Images For Science

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Scientists would find it extremely difficult to communicate their findings to other scientists and to the public without images to supplement the words. This review traces this practice over 2500 years, and also shows how science has been applied to the image-making process. This interdependence continues to the mutual benefit of scientists and all who make images.

Editor's Note: This article is adapted from the text of the introduction from the catalogue that accompanies Images From Science 2, an Exhibit of Scientific Images, which opened at Rochester Institute of Technology's School of Photographic Arts and Sciences Gallery on October 12, 2008. Images from the exhibit are featured in this issue's Showcase.

Introduction

As minds explore the workings of the world and the universe, words alone are often inadequate to describe new discoveries and knowledge. In these circumstances images supplement words. The ancient Chinese proverb about the value of a picture is a vast underestimation. Indeed, in many cases no finite number of words can express the information a photograph can convey. Science has always been intertwined with images.

Image Making the Hard Way

Early astronomers chiseled on stone plazas the daily progression of a gnomon's shadow to determine the solstices and to measure the sun's annual motion. They sketched charts of the wanderings of the planets against the background of fixed stars, eventually deducing the laws of planetary motion. Euclid scratched his triangles and circles in the sand as he taught geometry to his school. Leonardo sketched the moons of Saturn and the sinews of the human body for incredulous nobility. In the 17th century Robert Hooke in England and Anton von Leeuwenhoek in Holland were seeing marvelous things in their primitive microscopes. Actually seeing with these early instruments was not easy, and repeated attempts at observation required great patience and greater skill. How could they convince others of what they were seeing – the microbes in a drop of water, the wing scales of butterflies, the facets of a fly's eye? Hooke was quite good at sketching what he saw, but Leeuwenhoek had no such talent, and needed to describe his observations to an artist who made the drawings. It is amazing that such an arrangement could have resulted in images that stand the test of today's observations with modern instruments.

Scientists have always needed to communicate their discoveries with each other. In science it is necessary to repeat each other's findings to validate or disprove claims of new knowledge. To do this requires publication and worldwide distribution. While early photographs of scientific phenomena provided the original image, there was no way to get that image onto the printed page in a scientific journal for mass distribution. The printing methods of the 19th century could not handle the range of tones from white to black with all the intermediate gradations. Presses could only print black ink or nothing on the white paper. Engravers took the original photograph or sketch from the scientist, and line by line, scribed it into a printing plate. Days were sometimes consumed to make a single illustration. It is no wonder that early scientific books had few pictures. Eventually imaging scientists solved these problems. Around 1900 the optical scientist F. Eugene Ives cleverly used optical means to convert continuous tone photographs into millions of vanishingly small dots of varying sizes, enabling the printing press to produce a simulation of continuous tone. Newspapers and magazines still use a variant of this process. But that is getting ahead of the story.

Science Serves Image Making

As scientific knowledge grew, science eventually provided the means to make its own images. In the late 1700s Karl Wilhelm Scheele discovered that a slurry of silver chloride darkened upon exposure to light. This phenomenon had extremely feeble sensitivity by today's standards; it took hours of exposure to sunlight to make the image of a stencil. It would be another seventy years before chemists would find a way to amplify a minimal exposure to light to produce a visible image. Even these first images would fade if viewed in room light. Another chemist would find a way to make the fugitive images impervious to further exposure to light. Achievements in optics combined with chemical advances to become the basis of practical photography. With little fundamental knowledge to guide them, early experimenters tried even the most improbable things. Who would have thought that light could make images with asphalt and oil of lavender.

Early photography in the 19th century was more art than science, and very dangerous art at that. Louis Daguerre in France treated his plates of silver with the vapors of iodine and bromine, the fumes of hot mercury, and solutions of potassium cyanide to make his exquisite images in 1839. Today's safety watchdogs would be aghast at the use of those deadly poisons. Beautiful as the Daguerreotype process was, each exposure gave only a single image, which could not be easily or accurately copied. W.H. Fox Talbot in England, working at the same time as Daguerre, invented another silver halide process that yielded an image in which tones were reversed – lights were dark, shadows were bright. By copying this negative image to another sensitive sheet, natural tones were restored. Any number of positive images could easily be made from the original. From this process all subsequent silver processes have sprung.

