used to calculate the approximate color for the light striking the group of sensors. Generally, a mosaic technique is used where each group is composed of four sensors. The color filters vary, but are typically red, green, and blue with the fourth one being magenta, cyan, or yellow.

As a consequence of this averaging to create color, the accuracy of color response can vary from camera to camera. Also, this method of creating color may be prone to an electronic artifact known as aliasing. This is most often seen in areas of very high frequency patterns, such as vertical blinds, window screens, or clothing with striped or checked patterns.

#### Camera ergonomics: size and shape

As with film-based cameras, digital cameras within the \$1000 price range vary dramatically in shape and size (Fig. 4). Within the 1–3 mega-pixel range, camera size can

vary from ultra-compact pocket-sized units up to full-sized single lens reflex (SLR) body cameras with a gamut of attachments. This is an important factor to consider in the purchase decision.

The following important ergonomic questions must be addressed.

- 1 Does the user need the camera to be portable (hospital consultations, satellite clinics, operating rooms, etc.)?
- 2 Does the user have the dexterity to hold a tiny camera still and master small control buttons?
- 3 Are features that the user requires for excellent image quality in his/her practice available in compact cameras (i.e. ring flash attachment for a dermatologist specializing in intraoral lesions)?

Small size may offer portability, but may compromise optics. On the other hand, a full-featured camera with the best optics that is too cumbersome to carry around is a wasted investment.

#### Powering the camera: battery choices, a.c. adapters

Most cameras offered today include a.c. adapters; however, tethering the camera to an electrical outlet when moving about a busy clinic is inconvenient. Battery options range from alkaline batteries to rechargeable lithium-ion packs. Alkaline batteries offer convenience because they are widely available; however, heavy camera use (particularly when liquid crystal display (LCD) previewing is used for macrophotography) requires frequent battery changes that become costly and inconvenient. Although nickel cadmium (NI-CAD) or nickel metal hydride rechargeable AA batteries can be substituted, frequent battery swapping is still required, and operating time is typically less with NI-CAD batteries and only slightly longer with nickel metal hydride cells when compared with standard alkaline batteries. Several cameras include models which use rechargeable lithium-ion battery packs in lieu of the standard AA batteries. These lithium-ion rechargeable cells offer longer periods of camera use without the memory effect exhibited by the older rechargeable technologies. Unlike traditional film cameras, power is consumed by more than flash and simple electronics; in a digital camera, every action from LCD preview to writing and saving the image involves a power demand. Pay close attention to powering the camera.

#### Previewing the image: viewfinder vs. LCD

Most digital cameras provide both an optical viewfinder and an LCD (Fig. 5) for composing the image before it is taken. A viewfinder allows the photographer to look through a small window to correctly frame the subject, and define the borders of the image. The benefit of using the viewfinder instead of the LCD is that the

viewfinder does not consume battery power. The downside of many viewfinders is that they often do not accurately represent the borders of the image that will be captured by the camera, referred to as parallax

error.<sup>19</sup> This is unacceptable when careful framing of the subject is needed. Cameras with accurate framing through the viewfinder are SLR cameras. In SLR cameras, the exact image that will be transmitted to the "digital film" is reflected to the viewfinder. These cameras are generally larger and more costly than \$1000, but allow the best framing without the use of the LCD.

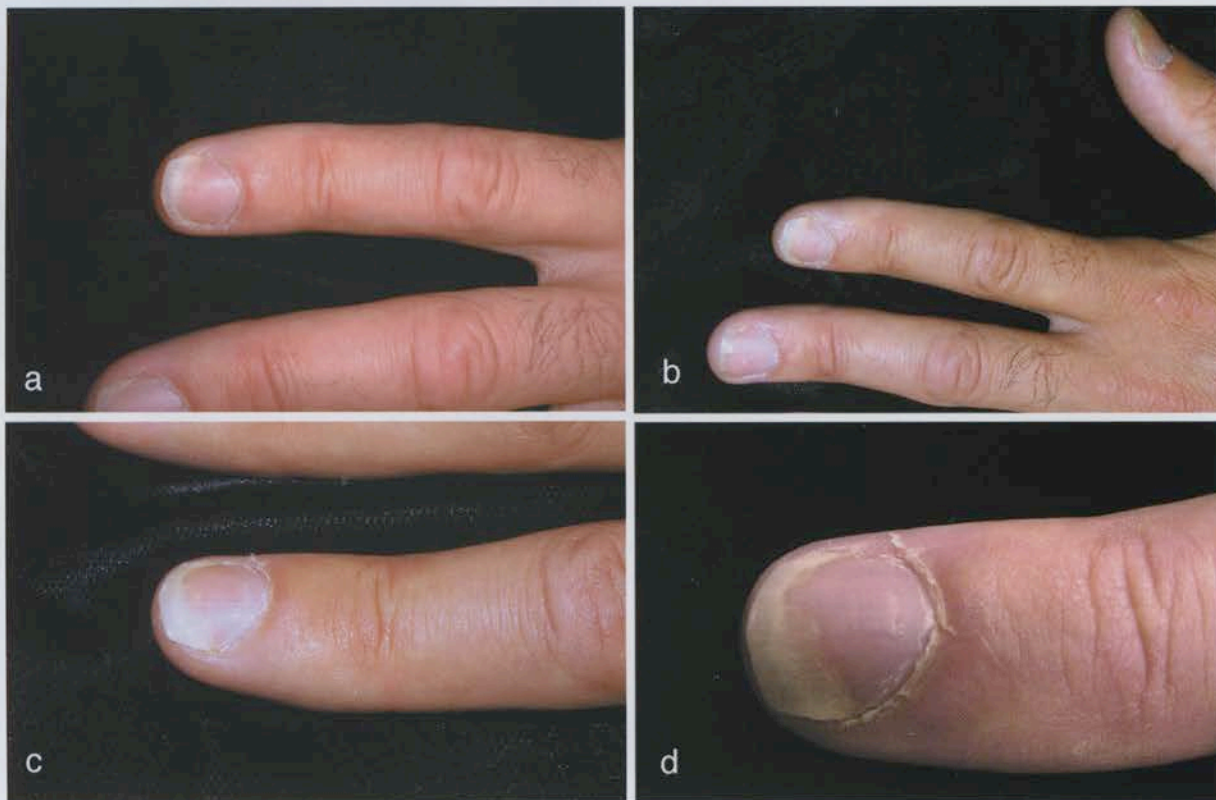
The LCD is a powered display which resembles a small TV screen, and is typically located on the back of the camera. It is a feature included on almost all models, and provides an accurate, through-the-lens preview of the image to be taken. It also functions as a display for viewing previously stored images, as well as setting camera features through on-screen menus.



