Science in the Age of Mechanical Reproduction: Moral and Epistemic Relations Between Diagrams and Photographs

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ABSTRACT: Sociologists, philosophers and historians of science are gradually recognizing the importance of visual representation. This is part of a more general movement away from a theory-centric view of science and towards an interest in practical aspects of observation and experimentation. Rather than treating science as a matter of demonstrating the logical connection between theoretical and empirical statements, an increasing number of investigations are examining how scientists compose and use diagrams, graphs, photographs, micrographs, maps, charts, and related visual displays. This paper focuses on diagrams in biology, and tries to demonstrate how diagrams are an integral part of the production of scientific knowledge. In order to disclose some of the distinctive practical and analytical uses of diagrams, the paper contrasts the way diagrams and photographs are used in biological texts. Both diagrams and photographs are shown to be "constructions" that separately and together mediate the investigation of scientific phenoman.

KEY WORDS: Diagrams, ethnomethodology, knowledge, photography, representation, science, sociology.

INTRODUCTION

Although it may strike some readers as an unusual subject for sociological research, visual representation turns out to be significant and relevant for investigations in the sociology of scientific knowledge. To understand why sociologists might be interested in this topic, it will be necessary to put aside the standard textbook definition of sociology as the scientific study of human beings in groups. This definition is simply too narrow to describe a substantial portion of the research in sociology of scientific knowledge, a field that is linked at least as closely to the history and philosophy of science as it is to the overall discipline of sociology. Research in that field often makes a distinctive sociological contribution to discussions and debates on rationality, experimental procedure, observation, and representation. In contrast to philosophical epistemology, "epistemic sociology" (Coulter 1989) investigates the *pragmatic* and

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communicative production of knowledge, including the various textual and material artifacts through which knowledge is produced and objectified.[1]

Epistemic sociologists continue to pursue Karl Mannheim's (1936) mandate to study the existential determination of "thought," but many of them have grown increasingly dissatisfied with conceptions of knowledge that focus upon "ideas," "belief systems," "mind-sets" and "world-views". When defined as "justified true belief" or, less stringently, as an abstract cognitive structure shared by members of a community, *knowledge* seems beyond the reach of any study of tangible communicational practices. At the risk of seeming overly concrete, and perhaps profane, sociologists of scientific knowledge prefer to examine what *counts* as knowledge in particular circumstances. From this point of view, the term "knowledge" is a shorthand expression for heterogeneous orders of things, artifacts, and expressions. Such epistemic orders are public, and it makes little sense to assume that the "queer phenomenon of knowledge" is to be found (either literally or figuratively) in people's heads (Wittgenstein 1958:§363). To say that knowledge is in the *culture*, that it is *ideological* (in the non-pejorative sense of the term), or that it is a *spiritual legacy* of an era, is only slightly more satisfying. Although epistemic sociologists do not expect to collect concrete bits of knowledge to place under the microscope or preserve in formaldehyde, they act on the assumption that knowledge can be investigated by examining objectified communicational devices and practices. These include textual arguments, conversational routines, embodied skills, visual displays, organizational records, artifacts, and built environments. Knowledge is not identical with any of these tangible literary and pragmatic phenomena, but the organization and use of specific artifacts and communicational devices can have a great deal to do with rationality, reasoning, meaning, innovation, and related themes from intellectual history (Garfinkel 1988).

Consequently, epistemic sociology is neither sociology nor philosophy as usually conceived. Instead, it is a novel form of natural philosophy whose objects of interest include mundane communicational artifacts. There is no reason to suppose that this form of study will follow in the footsteps of seventeenth century physics or nineteenth century natural history, since the phenomena of study are radically different. Like natural philosophers, epistemic sociologists try to bring empirical modes of investigation to bear upon the classic themes, distinctions, and debates in philosophy, but they do not simply use observation and representation to describe independent natural objects. Among other things, they investigate how observation and representation are *themselves* done. Nobody quite knows what it means to conduct such peculiar investigations, and there are plenty of debates on the subject (see the edited collections by Knorr-Cetina and Mulkay 1983; and Pickering, in press). Nevertheless, at least some of us agree that the initial task at hand is to begin to examine particular instrumentalities of knowledge.

