13

Technoconstruction

Moving now from the implicit hermeneutics within science praxis to the more complex practices—increasingly technologically embodied and instrumentally constructed—we are ready to take note of a stronger program.

1. The "Strong Program": Hermeneutic Sophistication

In the "weak program" I chose to outline what could easily be recognized as hermeneutic features operative within science. As I now turn to a stronger program, I shall continue to examine certain extant features within science practice which relate to hermeneutic activity, but I shall increasingly turn here to forefront modes of investigation which drive the sciences closer to a postmodern variant upon hermeneutics.

A. Whole body perception

It is, however, also time to introduce more fully, albeit sketchily, a phenomenological understanding of perception in action. This approach will be recognizably close to the theory of perception developed by Merleau-Ponty, although taken in directions which include stronger aspects of multistability and polymorphy, which earlier investigations of my own developed.

1. I have already noted some perceptual *Gestalt features,* including the presentation of a perceptual field, within which figure/ground phenomena may be elicited. Following a largely Merleau-Pontean approach, one notes that fields are always complexly structured, open to a wide variety of intentional interests, and bounded by a horizonal limit. Science, I have claimed, in its particular style of knowledge construction, has developed a visualist hermeneutic which in the contemporary sense has

fulfilled its interests through *imagery* constituted instrumentally or technologically. The role of repeatable, Gestalt patterns, in both isomorphic and graphic directions, is the epistemological product of this part of the quest for knowledge.

2. In a strong sense, all sensory fields, whether focused upon in reduced "monosensory" fashion, or as ordinarily presented in synthesized and multidimensional fashion, are *perspectival* and concretely *spatial-temporal.* Reflexively, the embodied "here" of the observer not only may be noted but is a constant in all sensory perspectivalism. This constant may be enhanced only by producing a string of interrelated perspectives, or by shifting into multiperspectival modes of observation. The "ideal observer," a "god's eye view," and nonperspectivalism do not enter a phenomenology of perception.

3. However, while a body perspective relative to the perceptual field or "world" is a constant, both the field and the body are *polymorphic* and *multistable.* In my work in this area, I have shown that multistability is a feature of virtually every perceptual configuration (and the same applies to the extensions and transformations of perception through instrumentation), and that the interrelation of bodily (microperceptual features) and cultural significations (macroperceptual features) makes the polymorphy even more complex. *There is no perception without embodiment; but all embodiment is culturally and praxically situated and saturated.*

4. While I have sometimes emphasized spatial transformations (Galileo's telescope) in contrast to temporal transformations (still photography), all perceptual spatiality is *spatial-temporal.* This space-time configuration may be shown with different effects, as in contrasts between visual repeatability and auditory patterning, but is a constant of all perceptions.

5. All perceptual phenomena are synesthetic and multidimensioned. The "monosensory" is an abstraction—although useful and possible to forefront—and simply does not occur in the experience of the "lived body" (*corps vécu).* The same applies, although not always noted, in our science examples. I will say more below on this feature of perception. The issue of the "monosensory" is particularly acute with respect to the technological embodiments of science, since instruments (not bodies) may be "monosensory." Again, we reach a contemporary impasse which has been overcome only in part. Either we turn ingenious in the ways of "translating" the spectrum of perceptual phenomena into a visual hermeneutic—perhaps the dominant current form of knowledge construction in science—or we find ways of enhancing our instrumental reductions through variant instruments or new modes of perceptual transformation (I am pointing to "virtual reality" developments here).

A "strong program," I am hinting, may entail the need for breakthroughs whereby a fuller sense of human embodiment may be brought into play in scientific investigations. Whereas the current, largely visualist hermeneutic within science may be the most sophisticated such mode of knowledge construction to date, it remains short of its full potential were "whole body" knowledge made equally possible. This would be a second step toward the incorporation of lifeworld structures within science praxis.