**Figure 5** Liquid crystal display (LCD). The LCD preview is an excellent tool to assess proper exposure, correct focus, evaluate composition and perspective, and confirm the correct color

**Lens choices: macro capability is critical in dermatology**

The ability to take "close-up"<sup>20</sup> images is called a "macro"<sup>21</sup> function. In standard film photography, this is achieved by the addition of a macro lens. In digital imaging, macro features are typically built in to the camera, and are activated by pressing a button. The macro



**Figure 6** Camera working distance. This composite demonstrates the highest picture magnification that the following cameras could produce. These files were exported directly from the camera. The pictures were taken at the closest distance at which the cameras could be operated from the patient and still achieve a proper focus: (a) Fuji MX-2700; (b) Kodak DSC265; (c) Nikon CoolPix 950; (d) Sony FD-88

close as possible to the subject to obtain a well-framed image (Fig. 6). A quick survey of consumer and professional level cameras will reveal a wide range of minimum distances at which the camera can focus on the subject. This distance varies from 3 in to 12 in depending on the camera.

Digital cameras offer a large variety of lenses. One of the most common complex lens configurations is the zoom lens. This type of lens allows magnification of the subject without loss of resolution. Many digital cameras also provide a digital zoom function. This method electronically "magnifies" the subject by enlarging the pixels at the central portion of the CCD and excluding the pixels at the periphery. This method compromises resolution for subject enlargement.

#### Lighting choices: ambient vs. flash

Digital cameras take high-quality images in ambient room lighting conditions. Most also have a built-in flash. The flash is essential in low or variable lighting conditions, or when uniform color balance is desired (Fig. 7). Typically, color/white balance is automatically or manually set on the camera, depending on the ambient lighting condition. If the flash is used, some cameras use a preset color/white balance setting for flash photography, while others dynamically set the color/white balance and exposure time during a "pre-flash." A "pre-flash" is a firing of the built-in flash just milliseconds before the actual flash photography takes place. This method avoids red eye. Careful evaluation of cameras is required for close-up photography using the flash. Using a flash will give the most uniform color results between rooms with different lighting situations, but often will exhibit overexposure from the short working distance.

#### Color balance algorithms

Most traditional film-based medical photography is carried out using a flash with daylight-balanced negative or slide film. Due to the quality of the light produced by the flash system, color balance is assumed to be constant. When a digital camera is used without a flash, the constant lighting may be lost, and color balance becomes an issue.<sup>22</sup> In addition, even when a flash is used, most digital cameras will have a sensitivity to ambient light.

The ability to alter white balance is a valuable feature of digital cameras. As the digital camera can capture effective color using a variety of light sources, the chip's response must be calibrated to the light source, providing a higher degree of accuracy in color reproduction.

Various mechanisms are used to allow color balance adjustment. Most cameras provide several settings,



**Figure 7** Ambient/flash. This photograph reveals how various light sources can influence the quality of the color rendition of skin when captured by the camera's CCD. This is a consequence of the spectrum emitted from the light source itself. The electronic flash (a) is the best light for photographic applications in dermatology as compared to ambient office light (b)

depending on what type of available light is being used (e.g. tungsten, fluorescent, or daylight settings). A more accurate method of setting the white balance is performed by aiming the camera at a neutral white object illuminated by ambient light and engaging the white balance feature. The camera calibrates to the light allowing for accurate color reproduction. This calibration must be performed whenever different lighting is used. When using the flash, the manual white balance

feature is often disabled as the camera adjusts automatically for that light source. All cameras have the automatic white balance feature.

### Image compression

Uncompressed or "raw" digital image files captured with a digital camera are very large. These "raw" image files take up large amounts of storage space on the camera's memory card and computer's hard drive, and transfer very slowly from the camera to the memory card and to the computer. For example, without compression, a "raw" 2 mega-pixel image may use 2 megabytes (MB) of memory storage space. At this size, only 10 or 15 images can be stored on a 32-MB removable storage media card.

To decrease the amount of space and transfer times, software compression algorithms are commonly used to reduce the file size of an image. Compression is a technique of shrinking down an image data file, allowing an image to be stored and saved as a smaller file. Compression can be accomplished either through image processing software built into most digital cameras, or post-production with the use of computer software. By utilizing compression, many more images can be stored on the same medium that previously could only store 10 or 15 "raw" images.