Light sensitivity is a property of several elements or their compounds: iron, mercury, selenium, silver, to name a few. One element alone possesses this property to a supreme degree – silver. Compounds of silver with a halogen—the elements chlorine, bromine, and iodine—have the ability to remember a brief exposure to the image projected by the lens of a camera. That memory can be awakened by chemical processing to take this invisible "latent image," and amplify it to a very visible, permanent picture. This silver halide process dominated photography for one hundred and fifty years. Originally it made pictures in shades of gray, but by mid-20th century chemical research brought full color snapshots and movies within the budgets of almost everyone.

Groping in the Dark

Early photographic experimenters had little scientific understanding to build on. Would a splash of beer, or a dollop of honey improve a silver halide emulsion? Would extracts of plant leaves and blossoms? Would boiling increase sensitivity? One early emulsion maker found that eating a raw onion for lunch, then adding his urine to the emulsion made a great improvement in sensitivity. (It would be decades till the chemical reason for this would be discovered.) Once in the 1880s when batch after batch of emulsion failed to work, a desperate George Eastman called his workers to a meeting to pray for the emulsion. Hiring a good chemist eventually proved to be more reliable than divine intervention. Improvements accelerated when university-trained scientists eventually replaced intuitive experimenters.

The sciences of theoretical and applied chemistry promoted early photography from a slow, tedious, failure-prone, trial-and-error process to its ultimate technological triumph. This mention of chemistry should remind us that images born in chemistry will die in chemistry unless prevented by intelligent conservation techniques. Here science is again serving image-making through ongoing studies of image conservation at universities and museums. This back-and-forth cooperation of scientists and image-makers continues to the advantage of all who make, or use, or enjoy images.

Image Making Serves Science

In the mid-19th century scientists quickly took up this new tool—photography—and applied it to the microscope, to the telescope, to the spectroscope. Archeologists, explorers, and ethnographers put cameras in their field kits. Later, through the use of motion pictures, scientists were able to stretch and shrink time to study extremely rapid phenomena – the flight of a bullet, or the very slow – the growth of plant roots and the movement of glaciers. Data gathering was greatly speeded up. To measure the magnitude (brightness) of a single star using visual methods at the telescope required several minutes. A single photographic plate could record the magnitudes of hundreds of stars in one exposure.

Astronomers rate the intensity of starlight in terms of a magnitude scale. (Contrary to intuition, the greater the magnitude, the dimmer the star.) Each unit of magnitude represents a factor of about 2.5 in brightness. On a good night, the dark-adapted human eye can see stars of magnitude about 6.5. The digital sensors of the Hubble Telescope staring for long exposure times can see objects fainter than magnitude 30. That's over two and a half trillion times fainter than a human can see. The aptly named OWL Telescope (Overwhelmingly Large Telescope) now in the planning stage is expected to see to the 38th magnitude. Only electronic sensors, not human eyes or silver halide plates, will ever receive its images. The astronomer need not even be present at the telescope when the images he has requested are being acquired. He may be in his office half a world away, "seeing" through OWL on his computer screen.

Scientists need new tools to study new fields. They rely on imaging scientists for help. Biologists ask optical scientists for microscopes capable of revealing finer details. Astronomers want telescopes with more power to grasp the feeble light of distant galaxies. Scientists of all stripes ask for detectors that are not limited to the visible spectrum, detectors that will lift faint signals from noisy backgrounds. Imaging scientists take up these challenges.

This interplay of science and image making was well understood by Dr. C.E.K. Mees, Kodak's first director of research and holder of that position for over forty years. Great commercial success was gained by applying science to the invention of new photographic products. Paraphrasing Mees: "Science has been good to Photography, and Photography should be good to Science." Guided by that motto, he made many special films and emulsions for scientists with no regard for profitability. Indeed, many such materials were given to scientists free of charge. That all sounds very altruistic, but sometimes there were unexpected rewards. A technique learned while making a special emulsion for an astronomer was later adapted to produce one of the most successful films ever made for general photography, Kodak Tri-X. There were also non-tangible rewards from making special materials for Science. One special spectroscopic plate produced for astronomers doubled the size of the knowable universe at one stroke! The reward for that was the satisfaction and pride in literally advancing the frontiers of knowledge.