B. Instrumental phenomenological variations

In the voice metaphor I used to describe the investigation of things, I noted that the "giving of a voice" entails, actually, the production of a "duet" at the least. But this also means that different soundings may be produced, either in sequence or in array, by the applications of different instruments. This is a material process which incorporates the practice of "phenomenological variations" along with the intervention within which a thing is given a voice. This practice is an increasing part of science practice and is apparent in the emergence of a suite of new disciplines which today produce an ever more rapid set of revolutions in understanding or of more frequent "paradigm shifts."

I use this terminology because it is a theme which regularly occurs in science reporting. A Kuhnian frame is often cast over the virtually weekly breakthroughs which are reported in *Science, Scientific American, Nature,* and other magazines. Challenges to the "standard view" are common. I shall look at a small sample of these while relating the challenges to the instrumental embodiments which bring about the "facts" of the challenges. Here the focus is upon *multiple instrumental arrays* which have different parameters in current science investigation.

1. *Multiple new instruments/more new things.* The development of multivariant instruments has often led to increased peopling of the discipline's objects. And much of this explosion of scientific ontology has occurred since the mid–twentieth century. This is so dramatically the case that one could draw a timeline just after World War II, around 1950 for most instrumentation, and determine new forms for many science disciplines. For example, in astronomy, until this century, the dominant investigative instrumentation was limited to *optical* technologies and thus restricted to the things which produce *light.* With the development of *radio-telescopy,* based upon technologies developed in World War II—as so many fields besides astronomy also experienced—the field expanded to the forms of microradiation which occur along spectra beyond the

bounds of visible light. *The New Astronomy* makes this "revolution" obvious. The editors note that

> The range of light is surprisingly limited. It includes only radiation with wavelengths 30 per cent shorter to 30 per cent longer than the wavelength to which our eyes are most sensitive. The new astronomy covers radiation from extremes which have wavelengths less and one thousand-millionth as long, in the case of the shortest gamma rays, to over a hundred million times longer for the longest radio waves. To make an analogy with sound, traditional astronomy was an effort to understand the symphony of the Universe with ears which could hear only middle C and the two notes immediately adjacent.[1]

Without noting which instruments came first, second, and so on, expanding out from visible light, first to ultraviolet on one side, and infrared on the other, now reaching into the previously invisible-to-eyeball perceptions, but still within the spectrum of optical light waves, the first expansion into invisible light range occurs through types of "translation" technologies as I have called them. The usual tactic here is to "constitute" into a *visible depiction* the invisible light by using some convention of *false color* depiction.

The same tactic, of course, is used once the light spectrum itself is exceeded. While some discoveries in radio astronomy were made by *listening* to the radio "hiss" of background radiation, it was not long before the gamma-to-radio wavelengths beyond optical capacities were also "translated" into visible displays.

With this new instrumentation, the heavens begin to show phenomena previously unknown but which are familiar today: highly active magnetic gas clouds, radio sources still invisible, star births, supernovas, newly discovered superplanets, evidence of black holes, and the like. The new astronomy takes us closer and closer to the "birth" of the universe. More instruments produce more phenomena, more "things" within the universe.

The same trajectory can be found in many other science disciplines, but for brevity's sake I shall leave this particular example as sufficient here.

2. *Many instruments/the same thing.* Another variant, now virtually standard in usage, is to apply a range of instruments which measure different processes by different means to the same object. Medical imaging is a good example here. If some feature of the brain is to be investigated, perhaps to try to determine without surgical intrusion whether a

formation is malignant or not, multiple instrumentation is now available to enhance the interpretation of the phenonomenon. A recent history of medical imaging, *Naked to the Bone,* traces the imaging technologies from the inception of X-rays (1896) to the present.