The most common compression method used by digital cameras today is called JPEG compression. JPEG<sup>22</sup> compression is a "lossy" method of compression. This means that, each time the image is recompressed and saved, the image quality will deteriorate

due to the "loss" of information in exchange for compression. Most digital cameras offer several levels of JPEG compression, commonly labeled with generic designations such as "good, better, and best." The *more* an image is compressed, the smaller the file that will be created. Compression follows the laws of diminishing returns. Thus an image captured in the "good" setting may be quite small, but quality may suffer dramatically. Depending on the application, a level of compression must be chosen that provides an acceptable image of high quality, yet sufficiently compact size.

### Recommended camera features for dermatology

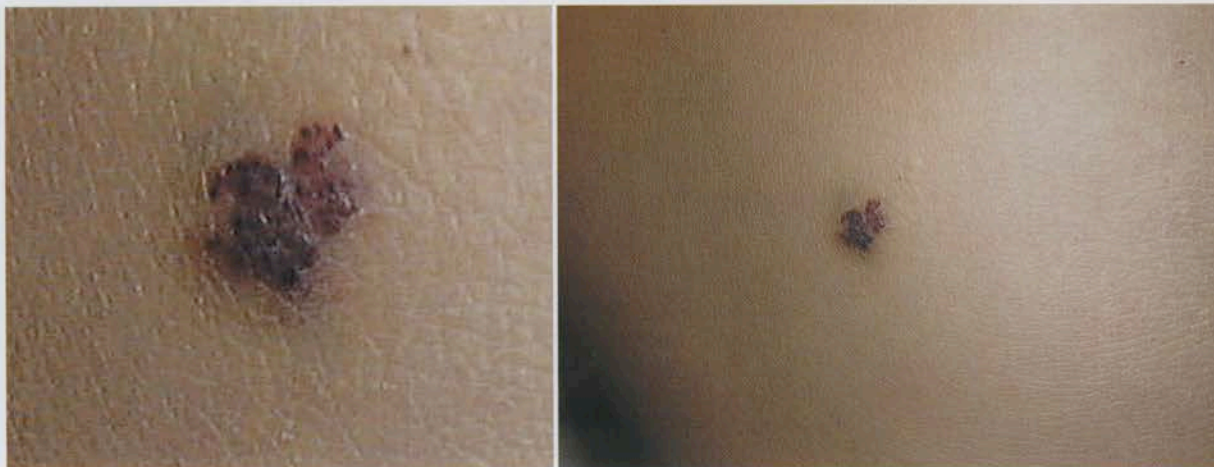
The recommended camera features for dermatology are outlined in Table 3.

### Focusing

Specific to dermatology applications, cameras will need to have some control as to where focus is placed, whether as an automatic feature or controlled manually. Cameras must be able to get close enough to photograph small objects such as nevi. This requirement makes the SLR camera ideal for dermatology applications, but the price point for this type of camera is above \$1000, an amount we have arbitrarily chosen to establish. There are, however, several recent new camera releases that provide this manual focusing feature as well as the macro feature. Careful attention should be given to this control in selecting cameras.

**Table 3** Recommended camera features for dermatology

Chip size	Minimum of 1 mega-pixel, 2 mega-pixel desired
Storage media	Easy to access, minimum of 8 MB, 32 MB suggested
Lens focal length	Fixed focal length is ideal, while variable focal length most common
Various ISO settings	Minimum ISO of 200 is desirable, variable ISO is very useful
Focus placement	LCD preview with auto focus
Aperture	Auto aperture is the standard, manual override is an excellent feature when close up
Minimum working distance	Macro capability essential (dependent on focal length of camera)
Auto/manual exposure	Both
Read/write	Faster is best. The camera inactivity can be frustrating when a picture needs to be made and the camera will not operate. Once an image has been recorded, slower cameras require the photographer to wait before additional pictures can be made, while the image is written to the storage medium. Once the system is ready, images can be made again
Focus control	Auto focus with manual override and LCD preview
LCD display	2 in minimum
Video out	NTSC useful in special applications
White balance	Manual or auto
File format	JPEG in the camera or TIFF is ideal for direct to printer
Resolution	Variable



**Figure 8** Cropping and resolution. It is always best to fill the frame rather than try to crop and magnify a part of a picture. In this example, the angiokeratoma found in the left picture is not sharp because there were insufficient data in the original file to make an 8-cm enlargement of that section when setting a resolution of 300 DPI used for printing

#### The digital image and resolution

Everyday, the resolution of digital cameras increases and the cost of digital cameras decreases. At this time, digital cameras are commonly classified by their resolution. Advertisements and product literature typically refer to a camera as a 1, 2, or 3 mega-pixel camera. This simply refers to the number of individual pixels which the camera is capable of resolving per image. A 1 mega-pixel image is one where roughly one million "dots" or pixels make up an image. The more pixels per image, the more detail that the camera has captured per image. Higher mega-pixel images possess tremendous detail, and can be enlarged greatly without "pixelation." Pixelation occurs when the image is enlarged to the point where the individual pixels (perceived as squares) that compose the picture can be easily seen (Fig. 8). Another term used to classify these 1–3 mega-pixel CCD cameras is the "prosumer" category of digital, derived from the combination of professional and consumer/amateur.<sup>23</sup> The number of pixels is calculated by multiplying the number of horizontal pixels by the number of vertical pixels in an image. For example, a camera with a CCD resolution of 1200 by 1000 pixels can capture 1.2 million pixels in each image.