As Garfinkel (1967) and Berger and Luckmann (1967) argue, the production of knowledge is an ordinary phenomenon, and the sociology of knowledge is no longer limited to studies on the "high" culture of the intelligentsia. Since people

from all walks of life engage in representational activities, from the point of view of the sociology of knowledge there is no reason to confer special status upon professional scientific and artistic endeavors. Nevertheless, a certain clarity can be gained by focusing on how scientists use representational artifacts. This is because, even the most "normal" of sciences continue to develop novel modes of representation and intervention. The daily struggle to achieve representational adequacy, to sort out signal from background, and to debug techniques and instruments, makes the natural science laboratory a particularly interesting place to make *sociological* observations. The natural science laboratory is also a sociological laboratory, not because if offers an environment in which a sociologist can make controlled observations by systematically manipulating the relevant variables, but because it is a site where problems in designing and using representational devices are put on display. Such problems can be extremely technical, so that a great deal of preparation may be necessary before a sociologist can understand and expound upon them, but they *are* sociologically investigable.

Investigations of scientists' representational practices offer the immediate payoff of a more refined understanding of classic philosophical themes. As I shall try to demonstrate in this paper, a detailed examination of visual representations of biological phenomena can sensitize us to complex relationships that are obscured in debates over whether scientists' representations "reflect" or "construct" the objects of study. Although detailed empirical investigations are not likely to bring the realist-constructivist debate to a close, they can enable a more differentiated conception of the phenomenon of representation. In this case, I shall argue that the question of realism *versus* constructivism is miscast, because it should not be posed in such a polarized fashion. As I hope to demonstrate, biologists' representations are *constructed to be realistic.* Moreover, representational realism is not a static phenomenon. As the history of art shows, artistic realism includes an abundance of painterly techniques and stylistic conventions which do not simply fall in line along a continuum from "non-realistic" to "completely realistic" (Gombrich 1960). Scientific realism is no less nuanced than artistic realism, and, in fact, scientists have often made use of artistic conventions and techniques for documenting observations and illustrating texts (Edgerton 1975; Alpers 1983).

As readers of this journal should appreciate, the practices of field and laboratory biology are "realist" in the sense that researchers unabashedly aim to describe and explain "real worldly" phenomena. But the question I want to address here, is *just how* are they realistic? Even though the commitment to representational realism is deeply entrenched in biology, as it is in any other science (Bastide 1990, p. 226), modalities of realism may vary across lines in a debate and from one time to another in a single line of investigation (Pinch 1985). A biologist may admit during a moment of philosophical reflection that everything she studies is an "artifact" of her research procedures, but this does not prevent her from assiduously searching her own and others' data for evidences of the more insidious kinds of artifact arising from erroneous or

haphazard techniques, extrinsic sources of noise, and instrumental mediation. Similarly, while biologists sometimes explicitly refer to their work as a matter of "construction" (cf. Cohen et al. 1973), they vigorously resist any suggestion that the objects they construct are unreal, or merely apparent, phenomena. Although particular distinctions between natural and constructed phenomena can become relevant in patent disputes and interpretive disputes between rival labs (Cambrosio et al. 1990), a "constructed" genetic sequence, strain of virus, or Harvard mouse is not essentially less real than a "natural" one. The distinction is deeply intertwined with work processes, but it does not necessarily point to an ultimate separation between orders of "reality".