As noted above, X-rays allowed the first technologized making of the body into a "transparent" object. It followed the pattern noted of preparing the phenomenon for a scientific "reading" or perception. Early development entailed—to today's retrospective horror—long exposures, sometimes over an hour, to get barely "readable" images sometimes called "shadowgraphs." This is because X-ray imaging relies upon radiation sent through the object to a plate, and thus the degrees of material resistance cast "shadows" which form the "picture." The earliest problems focused upon getting clearer and clearer images.[2]

I have noted that the microscope became useful only when the specimen could be prepared for "reading" through a dye process which enhanced contrasting or differentiated structures (in the micro-organism). This image enhancement began to occur in conjunction with X-rays as early as 1911 with the use of *radioactive tracers* which were ingested or injected into the patient. This was the beginning of nuclear medicine (304).[3]

Paralleling X-ray technologies, *ultrasound* began to be explored with the first brain images produced in 1937 (310). The quality of this imaging, however, remained poor since bone tended to reduce what could be "seen" through this sounding probe. (As with all technologies, it takes some time before the range of usefulness is discovered appropriate to the medium. In the case of ultrasound, soft tissue is a better and easier-to-define target.)

But, even later than the new astronomy, the new medical imaging does not actually proliferate into its present mode until the 1970s. Then, in 1971 and 1972, several patents and patent attempts are made for magnetic resonance processes (MRIs) (314). These processes produce imagery by measuring molecular resonances within the body itself. At the same moment, the first use of the computer—*as a hermeneutic instrument*—comes into play with the refinement of *computer-assisted tomography* (CT scanning). Here highly focused X-ray beams are sent through the object (brains, at first), and the data are stored and reconstructed through computer calculations and processes. Computer-"constructed" imaging, of course, began in the space program with the need to turn data into depictions. Kevles notes that

> After the Apollo missions sent back computer-reconstructed pictures of the moon, it did not stretch the imagination to propose that computers

> could reconstruct the images of the interior of the body, which, like pictures from space, could be manipulated in terms of color and displayed on a personal video moniter. (143–44)

Here mathematics and imagery or constructed perceivable depictions meet. I claim this is important to a strong hermeneutic program in understanding science.

By 1975 the practical use of positron emissions is captured in the PET scan process. These emissions (from positrons within the object) are made visible (314). This imagery has never attained the detail and clarity of the above technologies but has some advantage in a dynamic situation when compared to the "stills" which are produced by all but ultrasound processes (and which also are limited in clarity). Thus living brain *functions* can be seen through PET instrumentation. Then, in the 1990s, functional MRI and more sophisticated computer tomographic processes place us into the rotatable, three-dimensional depictions which can be "built up" or "deconstructed" at command, and the era of the *whole body image* is attained (314).

While each of these processes can show different phenomena, the multiple use is such that ever more complete analysis can also be made of single objects, such as tumors, which can be "seen" with differences indicating malignancy or benignity. This, again, illustrates the ever more complex ways in which science instrumentation produces a visible result, a visual hermeneutics which is the "script" of its interpretive activity.

3. *Many instruments/convergent confirmations.* Another variant upon the multiple instrument technique is to use a multiplicity of processes to check—for example, dating—for greater agreement. In a recent dating of Java *homo erectus* skulls, uranium series dating of teeth, carbon 14, and electron spin resonance techniques were all used to establish dates much more recent (27,000 B.P. +/- 53,000 B.P. for different skulls) than previously determined and thus found *homo erectus* to be co-extant with *homo sapiens sapiens.*[4] And, with the recent discovery of 400,000 B.P. javelin-like spears in Germany, one adds thermo-luminescence techniques to establish this new date for human habitation in Europe, at least double or triple the previously suspected earliest date for humans there. (Similar finds, now dated 350,000 B.P. in Siberia, and 300,000+ B.P. finds in Spain, all within 1996–97 discovery parameters, evidence this antiquity.)[5]

4. *Single instrument (or instrumental technique)/widespread multiple results.* Here perhaps one of the most widely used new techniques involves DNA "fingerprinting," which is now used in everything from forensics (rapists and murderers both convicted and found innocent and released), to pushing dates back for human migrations or origins. (The