So how much resolution is enough for dermatologic use? We know that camera resolution and color accuracy must be of high enough quality to faithfully render what is seen on the patient examination. Minimum standards for digital imaging and display have been studied in the medical environment. Perednia *et al.*<sup>24</sup> demonstrated that there was no significant difference in the useful information delivery between digital images at a resolution of 574 × 489 pixels and slide images. Bittorf *et al.*<sup>25</sup> in a side-by-side compar-

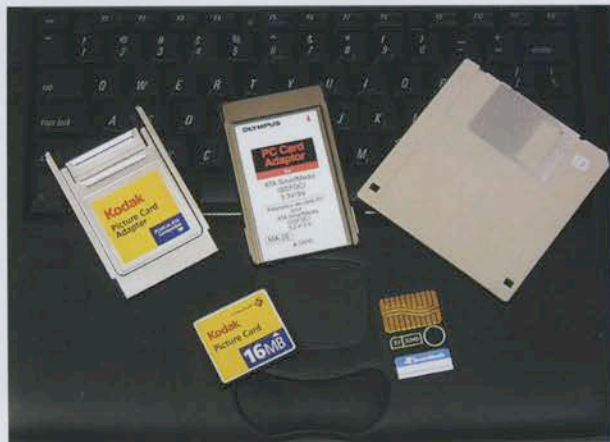
ison using projected slides demonstrated that 768 × 512 resolution is sufficient for viewing dermatology images. This minimum requirement of 768 × 512 pixel resolution is significantly less than is found in most low-cost digital cameras available today.

The final use of the digital image will determine how much resolution is really required.<sup>26</sup> The higher the resolution of the digital image, the finer the detail available for examination. Most computer screens have a resolution of 72 dots per inch (DPI), and a display size of 600 × 800 pixels or 1024 × 768 pixels depending on screen size and user settings. Thus, a 1 mega-pixel image might fill an entire computer screen. While screen resolution is 72 DPI, however, printing images requires higher resolutions to obtain a high-quality output. A resolution of 300 DPI is required for near photographic quality.

More simply, if a 4 × 6-in print is desired, approximately 1 mega-pixel of data will be needed, while a 5 × 7-in print will require 2 mega-pixel (1500 by 2100 pixel resolution image) (5 × 300 = 1500 by 7 × 300 = 2100 pixels). Conversely, if a web site were being authored using a monitor resolution of 72 DPI, then the same 5 × 7-in image would only require 360 pixels × 504 pixels (5 × 72 = 360 and 7 × 72 = 504).

Although a digital camera may be "rated" at a specific resolution, almost all cameras will allow image resolution to be reduced based on need and storage capacity. Depending on the final use of the images, lower resolution requirements may be chosen where appropriate, requiring less storage space on the camera's memory card and allowing images to be written to the camera faster.





**Figure 9** Media. Once the image has been captured by the camera, it is stored on the camera's removable medium. This picture shows current varieties of storage media used by different manufacturers: Compact Flash, floppy disk, Smartmedia, and a card adapter that would be required for use with a card reader



**Figure 10** Mavica and disk. Sony adopted a different storage medium approach than other brands for a less equipment-dependent approach. The Mavica uses the standard floppy disk rather than newer unique memory cards. Included in this picture is the Kodak Compact Flash disk for reference to a compact card

#### In-camera storage and transfer media

Digital cameras write images to small removable memory cards or hard drives. Typically, "prosumer" cameras utilize smaller memory cards such as Compact Flash, Smartmedia, or Sony's memory sticks (Fig. 9) (IBM has produced a Compact Flash-sized memory device that has a 100-MB hard drive within it, called the minidrive; it is not yet seen in consumer digital cameras). The media cards are currently sold in a variety of storage capacities commonly ranging from 4 to 64 MB. The Sony Mavica cameras use a standard high-density 3.5-in floppy disk to hold images (Fig. 10). In all contemporary cameras, files are typically

**Table 4** Data transfer speeds

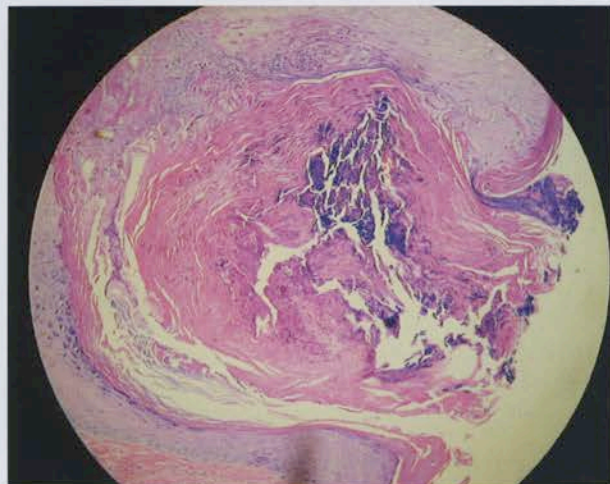
Serial cable	1 MB/min
USB cable	10 MB/min
SCSI cable	18 MB/min
SCSI wide cable	72 MB/min
Firewire cable	25 MB/s

saved in either JPEG or TIFF formats. There still exist a few cameras that use proprietary file codes.

#### Moving images from the camera

There are many ways to move images from the card/camera to the computer. One method is to connect a serial or parallel cable between the camera and computer. The speed of data transfer (Table 4) using this type of cabling is quite slow. Software is bundled with each camera to control this flow of image data from camera to computer. Recently, USB (Universal Serial Bus) connectivity has been introduced on many cameras and computers, supporting image transfer which is 10 times the speed of a serial or parallel transfer.