Biologists representations are not transparent windows on an independent reality, since in many fields of biology, visual and other forms of representation are the only way phenomena can become materially witnessable. Researchers cannot directly observe living brain cells, ribosomes, strands of DNA, or bird migration routes without making use of complex procedures for technically visualizing these phenomena as picturable, graphable, mappable, or measurable configurations. Even the low-tech observations made by early ornithologists were mediated by methods of drawing and engraving (Farber 1982). In many cases there is no way to compare a representation of a biological phenomenon to the "real" thing, since the thing becomes coherently visible only as a function of representational work. Consequently, we can begin to appreciate that representation in science is far more pervasive than selecting illustrations for texts or drawing diagrams of what we can otherwise see with the naked eye. And "reality" is not an entirely independent standard of reference separate from representational work. To say this, however, does not imply that representations are complete fantasies, or even that they are especially problematic in many cases. The absence of absolute criteria for distinguishing constructions from natural reality simply means that the distinction is made circumstantially and for all practical purposes.

In the remainder of this essay I intend to demonstrate some of the variations in the *accent of reality* associated with two different modes of representation. One of these is what I shall call "manual reproductions". These are line drawings, tracings, and engraved diagrams. The other mode is what Benjamin (1969) called "mechanical reproductions," a category of representations including photographs, micrographs, and related imaging technologies.[2] Manual reproductions are generally produced through artistic handiwork by scientists or hired specialists, whereas mechanical reproductions utilize various recording instruments for automatically producing "unmediated" images. Although the latter modes of reproduction are associated with modern science, and modernity *as such*, diagrams continue to be used in laboratories and in scientific texts. I shall argue that their continued use has to do with the distinctive mode of realism they produce. This will be elucidated in reference to photo-diagram pairings of the "same" objects. After explicating the differences between photographs and diagrams, I will suggest that a merger of the two is currently being produced by the use of digital image processing. Before discussing

manual and mechanical modes of reproduction, I wall lay out some general remarks about contextual uses of diagrams.

CONTEXTUAL ORDERS OF DIAGRAMS

Diagrams are but one type of representation used in science. They are used together with photographs, sketches, tables, graphs, instrumental displays, and verbal and written discourse. Particular pictures or graphs are less significant as self-sufficient objects than as moments within a complex order of practices for visualizing and constructing phenomena. Two of the lessons drawn from ethnographic studies of scientific work are (1) that the referential sense and value of diagrams is contextually dependent; and (2) diagrams are constituents of a work process:

(1) Diagrams are not isolated representations. Although many sketches and pictures can easily be seen to resemble a familiar object of interest (a cellular organelle; an animal or plant of a particular species, age, or sex category; a complex tissue structure; the major organ systems of the human body), what a picture is *doing* in a textual representation is not disclosed by naming what it resembles. Many diagrams take the form of "conceptual" models of, for instance, a flow of ions across a membrane, a cycle of biochemical transformations, or a molecular sequence. At times, such images include symbolic, iconic and even fantastic features; for example, vectors, anthropomorphized cartoon figures, chemical formulae, and labels. Such hybrid combinations of schematic, pictorial, and verbal constituents make up what Gilbert and Mulkay (1984) call "working conceptual hallucinations." Even when a picture obviously resembles an object, just *how* it does so can be far from obvious when the picture is viewed in isolation. For instance, a picture of a seagull in flight can variously be used to illustrate the aerodynamics of flight, to display the characteristic field marks of a particular species or age-class of gull, to exemplify the basic anatomical features of birds, to demonstrate techniques of nature photography, or to give a pictorial inventory of typical constituents of a shoreline habitat. An appreciation of the picture's conceptual and documentary functions can be gained only when one places it within a cross-referential network. This network includes various other textual features – captions, headings, narratives, and other tables, graphs, photographs and pictures – as well as the practices within which these textual features have a role. The polysemous properties of pictures are readily grasped when one flips through an illustrated text and examines the pictures while covering-up the captions. Some pictures may include conventional clues for recognizing topics and themes, but in many cases what any picture is used to illustrate and how it functions as a representation remain elusive until one reads the caption, takes account of relevant chapter and section headings, and finds the textual passage that refers to the picture.