"reading" process which goes with DNA identification entails matching pairs and includes visualizations once again.) *Scientific American* has recently reported that DNA tracing now shows that human migrations to the Americas may go back to 34,000 years (not far from the dates claimed for one South American site, claimed to be 38,000 B.P., which with respect to physical data remain doubtful), with other waves at 15,000 B.P., to more recent waves, included a set of Pacific originated populace around 6,500 B.P.)[6] The now widely cited DNA claims for the origins of *homo sapiens* between 200,000 and 100,000 B.P. is virtually a commonplace.

DNA fingerprinting has also been used in the various biological sciences to establish parentage compared to behavioral mating practices. One result is to have discovered that many previously believed-to-be "monogamous" species are, in fact, not. Similarly, the "Alpha Male" presumed successful at conveying his genes within territorial species has been shown to be less dominantly the case than previously believed.[7]

5. *Multiple instruments/new disciplines.* Beginning with DNA (mitochondrial DNA matching) again, the application of this technique has given rise to what is today called "ancient DNA" studies, with one recent result developed in Germany this year, which purports to show that Neanderthals could not have interbred with modern humans, due to the different genetic makeup of these hominids who coexisted (for a time) with modern humans.[8]

Then, returning to variants upon imaging, the new resources for such disciplines as archeology produce much more thorough "picturing" of ancient sites, activities, and relations to changes in environmental factors. Again, drawing from *Scientific American*—one can draw similar examples from virtually every issue of this and similar science-oriented magazines—the array of instruments now available produces, literally, an "in-depth" depiction of the human past. In part, now drawing from uses originally developed for military purposes, imaging from (1) *Landsat,* which used digital imaging and multispectral scanners from the 1970s, to (2) refinements for *Landsats 4* and *5* in the 1980s, which extended and refined the imaging and expanded to infrared and thermal scanning, (3) to *SPOT,* which added linear-array technologies to further refine imaging, to (4) imaging radar, which actually penetrates below surfaces to reveal details, to (5) *Corona,* which provides spectrographic imagery (recently declassified), the modern archeologist, particularly desert archeologists, can get full-array depictions of lost cities, ancient roads, walls, and the like from remote sensing used now.[9]

Once located, instrumentation on Earth includes (1) electromagnetic sounding equipment, which penetrates up to six meters into the earth, (2) ground-penetrating radar, which goes down to ten meters,

(3) magnetometers, which can detect such artifacts as hearths, (4) resistivity instruments, which detect different densities and thus may be used to locate artifacts, and (5) seismic instruments, which can penetrate deeper than any of the above instruments. At a recent meeting in Mexico, an anthropologist reported to me that a magnetometer survey of northern Mexico has shown there to be possibly as many as 86,000 buried pyramids (similar to the largest, Cholula, although the remainder are smaller).[10]

In short, the proliferation of instrumentation, particularly that which yields imagery, is radical and contemporary and can now yield degrees and spans of three-dimensional imagery which includes all three of the image breakthroughs previously noted: early optics magnified the micro- and macro-aspects of barely noted or totally unnoted phenomena through magnification (telescopy and microscopy) but remained bound to the limits of the optically visible, by producing "up close" previously distant phenomena.

Photography increased the detail and isomorphy of imaging in a repeatable produced image, which could then be studied more intensely since "fixed" for observation. It could also be manipulated by "blowups" and other techniques, to show features which needed enhancement Then, with X-rays, followed by other interior-producing imagery, the possibilities were outlined for the contemporary arrays by which image surfaces are made transparent so that one may see interiors. Then add the instruments which expand thoroughly beyond the previously visible and which now go into previously invisible phenomena through the various spectra which are "translated" into visible images for human observation.