A far faster method of image transfer involves the use of a device such as a card reader. Using a card reader is by far the most advantageous and efficient way to move images. A card reader is nothing more than a very small drive designed specifically for memory cards. The drive is connected to the computer by USB or SCSI cable, and the memory card inserted into the drive is addressed through an image acquisition program or with a PhotoShop® Plug-in. Each camera/manufacturer will offer image transfer protocols and software to load into the computer, which allows the computer to find the images on the memory card when it is inserted into the card reader. Cameras are often supplied with stand alone transfer software that will have basic image processing utilities. Examples of this software include Photo Deluxe, Photo Wise, or Picture Easy. As the camera removable medium is usually a minicard (e.g. Smartmedia, Compact Flash), a card adapter is required; the medium slides into the adapter and then the adapter with medium is inserted into a standard reader connected to the computer or PCMCIA slot within the laptop. These adapters are readily available and can be ordered at the time the camera is purchased. The Mavica camera, as mentioned, uses a floppy disk as its storage medium. This disk requires no accessories beyond the traditional floppy disk drive, which is slower than a card reader even though it is built into the computer.



**Figure 11** Hand-held photomicrography. By holding the digital camera directly to the eyepiece of the microscope, photomicrographs can be captured. This image was taken with a Fuji MX-2700 digital camera



**Figure 12** Hand-held photography through an episcope. By holding the digital camera directly to the eyepiece of an "episcope," one can capture very good images. Note the millimeter ruler used to measure the pigmented lesion. This image was taken with a Fuji MX-2700 digital camera

extremely common and important. Additional nonessential but handy features include video output ports which allow the camera to be directly connected to a TV, VCR, or digital projector. External flash sync connections, remote control units, voice recording for annotation, and detachable lenses are also valuable features in certain settings. Motion image recording is available on some of the digital cameras. Digital cameras have certain capabilities useful to dermatology which are difficult to achieve with traditional photography. Imaging through the microscope (Fig. 11) can easily be performed, as well as imaging through an

episcope (Fig. 12) directly without a specialized camera mount.

### Storage and retrieval

#### Computer central processing unit

A computer is imperative for storing and managing a digital photography archive. The main computer chip or central processing unit (CPU) indicates computer processing speeds. One measure of performance can be defined by the clock speed. At the time of writing this article, in the IBM-compatible world, personal computers typically contain Intel Pentium II or III generation chips (or compatibles) and are available at 400 MHz or greater, with 800 MHz chips on the horizon. Apple computers, which use the PowerPC G4 chip, exhibit similar if not greater "clock" speeds. For electronic imaging applications, the CPU must be fast; generally, a computer purchased with a Pentium II or III chip will have clock speeds of 300 MHz or better. The computer must also have adequate random access memory (RAM); this is the type of virtual memory the computer temporarily stores working files within. A machine with 128 MB of RAM would be the minimum required for seriously pursuing digital photography, although 256 MB would guarantee speed when handling and processing large image files. Computers should also have a very large hard drive such as 10 GB or larger.

#### Software

Image database software will greatly enhance the power and utility of a digital image archive. If the goal is to archive images for teaching, research, or patient care, reliable efficient cataloging is a critical step. Anyone that has managed a large collection of 35-mm transparencies realizes that labeling and storing the slides is a labor-intensive task. In the digital world, the analogous task is entering the same information (or more) into a database. At the time of writing this article, there are no automated pathways for entering data such as patient name, diagnosis, or other identifying characteristics of the image into the database; therefore, close attention must be paid as to how image-specific data will be entered into the software application. As the digital system is planned, there is a need to think about who will be responsible for the data entry task and when it will occur. Unlike boxes of 35-mm transparencies that are returned from the photo finisher, images must be transferred to the computer soon after they are captured; the film card in the camera will need to be cleared of prior images and "re-used" for another imaging session. Once the image is captured by the camera and transferred to the computer, it will be saved to the hard drive. If thousands of images are simply stored within

drive. If thousands of images are simply stored within "folders" on the computer hard drive, they will quickly become as difficult to find as unlabeled photographs in a drawer. The image database allows images to be filed and categorized by as many categories as desired: diagnosis, patient name, morphology, age of patient, date of photograph, virtually as many categories as are relevant to the mission of the image collection.

#### Storing and retrieving the image: databases

As most dermatologist photographers know, 35-mm images have been traditionally cataloged by writing the patient name and diagnosis on the actual slide mount, usually along with a number that corresponds to one of the many numerical cataloging systems. Slides are then stored in "loose-leaf style" binders in Print file® pages, or slide storage cabinets which are likewise organized and filed by the particular numerical system chosen by the photographer. The difficulty with such a system is that the filing system or database is unidimensional; one can only look for images based upon the chosen code, which often corresponds to a diagnosis. If images are filed by diagnosis, and there is a need to find images by patient name or, say, lesion morphology (as images are needed for a particular lecture), easy retrieval of the desired images is near impossible. Another limitation is that the collection may be physically inaccessible to the users of the collection. Images are stored in one location, but patients are seen at another office. Residents need access to an image, but the image is not in the patient chart, but in the teaching file at a remote location.