Just as some philosophers of language argue that linguistic statements express stable propositional contents independent of the occasions on which they are used, it might also be argued that pictorial features have literal meanings separate from their textual placement and pragmatic use. The problem with such treatments of both verbal and pictorial "language" is they presuppose the practical and textual contexts of those pictorial features. When the social use of a communicative object is coherent and stable it is far too easy to conclude that the object "contains" a stable meaning. The fragility of this assumption can be exposed when we follow how an "original" representation undergoes transformations of form, meaning, and pragmatic use. So, for instance, Audubon's bird illustrations become different objects when hung on the wall of a museum, reproduced in a folio edition of Audubon's works, copied for a text on the history of ornithology, printed on a postcard or stamp, printed on an announcement for a local meeting of the Audubon Society, or placed in a popular guide for identifying North American birds. Audubon's original artwork becomes aestheticized, commodified, fetishized, bowdlerized, and naturalized depending upon the textual sites, institutional settings and pragmatic contexts into which it is inserted. Each copy of the picture contributes to these social contexts while simultaneously deriving its particular illustrative and asesthetic functions from them.

For example, Ludlow (1950) selected 288 of Audubon's original folio of 435 different birds (Audubon, 1937), and then presented them in a pocket-sized edition. Ludlow (p. 28) states that he eliminated Audubon's portraits of "mere vagrants and waifs to our shores," and re-arranged the folio in "scientific" order, adding brief captions for each picture. He remarks that his book was not designed to be used as a "technical" field manual, but that it was intended to give the common reader both an appreciation of Audubon's artwork and an inventory of common American birds. Concerns about art and originality become subordinated when a book like Ludlow's is used as a field manual. The pictures are scaled-down to fit a portable size of the manual, and less care is taken to make faithful copies of the original artwork. Despite their artistic quality, Audubon's spectacular portraits may be less useful for quick identification of elusive specimens than the highly schematic drawings and paintings in a popular field manual (Peterson 1980, p. 7). While the pictures in some field manuals may evoke aesthetic appreciation, when they are used strictly as devices for identifying birds in the field they are not likely to be judged by the same criteria as original works of art. Instead, they will be evaluated in terms of how well they enhance the birdwatcher's pragmatic activity (Law and Lynch 1990). This is not to argue for a rigid separation between aesthetic and pragmatic considerations. To the contrary, it can be argued that "aesthetic" criteria for judging illustrations are always bound-up with pragmatic contexts (Lynch and Edgerton 1988). The 'high' aesthetic of the art museum is not the only source of conventions and standards for crafting illustrations and assessing their visual qualities.

(2) Diagrams are constituents of a work process. They are *used.* Although it may seem especially suitable to study diagrams by examining examples found in historically significant publications, *published* illustrations are not the only, or even the most common, form of pictorial display in scientific research. Lab researchers typically produce numerous sketches, data displays, micrographs, and other "inscriptions" that do not appear in their publications (Latour and Woolgar 1979). Such displays sometimes provide relatively "raw" forms of data, and they are assembled, examined, measured and analyzed over the course of laboratory projects. The resultant publications often present verbal, tabular, and graphic summaries of these data, but they usually include only a few illustrative diagrams or photographs of 'typical' specimens (cf. Lynch 1985b). Researchers select and prepare such portraits with an eye to particular audiences. Pictures in popularized magazines and elementary texts tend to be "glittery": large, glossy, colorful (and sometimes color enhanced), richly textured and naturalistic. Partly due to budgetary constraints on color illustrations, pictures in specialized journals tend to be small, black and white, graphic, and densely surrounded by text and equations. Beyond these economic considerations, scientists express aesthetic preferences for subdued imagery and a distaste for the "glitter" they associate with vulgar appreciations of science (Lynch and Edgerton 1988; also see Tufte 1983: 107ff. on "chartjunk"). Such professional conventions do not preclude careful selection and preparation of representative illustrations. In fact, data displays are often prepared with a careful attention to their cosmetic qualities and illustrative functions.