Here we have the decisive difference between ancient science and Modern science: Democritus claimed that phenomena, such as atoms, not only were in fact imperceptible, but were *in principle* inperceptible. A modern, technologized science returns to Democritus to the "in fact" only—that is, the atomic is invisible only until we can come up with the technology which can make it visible. This, I claim, is an instrumental *visual hermeneutics.*

C. Technoconstitution

In the reconstrual of science which I have been following here, I have argued that late Modern science has developed a complex and sophisticated system of *visual hermeneutics.* Within that visualist system, its "proofs" are focused around the things seen. But, also, things are never just or merely seen—the things are *prepared* or made "readable." Scientifically, things are (typically, but not exclusively) *instrumentally mediated,* and the "proof" is often a *depiction* or image.

Interestingly, if in ordinary experience there is a level of *naive realism* where things are taken simply to be what they are seen to be, similarly, within imaging there is at least the temptation to an imaging naive realism. That naïveté revolves around the intuitive taking of the image to be "like" or to "represent" an original (which would be seen in unmediated and eyeball perceptions). In short, "truth" is taken to be some kind of *isomorphism* between the depiction and the object.

By putting the issue in precisely that way, there are many traps which are set which could lead us back into the issues of modern (that is, Cartesian or seventeenth- and eighteenth-century) epistemologies. But to tackle these would lead us into a detour of some length. It would entail deconstructing "copy theory" from Plato on, deconstructing "representationalism" as the modern version of copy theory, before finally arriving at a more "postmodern" theory which entails both a theory of relativistic intentionality, a notion of perspectivalism, and an understanding of instrumental mediations as they operate within a phenomenological context. (I have addressed these issues in some degree in essays which preceded my formulation here.).[11] I simply want to avoid these traps.

To do so, I shall continue to interpret science in terms of a visual hermeneutics, embodied within an instrumentally realistic—but *critical*—framework in which instruments mediate perceptions. The device I shall now develop will fall within an idealized "history" of imaging, which, while containing actual chronologically recognizable features, emphasizes patterns of *learning to see.*

1. Isomorphic visions

The first pattern is one which falls into one type of *initial isomorphism* within imaging. As a technical problem, it is the problem of getting to a "clear and distinct" image. Imaging technologies do not just happen, they develop. And in the development there is a dialectic between the instrument and the user in which both a learning-to-see meets an elimination-of-bugs in the technical development. This pattern is one which, in most abstract and general terms, moves from initial "fuzziness" and ambiguity to greater degrees of clarity and distinctness.

Histories of the telescope, the microscope, photography, and X-rays (and, by extension, all the other imaging processes as well) are well documented with respect to this learning-to-see. Galileo, our quasi-mythical founder of early Modern science, was well aware of the need to teach telescopic vision, and of the problems which existed—although he eventually proclaimed the *superiority* of instrumentally mediated vision over ordinary vision. The church fathers, however, did have a point about how to take what was seen through the telescope. Not all of Galileo's observations were clear and easily seen by "any man." The same problem reemerged in the nineteenth century through the observations of Giovanni Schiaparelli, who gave the term the "canals of Mars." Schiaparelli was a well-known astronomer who had made a number of important discoveries, particularly with respect to asteroids and meteor swarms (because, in part, he had a much better telescope than Galileo). But in noting "canali"—which should have been translated into "channels"—which were taken to be "canals"—he helped stimulate the speculations about life on Mars. But neither channels nor canals existed—these, too, were instrumental artifacts.[12]

The dialectic between learning and technical refinement, in the successful cases, eventually leads to the production of clear and distinct images and to quick and easy learning. These twin attainments, however, cover over and often occlude the history and struggle which preceded the final plateaus of relative perfections. Thus, as in the previous illustrations concerning my guests and our Vermont observations of the Moon, once focused and set, it literally takes only instants before one can recognize nameable features of its surface. The "aha phenomenon," in short, is virtually immediate today because it is made possible by the advanced technologies. That instantaneity is an accreted result of the hidden history of learning-to-see and its accompanying technical debugging process.