Computerized databases solve this retrieval problem by providing the opportunity to easily retrieve images, at multiple sites, by any recorded criteria. At the most fundamental level, a computerized database is like a filing cabinet; the goal of a database is to organize data (in this case images) by a predetermined system. The difference between the computerized database and the filing cabinet database (or loose-leaf file) is that each image can be stored and then retrieved by any number of characteristics. With regards to a dermatology database, images would likely be stored by a number of different criteria. The criteria for retrieval would be determined by the particular needs of the user(s) of the collection. If images are to be used simply for patient care, and never for teaching, then it is likely that images will be organized by patient name, date of care,

diagnosis, etc. On the other hand, if the primary function of the collection is to support medical and resident education, one will need additional searchable categories, such as lesion morphology, body location, etc.

The successful design and implementation of a complex relational database or object-oriented image database is not the goal of this review, as creating image database software from the "ground up" is not only impractical for the dermatologist, but prohibitively expensive. Thankfully, there are a number of "off-the-shelf" image database solutions which the interested dermatologist can customize to fit a particular need. These software packages are available on both the Windows and Apple platforms. They can be "customized" to some extent to fit certain needs. Portfolio (Extensis Corporation), Cumulus (Canto Corp.), Folio, Image AXS (Caere Corporation), and others are low-cost affordable image databases; demonstration versions can often be easily downloaded from web sites (see Table 5). Generically, databases allow one to cross-index and perform more powerful searches because data are organized into fields. Fields within a database are categories, where the builder of the database makes a logical decision to place only one type of information within the field or category. For instance, one could create fields for patient-related information, such as patient name, sex, date of birth, diagnosis, biopsy result, or therapy. Likewise fields could be created for image-related data, such as photographer name, film type, etc. One can easily realize that, when it is time to search the database for the name of the photographer, it will be much more efficient to search a field labeled photographer, rather than say a mix of all types of fields, such as those listing patient names and photographers.

#### What is an image database?

Let us suppose that you have bought a low-cost digital camera, and have begun to save digital files on the hard drive of your computer. You understand how to capture the image, load it into a folder on your computer, and label the folder "patient images." Suppose you create a folder for every day you take patient images, and every day you take 40 images. In 48 weeks, you will have roughly 9600 images. Image databases allow you to organize and retrieve these images. Most image databases usually use a "load" or "acquire" command to direct the database application to build a connection between the catalog of your images and the image

**Table 5** Database software and their World Wide Web addresses

Image AXS	Caere Corporation	<a href="http://www.caere.com/products/">http://www.caere.com/products/</a>
Extensis Portfolio	Extensis Corporation	<a href="http://www.extensis.com/index.html">http://www.extensis.com/index.html</a>
Canto Cumulus 5.0	Canto Corporation	<a href="http://www.canto.com">http://www.canto.com</a>
Filemaker Pro 5.0	Filemaker Corporation	<a href="http://www.filemaker.com/">http://www.filemaker.com/</a>

files, which reside on your hard drive. What the database does is find, locate, and store a reproducible pathway to your digital image file. These packages create a surrogate for the actual image file by creating small, "thumbnail" images of the actual file to help you recognize images without opening the entire large image every time. This is a very useful feature, as it means you will not have to open every image file when looking for a particular image. Once the thumbnails have been created with links to the actual image file, most of these packages allow you to create user-defined fields within the database to aid retrieval of each image. Many of these fields are generic to photography in general; others can be specific to your unique archive mission. Generic fields include photographer name, date, image type, location, etc. Dermatology-specific fields which may be of interest include diagnosis, morphology, distribution, diagnostic group, patient name, etc. Once you have created your fields, the software then allows you to catalog each image.

#### Other software applications which can be used to store images

Another possibility for organizing images would be to utilize a computerized medical record system, which has image databasing capability. These software packages are new and evolving. Some of these systems can be typically viewed at trade exhibits, such as the American Academy of Dermatology Meeting exhibit hall; others can be researched on the Internet. Computerized medical records which allow for patient scheduling, billing, medical records, and have an integrated, complete digital image capability are a compelling vision, but, to the authors' knowledge, an integrated system which improves both the quality and efficiency of dermatology clinical practice has not yet appeared.

#### Basic image processing

Processing digital images has great value and aids greatly in the effectiveness of an image. Creating file sizes that are appropriate for use in presentation software, such as Powerpoint®, clarifying tones in an image, or sharpening details are but a few of the many features. Naturally, images can be altered, and deception is possibly a mouse click away.<sup>27</sup> For those with an interest, there are many excellent sources, including on-line training, books, and software tutorials to broaden understanding of this field.<sup>28-30</sup> Basic processing techniques allow the user to sharpen, adjust, contrast, crop, size, and compress the image. Obscuring the identity of the patient can be achieved with these packages, either by a combination of "zooming" and cropping the image to hide distinguishing characteristics, or by using more sophisticated tools. Many digital cameras include entry level software to accomplish these tasks. Software, such as Adobe Photodeluxe®, is commonly found. For those with more sophisti-

cated needs and time, Adobe Photoshop® is the graphics industry standard and a powerful image processing tool for those with advanced requirements.

#### Conclusions

Imagine the following. A dermatology clinic with a flat panel display located within each clinical examination room. Images of patients and their prior clinical examination available instantaneously at the time of their visit. A computerized medical record which records voice input and automatically transcribes clinical notes. Pattern recognition software which can alert the user to subtle changes in nevi and therefore the need to biopsy. Imagine sequential imaging of chronic ulcers, or other chronic dermatoses, and objective assessment of the validity of current therapy. Many of these futuristic technologies are within reach. Digital imaging and computing, tied to sound epidemiologic methods, will soon open a window onto a more detailed view of the patient, their treatments, and their response to treatment in ways unthinkable a decade ago.