What counts as a "good" picture can depend upon the context in which it is used and the audience to which it is shown. "Messy" (artifact ridden) data displays can be judged sufficiently accurate for analytic purposes, even when they would never be shown to outsiders in their relatively "raw" form. In most cases, however, data are rarely used without first preparing and processing them for analysis. They are "cleaned up" and reoriented in order to make them look more "natural" and to facilitate measurement. These procedures necessarily involve assumptions about possible sources of data and sources of interference, so that the resultant processed image, to be used as data for subsequent phases of a project, is shaped according to assumptions about what the object *should* look like. While these procedures may later be found to have "distorted" the data, this does not imply that the unprocessed "raw data" gave a more accurate picture of reality than did a processed image. There is no escape from having to work-over such data to "decontaminate" them and to shape them in accordance with the project at hand.

MANUAL REPRODUCTION

Diagrams are systematic drawings, often line drawings made by hand or reproduced from engravings. Traditionally, they aid identification and classification by isolating or targeting 'essential details' of a specimen. An anatomical

diagram, for instance, employes a variety of conventions for isolating and delineating relevant organs while discarding "gratuitous details" (Myers 1990). Because diagrams are used along with numerous other forms of representation, their representational uses are less a function of diagrams *per se* than of the way diagrams are inserted into texts and activities.

Diagrams are often said to be fallible and subject to error, since their relation to the phenomena they depict is mediated by a scientist's or hired assistant's hand, and the form of the diagram is infused with conceptual schemata imposed upon the concrete configuration of visually inspectable details. As in the case of the notorious drawing of sperm by the preformationist Hartsoeker (see Figure 1), the diagram synthesizes a fantastic vision. Given our current disbelief in the represented homunculus, we are easily able to recognize how Hartsoeker's

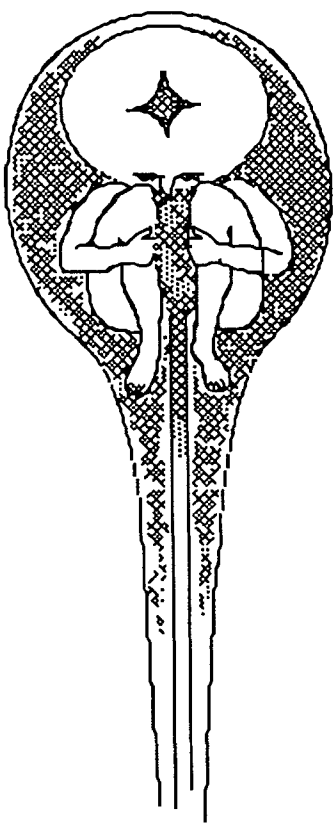

Fig. 1. Confabulated sperm – after Hartsoeker.

remarkably clear-headed vision of what sperm should look like helped him to 'improve upon' the blurry and aberrant imagery provided by his microscopes.

In examples like this one the artist's hand embodies all of the "low" and disreputable features of the subjective idols a Baconian science aims to abolish. According to this view, the hand is fallible and hopelessly judgmental, it is associated with manual labor, artifice, artifact, and the contamination of the natural subject with vulgar 'pre-notions'. The artist's sleight of hand, of course, can also have indispensable advances, since it creates and embodies a concept-laden vision of things. When supported by a context of belief, the 'low' art of manual representation can be transformed into the 'high' science of conceptual understanding. Because the diagram provides a continuous field in which no clear demarcation is made between conceptually assumed and concretely seen detail, it is often regarded as a suspect form of original evidence. In contrast, we often assume that mechanical reproduction provides a direct transfer from nature to image, untouched by human hands and uncontaminated by preconceived ideas.