This same pattern occurred with the microscope. Although microorganisms never before seen were detected early, the continued problems of attaining clear and distinct microscopic vision was so difficult that it did not allow the microscope to be accepted into ordinary scientific practice until the nineteenth century. Again, the dialectic of learning how and what to see meets the gradual technical improvement concerning lenses and focusing devices, and finally the application of dying procedures to the things themselves. (This is an overt example of preparing a thing to become a scientific or "readable" object!)

Photography stands in interesting contrast to microscopy—if it took a couple of centuries for microscopy to become accepted for scientifically acceptable depiction, photography was much faster to win the same position. From Niepce's first "fixed" image in 1826, to the more widely accepted date of 1839 for Daguerre's first images, it was less than a half century until, as Bettyann Kevles notes in her history of medical imaging, "By the 1890's photographs had become the standard recorders of objective scientific truth."[13]

The same pattern occurs, but with even greater speed, in the history of early X-rays. In publicizing his new invention, Wilhelm Röntgen made copies of the X-ray of his wife's hand, which showed the bones of her fingers and the large ring which she wore, and sent these to his colleagues across Europe as evidence of his new process. That X-ray (with a long exposure time) was fuzzy, and while easily recognizable as a skeletal hand and ring, contrasts starkly with the radiograph made by Michael Pupin of Prescott Butler's shot-filled (shotgun-injured) hand later the same year (21, 35). X-rays, duplicated across Europe and America almost immediately after Röntgen's invention, were used "scientifically" from the beginning.

The acceleration of acceptance time (of the learning-technical vision dialectic) similarly applies to the recent histories of imaging, which include, as above, sonograms (1937) and MRIs (1971) in medicine, of remote imaging since the *Tiros* satellite (1965), or of digitally transmitted and reconstructed images from *Mariner 4* (1965) in Earth and space science.

All of the above samples, however, remain within the range of the possible "naive image realism" of visual isomorphisms in which the objects are easily recognizable, even when new to the observer's vision. (Even if Röntgen had never before seen a "transparent hand" as in the case of his wife's ringed fingers, it was "obvious" from the first glimpse what was seen.) The pattern of making clear is an obvious trajectory. Yet we are not quite ready to leave the realm of the isomorphic.

How does one make "clearer" what is initially "fuzzy"? The answer lies in forms of manipulation, what I shall call *image reconstruction*. The techniques are multiple: enlargements (through trajectories of magnification noted before), enhancements (where one focuses in upon particular features and finds ways to make these stand out), contrasts (by heightening or lessening features of or around the objects), and so on. In my examinations I shall try not to be comprehensive, but to remain within the ranges of familiarity (to at least the educated amateur) concerning contemporary imaging. All of these manipulations can and do occur within and associated with simply isomorphic imaging and, for that matter, within its earlier range of black-and-white coloring. Histories of the technical developments which go with each of these techniques are available today and provide fascinating background to the rise of scientific visualism.

The moral of the story is images don't just occur. They are made. But, once made—assuming the requisite clarity and accuracy and certification of origin, etc.—they may then be taken as "proofs" within the visual hermeneutics of a scientific "visual reading." We are, in a sense, still within a Latourean laboratory.

2. Translation techniques

Much of what can follow in this next step has already been suggested within the realm of the isomorphic. But what I want to point to here is the use in late Modern science of visual techniques which begin ever more radically to vary *away from the isomorphic.*

One of these variables is—if it could be called that—simply the variable use of *color.* Returning to early optics, whatever Galileo or Leeuwenhoek saw, they saw in "true color." And, as we have seen, sometimes that itself was a problem. The transparent and translucent micro-organisms in "true color" were difficult to see. With aniline dyes, we have an early use of "false color." To make the thing into a scientific or "readable" object, we intervene and create a "horse of a different color." "False coloring" becomes a standard technique within scientific visual hermeneutics.