As mentioned already, it is relatively easy to use a digital camera and, by using sound photographic techniques, excellent, low-cost digital images of patients can be captured. While traditional photographic equipment and materials have worked well for many years, they may eventually be considered to be cumbersome and expensive, in the same way that 8-mm "home movies" were replaced with the video camera. We are in the infancy of the digital revolution. As with any new technology, accepted standards are yet to develop and change is the only constant. Converting to a digital photography system in the current environment of rapid change will not be without start-up costs and a learning curve. What to do? Think first about your needs and goals. Compare the costs of your present film-based system with a digital system. Purchase what you need, will use, and will improve patient care, teaching, or research.

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## Glossary

**Adapter (card).** Most memory cards will be different from manufacturer to manufacturer. They may be referred to as ATA cards, Smartmedia, memory sticks, Compact Flash, or film cards. These various devices will often require an adapter to be used for reading in a computer. The adapter will have minimal impact on image transfer speed.

**Aliasing.** Low- and medium-resolution computer imaging systems normally create and display images with smooth edges. When image artifacts exist, they may appear as jagged edges or not smooth. They are often a result of insufficient data or are created when the fine detail exceeds the rendering ability of the system. They are evident around high-frequency subjects and appear as color patterns in these regions.

**Area array.** This is a method of pixel organization in a charged couple device (CCD). In this method, pixels are located in both the horizontal and vertical orientations ( $x$ ,  $y$  matrix). There will exist a finite number of pixels in each direction dictated by the manufacturing of the CCD.

**Bit.** A bit is the smallest unit of data in the digital world. As a basic unit, it can be off (0) or on (1). In imaging applications, the more bits, the greater the tonal ranges possible. A gray scale image is an 8-bit image and will display 256 different tones. Because RGB (red, green, blue) images have three channels, an RGB image is described as being 24 bit.

**Bit depth.** Brightness resolution refers to the number of shades of gray an image can display assigned to each pixel. The more bits, the greater the tonal range possible. A gray scale image, for example, that is an 8-bit image will display 256 different tones.

**Bit map.** A pixel-by-pixel description of an image that can be observed. When the resolution is high enough, the image is seen as a continuum; however, when there are insufficient data, there will be the appearance of image pixels, described as bit mapped.

**Buffer memory.** An intermediate location in an electronic imaging system. A system with a large buffer memory will allow faster functions, such as acquisition, reading, and writing, to occur. More advanced systems will have greater function in this system feature.

**CCD.** Charged couple device: an array of photosensors that detects light and produces readouts as electronic signals. It is often described as a function of its resolution.

**CDI.** A compact disk that is interactive is a new standard, and is used with disks containing still images, moving images, image sequences, or audio tracks. A CDI device allows a user to interact with the media, and requires a special player and monitor.

**CD-ROM.** These are disks that hold text, images, or sound and are a major means of storage and distribution of electronic data. The typical CD-ROM storage capacity is

650 MB. CD-ROM players are standardized at 150 kB/s. ROM refers to read only media.

**CMOS chip.** Yet another architecture used in chips. In the active pixel CMOS method, the electrical power design has been modified to use power more effectively by linking pixels together to lower power requirements. CMOS chips are not capable of higher resolution, but simply are more efficient. To find CMOS technology more integrated into digital cameras will require industry to reinvent manufacturing.

**CPU.** The central processing unit (CPU) is the heart of any computer and often refers to the computer's main processor to which everything is connected. Specifically, the CPU is the microprocessor in a single integrated chip. The vast majority of computers use Intel (PC) or Motorola (MAC) microprocessors. The CPU is responsible for executing software instructions and manipulating data.

**Display monitor.** The common monitor in an electronic imaging system is a device for displaying images, and is a cathode ray tube or CRT. It is coated with bands of phosphors that produce red, green, and blue color. The color and brightness of a monitor are highly variable. Calibration of monitors is essential for accurate rendition of the image.

**DPI.** Dots per inch. Similar to PPI or points/pixels per inch.

**Dye sublimation.** Refers to a process whereby a pixel-by-pixel image is written to a hardcopy output device. This type of printing results in a continuous tone image, similar to photographic paper printing in quality and resolution. Receiver material is exposed to cyan, yellow, and magenta dyes that are transferred by heat to the receiver material. This type of printer is capable of rendering 300 dots per inch (DPI) and is the most expensive type of digital printer.

**Dynamic range.** Scenes and subjects contain various brightnesses or reflectances within them. The difference between the region of highest brightness as compared to the region of least brightness describes a scene brightness range or dynamic range. Charged couple devices (CCDs) record data more effectively when using a narrow brightness range, similar to color slide films. High brightness ranges create problems for chip response.

**E-6.** A process used to develop certain types of color slide film. Typically, Ektachrome® and FujiChrome®, as well as other major manufacturer's films, are compatible with such a process. The E-6 process takes approximately 44 min to dry. The process creates color dyes in three separate emulsions. The stability of such dyes has been the subject of vigorous study and is considered to be, under average storage and usage, up to 75 years.

**Hard disk.** Hard disks use a series of rigid platters that can be recorded to (write) and played back (read). In much the same way as a floppy disk operates, these drives are built into computers. The plates that are used in hard drives typically have a very large capacity. Current drives may hold up to 10 GB of data for a

relatively nominal fee. Hard disks use parallel methods to talk to each other and demonstrate response times of 15 ms. This method of data storage is currently one of the fastest available.