MECHANICAL REPRODUCTION

The epitome of mechanical reproduction is photography. Barthes (1981, p. 4) identifies the mystique of the photograph with the way it "reproduces to infinity [what] has occurred only once." The photograph preserves and reproduces singularity, the contingent moment, and the deictic "this" of its subject:

> Show your photographs to someone – he will immediately show you his: "Look, this is my brother; this is me as a child," etc.; the Photograph is never anything but an antiphon of "Look," "See," "Here it is"; it points a finger at certain *vis-à-vis*, and cannot escape this pure deictic language.

Barthes is well aware that the hyper-realistic "mystique" of the photograph does not preclude a more critical analysis. The artifices of photography are apparent as soon as one considers how a photograph is a documentary construct: it is typically small, flat, narrowly framed, sometimes black and white, focused along a particular plane, frozen in time, taken under distinctive lighting conditions and at a particular exposure, etc. and etc. Furthermore, photography often evokes a pose from its subject, or otherwise intrudes upon the activities in the represented scene. This was particularly obvious when daguerreotypes were first used for portraiture. In contrast to the modern snapshot, a portrait required an extended pose under intense illumination, and the resultant pictures were sometimes subject to satirical complaints about their unnatural qualities (cf. Newhall 1964). As Wittgenstein (1958, p. 205) points out, *our* impression that the photograph directly shows us its object is by no means an automatic consequence:

> ... we *regard* the photograph, the picture on our wall, as the object itself (the man, landscape, and so on) depicted there.
>
> This need not have been so. We could easily imagine people who did not have this

> relation to such pictures. Who, for example, would be repelled by photographs, because a face without colour and even perhaps a face reduced in scale struck them as inhuman.

Our commonplace use of photographs collapses any apparent difference between "original" object signified and the mechanically reproduced signifier (cf. Benjamin 1969). When we point to a photograph we regard the original object *as if* it stood before us. "It is as if the Photograph always carries its referent with itself" (Barthes 1981, p. 5). Take, for instance the following interchange between a mother and her child as they page through a family photo album (from Edwards and Middleton 1988, p. 23):

> Mother: Who's that? (*pointing to a partially hidden figure*)
> Michael: It's me.

The hyper-realistic quality of the photograph can be so powerful as to overshadow any independent sense of an "original" moment captured within its frame. The photograph preserves moments in a past that would otherwise be forgotten, and provides an examinable record of details that would otherwise go unseen and unnoticed.[3] Barthes evokes this uncanny hyper-realistic quality by recounting the following episode:

> One day I received from a photographer a picture of myself which I could not remember being taken, for all my efforts; I inspected the tie, the sweater, to discover in what circumstances I had worn them; to no avail. And yet, *because it was a photograph* I could not deny that I had been *there* (even if I did not know *where*). This distortion between certainty and oblivion gave me a kind of vertigo, something of a "detective" anguish (the theme of *Blow-Up* was not far off); I went to the photographer's show as to a police investigation, to learn at last what I no longer knew about myself. (p. 85)

At first glance, the existential rupture that Barthes found so shocking may seem less troubling for natural scientists. For them, a hyper-real document may be just what is called for: it preserves a complexity of detail which overflows the capacities of "mere" common sense perception and memory; it "captures" more than any person can see or remember; it enables a leisurely inspection of a fixed datum; it holds things still. However, scientists are not entirely immune from the problem of *too much reality*. The circumstantial sensitivity and singularity of a photograph presents a problem for any effort to conceptualize the subject and represent abstract features. Although a photograph is set up through complex arrangements of the pose, lighting conditions, exposure, frame, and focus, the resultant picture may seem indifferent to what is "captures". It does not reproduce what an observer originally experiences, since it exposes an entire field of light, often including unseen, unanticipated, and unwanted visible configurations. In different circumstances such features can be treated as distortions of a scene's original features, or as surplus details that contribute to a heightened sense of the scene's reality. Ultimately, such surplus details can transform the very meaning of the "original" or "unmediated" scene. As Barthes points out, a photograph can cancel the primacy accorded to a "natural" or

"native" sense of the reality in which we live. Consequently, what stands as a mediated or unmediated representation can reverse, and the naked-eye vision and raw recollection of the human being can be transformed invidiously into refractory versions of a photographic reality.