The move away from isomorphism, taken here in gradual steps which do not necessarily match chronologically what happened in the history of science, may also move away from the limits of ordinary perception. As noted above, the "new" late Modern astronomy of midcentury to the present was suddenly infused with a much wider stretch of celestial "reality" once it moved beyond optical and visible limits into, first, the humanly invisible ranges of the still optical or light itself, in the ranges of the infrared and ultraviolet. The instrumentation developed was what I have been calling a *translation technology* in that the patterns which are recordable on the instrumentation can be rendered by "false coloring" into visible images. This same technique was extended later to the full wave spectrum now available from gamma rays (short waves) through the optical to radio waves (long waves), which are rendered in the standard visually gestaltable, but false color, depictions in astronomy. All this is part of the highly technologized, instrumentalized visual hermeneutics which makes the larger range of celestial things into seeable scientific objects.

The "realism" here—and I hold that it is a realism—is a Hacking-style realism: if the things are "paintable"[14] (or "imagable") with respect to what the instruments detect as effects which will not go away, then they are "real." But they have been *made visible* precisely through the technological constructions which mediate them.

3. Higher level construction

Within the limits of the strong program, I now want to take only two more steps: I am purposely going to limit this attempt to reconstrue science praxis as hermeneutic to contemporary imaging processes which make (natural) things into scientific, and thus "readable," visual objects. I am not going to address the related, but secondary, visual process which entails *modeling.* That process which utilizes the computer as a hermeneutic device is clearly of philosophical interest, but I shall stop short of entering that territory here.

Computers, of course, are integral to many of the imaging processes we have already mentioned. Medical *tomography* (MRI, PET, fMRI, etc.) entails computer capacities to store and construct images. What is a visual Gestalt is built up from linear processes which produce data which have to be "constructed" by the computer. Similarly, the digitally transmitted imagery from distance sensing in satellite, space, and other remote imaging processes also has necessary computer uses. Much of contemporary imaging is computer embodied. And computers open the ways to much more flexible, complex, and manipulable imaging than any previous technology. For the purposes here, however, they will remain simply part of the "black boxes" which produce images which mediate perceptions.

The two higher-level constructive activities I want to point to here entail, first, the refinement of imaging which can be attained through specifically recognizing our technologies as mediating technologies which, in turn, must take into account the "medium" through which they are imaging. I turn again to astronomical imaging: the *Hubble* space telescope has recently captured the most public attention, but it is but one of the instrumental variations which are today exploring the celestial realms.

The advantage *Hubble* has is that it is positioned beyond the effects of the atmosphere with its distortions and interferences—the clarity of *Hubble* vision in this sense is due in part to its extra-Earthly perspective. (Science buffs will recall that at launch it had several defects in operation which were subsequently fixed—thus placing the *Hubble* in the usual pattern of needing technical adjustment to make its images clear!) But, in part by now being able to (phenomenologically) vary *Hubble* with Earth-bound optical telescopes, the move to enhancing Earth-bound telescopy through computer compensations has become possible. Astronomy is moving toward technoconstructions which can account for atmospheric distortions "on the spot" through a combination of laser targeting and computer enhancements. Earth-bound telescopes are today being given new life through these hi-tech upgrades which "read" atmospheric distortions and "erase" these processes which can make clearer new "readable" images. *Science* regularly publishes an "imaging" issue devoted to updating what is taken as the state-of-the-art in imaging (in 1997 it was the 27 June issue). A description of how one "undoes the atmosphere" is included, which entails computer reconstructions, telescopes in tandem, and adaptive optics. This process, *Science* claims, "combat[s] the warping effects of gravity on their giant mirrors . . . reclaims images from the ravages of the atmosphere . . . [and] precisely undoes the atmospheric distortions."[15]

But alongside *Hubble* are the other variants: the infrared space observatory, the *Cosmic Background Explorer*, and other satellite instrumentation which produces imagery from the nonoptical sources. All these technologies are variants upon the same multidimensioned variables which produce readable images, or make things into readable scientific objects.