**Ink jet.** A computer-controlled output device that sprays ink through fine nozzles. The physical size of the nozzle opening determines the dot size. Typically, water-based inks will be sprayed in liquid form. These types of printers can resolve between 100 and 300 DPI. It should be noted that this type of device is not considered to be a continuous tone device and may be advertised to be capable of upwards of 1440 DPI.

**Interpolation.** This is a method of modifying the image size. Digital systems are capable of recording a fixed number of pixels. Sometimes there may not be sufficient pixels for a particular application, or there may be too many, and software may be called upon to change the amount of pixels. This type of image processing is defined as interpolation.

**Kodachrome.** This is the original color slide film invented by the Eastman Kodak Company in 1935. The film emulsion is actually a B & W film, and the cyan, magenta, and yellow color dyes are added during K-14 processing. Kodachrome has been an industry standard for many years because of its image permanence, although E-6 films now boast a very similar life expectancy and are more easily processed in a shorter time.

**LCD.** Liquid crystal display (LCD) is a method used for displaying images and is typically used on small devices; some overhead projectors and laptop computers now use LCDs. Individual pixels are controlled by a liquid crystal matrix or active matrix system.

**Linear array.** This is another method of pixel organization in a charged couple device (CCD). In this approach, a single row of pixels is located in only the vertical orientation (y matrix). There will exist a finite number of pixels in this direction dictated by the manufacturing of the CCD, just as in the area array device. The number of vertical pixels is fixed and the array is moved across the field using a small motor.

**Memory card.** Digital image files are stored at this temporary location in digital cameras. The memory card is capable of reading and writing, both while in the camera or in a card reader inserted in the central processing unit (CPU). Different names have been given by each company to its memory card. Some names include Smartmedia, memory stick, PCMCIA, and Compact Flash.

**Photo CD.** This is a proprietary product from the Eastman Kodak Company. Originating from film pictures, these images are scanned onto the disk at five various resolutions. The disk has the potential to hold up to 100 images in these five resolution formats. This product has had a

tures, these images are scanned onto the disk at five various resolutions. The disk has the potential to hold up to 100 images in these five resolution formats. This product has had a major impact in the area of desktop publishing, where various stock images are sold in this way.

*Pixel.* A picture element: the smallest component of an electronic picture that can individually be processed in an electronic imaging system.

*RAM.* Random access memory (RAM) is the part of a computer where data are temporarily stored. It represents the computer work space. The act of placing data in the memory is referred to as writing to memory, while the process of obtaining data is known as reading from memory. RAM is volatile in that, once the power supply is removed, the memory is not archived. For image processing requirements, a lot of RAM is imperative.

*Resolution.* In electronic imaging systems, the number of horizontal and vertical pixels that comprise the image. Typically, the minimum number of pixels required for scientific images is  $512 \times 512$ . If the term is used to describe brightness levels (contrast resolution), then the minimum brightness level is 256.

*Scratch disk.* Many image processing programs require that a copy of the image being processed be held in temporary storage so that operator errors can be undone. Because of the size of images, the copy is usually held in reserved areas of the computer referred to as the hard disk. Programs such as PhotoShop will require a scratch disk with proper memory allocation to be identified.

*Screen display.* Viewing electronic images on a screen is referred to as soft viewing. This is because there is no hardcopy image. Images viewed in this way contain 72 dots per inch (DPI).

## **Eczema**

Now, typical eczema is an acute inflammatory disease, characterized especially by an eruption, in connexion with more or less superficial redness, of small closely-packed vesicles, which quickly run together, burst, and are replaced by a slightly excoriated surface that pours out a serous fluid, which dries into crusts of a light yellow colour, of moderate thickness, and composed of granulation corpuscles, pus corpuscles, epithelial cells in an ill-developed state, and granular matter of an inflammatory and fatty nature. The discharge has the very peculiar property of stiffening linen. The vesicles appear in successive crops, and may prolong the disease for an indefinite time. Their formation is attended with itching and local heat. The skin is irritable, and occasionally excoriations or crackings of the part occur. The true skin itself is somewhat infiltrated, and sometimes the parts around the patch inflame, in some cases from the irritating nature of the discharge, whilst the disease is very apt to spread. The patches form on various parts of the body, are of variable size, and they are mostly symmetrically disposed. The discharge of an eczema may, however, be not serous but mainly purulent, and then large, thick, yellow crusts form. As the disease progresses towards cure, the discharge ceases, and a reddened scaly surface remains. If the disease is extensive and general there may be sharp pyrexia. Generally speaking, the attacked are of lymphatic aspect, and they often suffer from headache, loss of appetite, thirst, foul tongue, confined bowels, and the like. The mucous surfaces may become the seat of inflammation, either by the spread of disease from the skin or as a consequence apparently of the general condition. The disease is the most common of all skin diseases; it lasts a varying time, in consequence of successive local developments, and the tendency it has to spread. In the chronic state it often oscillates between cure and recurrence; the skin gets harsh, dry, red, and thickened from infiltration with the new inflammatory products. After its disappearance, the disease usually leaves no traces of its former presence; but if eczema lasts a long time induration, fissures, œdema, papillary hypertrophy, ulceration, &c, may ensue; but these are quite accidental and secondary.

From Fox T. *Skin Diseases: their Description, Pathology, Diagnosis, and Treatment*. New York: William Wood, 1875, pp. 164-165.