Amplifying Human Vision

There is a difference in the manner in which human eyes and manmade sensors respond to light. After the first few minutes in very dim light the eye becomes dark-adapted, and it sees things not at first visible when the lights went out. However, no amount of staring after that will reveal more. Chemical and electronic sensors can do better than that. The longer they stare, the more they can see. Unlike our eyes, they are able to continue to collect and store light. There is an old truism: "If you can see it, you can photograph it." Today an imaging scientist would add, "Even if you can't see it, you can probably photograph it."

Imaging scientists are most successful when the technology they develop for us is invisible to us. Much of our daily business depends on document copying. This is a function we all take for granted, not even thinking of it as a form of photography. The original Xerox copying machines depended on the light sensitivity of selenium. These machines are now digital. Looking back before Xerox in the history of the document copying field we find Photostat machines that used silver halide, also the blueprint process depending on the light sensitivity of iron compounds, and the whiteprint (blueline) process using diazonium compounds. Digital imaging here too has swept these earlier systems onto the junk pile.

The Spectrum of Imaging

The spectacular images of human's first venture to the Moon convinced American taxpayers that NASA's huge budget was worthwhile after all. Prior to that, Moon-orbiting cameras sent images that prepared the way for human landing. The citizenry came to love the Hubble Telescope after seeing its stunning views of beautiful galaxies, helping to save the instrument beyond its scheduled date for decommissioning. Cameras can go where humans have not yet been able to go, or will never go: thermal vents lying miles deep in the sea, the surfaces of Mars and the Moon. Cameras the size of a vitamin pill can be swallowed by sufferers with gastric diseases. These tiny cameras with built-in television transmitters send detailed images of the interior of the alimentary canal to tell surgeons exactly where the trouble lies.

The influence of scientific and technological imaging in our lives is staggering. Let's name some applications:

- ♦ The entire Earth is being mapped by satellite and low-altitude cameras to a degree of accuracy and detail impossible with land-based surveying.
- ♦ The core of each of today's electronic marvels is a computer chip that is actually manufactured solely by imaging processes – lenses projecting images on sensitive materials at extremely short ultraviolet wavelengths.
- ♦ The properties of nanostructures, claimed to be the wonder materials of coming technology, are studied mainly by electron microscope images.
- ♦ Molecular biology, using the images of fluorescence microscopy linked to intracellular molecules, is transforming our understanding of life itself.
- ♦ Jurisprudence relies increasingly on imaging technology to solve crimes and present evidence.
- ♦ Proof of identity through automatic fingerprint or retinal imaging seems soon to replace facial photographs for security purposes.
- ♦ Magnetic resonance imaging relates specific areas of the brain in real time to dynamic thought processes.

Using various imaging processes a scientist can detect or measure the position, orientation, color, temperature, speed, acceleration, chemical composition, state of health, distance, identity, internal structure, change-over-time, and other properties of the object he studies.

Changing Methods of Image Making

For over a hundred years, the great versatility of silver diverted photographic manufacturers from exploring other light-sensitive materials. Scientists in computer firms had no such veneration of silver. They used computer-chip technology to produce light-sensitive arrays on silicon wafers. These charge-coupled devices (CCDs) have evolved over the last several decades to the point where they have almost totally replaced silver halide technology for many applications. These electronic imaging systems store their images digitally in computer memory chips for viewing on computer screens or for printing with ink-jet technology. The wet processing of silver halide materials is virtually extinct, practiced by a few fine-arts photographers. Most photography through microscopes and all astrophotography are now done with electronic sensors. Digital cameras are the overwhelming choice of snapshotters and professional photographers today. Most cellular phones contain digital cameras.

Are today's imaging scientists, caught up in applying electronic digital techniques, perhaps overlooking the next technology that could replace it? Could Nature's living biological imaging systems provide a key to an imaging system of the future? Will something undreamed of supplant today's systems? Open minds will answer that. It seems likely that science and image making will continue their mutually beneficial relationship.

Author

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