The final set of instrumental productions I wish to note are the *composites* which produce variants upon "wholes." Chapter 4 deals with "whole Earth measurements" which constitute one realm of composite imagery. To determine whether or not sea levels are rising overall, the composite imagery produced combines (1) multiple satellite photo imagery, (2) Earth-bound measurements (such as buoys, laser measurements, and land markers), and (3) computer averaging processes to produce a depiction (false colored) which can, in comparing time slices, show how much the oceans have risen. The composite depiction displays a flat-projection map of the Earth with level plateaus in false color spectra which can be compared between years, decades, and so on.

Similar processes occur in medical imaging. The "whole body imagery" available today on the internet is the result of two full-body "image autopsies," one each of a male and a female, whose bodies through tomographic processes may be seen in whatever "slice" one wishes. The linear processes of tomography show, slice-by-slice, vertically, horizontally, or in larger scans, the full bodies of the corpses used. The dimensions can be rotated, realigned, sectioned, and so on. Tomography also allows one to "peel," layer by layer, the object imaged—from skin, to networked blood vessels, to bones, and so on. (Both the whole Earth and whole body images are probably among the world's most expensive "pictures.") Moreover, all the manipulations which entail enhancements, contrasts, colorings, translations, and the like are utilized in these "virtual" images. Yet, while these virtual "realities" are different from the examination of any actual cadaver, they clearly belong to the visual hermeneutics of science in the strong sense. Things have been prepared to be seen, to be "read" within the complex set of instrumentally delivered visibilities of scientific imaging.

Chapter 13

1. Nigel Henbest and Michael Marten, *The New Astronomy*, 2d ed. (Cambridge, 1996), p. 6.

2. Bettyann Holtzmann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, N.J., 1997), p. 20.

3. Kevles provides a time chart, paralleling the various developments in the multiple imaging instrumentation.

4. *Science* 274 (13 December 1996): 1870–73.

5. *Science* 276 (30 May 1997): 1331–34.

6. *Scientific American* 276 (August 1997): 46–47.

7. *Science* 243 (31 March 1989): 1663.

8. *Science* 277 (11 July 1997): 176–78.

9. *Scientific American* 276 (August 1997): 61–65.

10. The visit to the Cholula pyramid and conversations with anthropologists occurred during the 9th International Conference of the Society for Philosophy and Technology, November 1996.

11. Postmodernism is more thoroughly discussed in *Postphenomenology* (Evanston, 1993).

12. *Micropaedeia, Encyclopaedia Britannica,* 15th ed. (Chicago, 1994), vol. 10, p. 514.

13. Kevles, *Naked to the Bone,* p. 15.

14. I refer to Hacking's "if you can spray them then they are real" in *Representing and Intervening* (Cambridge, 1983), p. 23.

15. *Science* 276 (27 June 1997): 1994. This rhetoric is an example of the more-than-neutral language often employed by science reporting.

Chapter 14

1. Bettyann Holtzmann Kevles, *Naked to the Bone: Medical Imaging in the Twentieth Century* (New Brunswick, N.J., 1997), p. 13.

2. Zermeiz is well known in biological circles for his pioneering work in ecology and evolution.

3. *Scientific American* 276 (June 1997): 84–87.

4. Internet printout from Lynx site provided by Marshall Spector.

5. Edward Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences* (New York, 1996), pp. 43–44.

6. See Robert Crease, *The Play of Nature* (Bloomington, Ind., 1993), especially chapter 4.

Afterword

1. Larry Laudan, perhaps as good a spokesman for these positions as any, repeated affirms the fallibilist consensus for all the interlocuters in his *Science and Relativism* (Chicago, 1990).