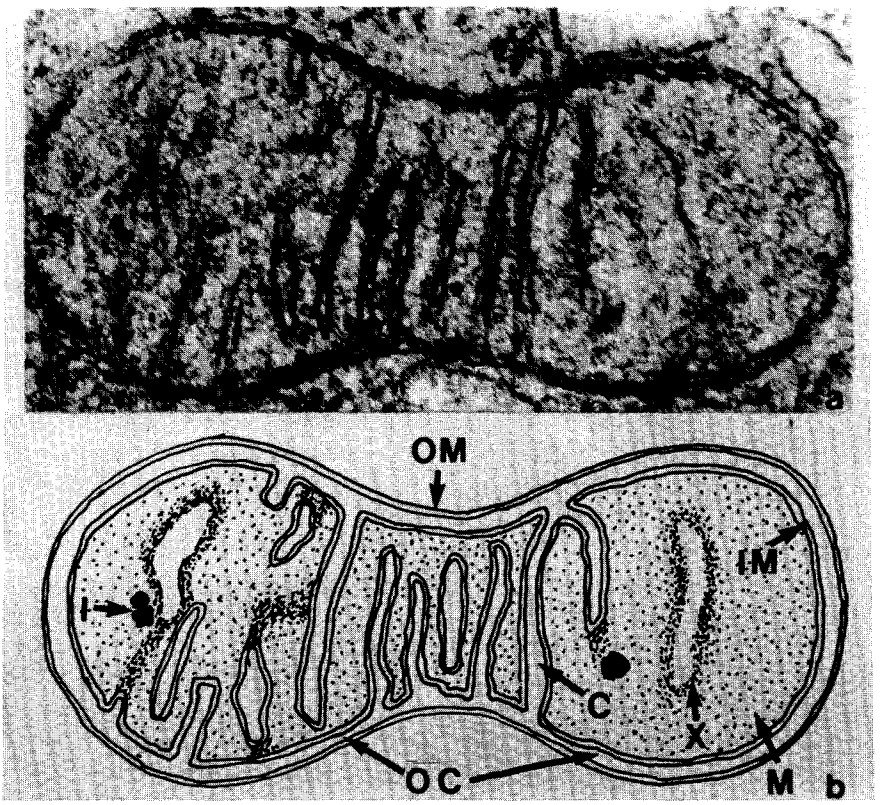

Fig. 2. Mitochondrion: Figure and caption from L. T. Threadgold, *The Ultrastructure of the Animal Cell*, Second Edition, p. 321. Oxford: Pergamon Press, 1976. (a) Mitochondrion from the pancreas of the mouse showing all the main characteristics features of this organoid which are labelled in the diagram in (b). OM and IM, outer and inner membranes; I, intramitochondrial granule; C, cristae; X, oblique section of cristae; OC, outer compartment; M, matrix.

PHOTO DIAGRAM PAIRS

Like professional photographers and art critics, scientists tend to take a relatively analytical attitude toward mechanically reproduced documents. They attend explicitly to the pictorial composition, the residues of the production process, and the traces of the idiosyncratic conditions under which the picture was taken and developed. But, they also make use of the "pure deictic language" when they exhibit photographs in texts. This can be appreciated by examining a visual format commonly used in research reports as well as didactic texts. This involves the juxtaposition of a photograph with one or another diagram, as in Figure 2.

Photo and diagram are placed side-by-side. The diagram appears to be a tracing of the photograph's details: it is parasitic upon the photograph, and it schematizes the photograph's details. The outlines and uniform regions of shading in the diagram bring out details that otherwise appear less discriminately in the photograph. Elsewhere, I have outlined some of the organizational features of such pairings in greater detail than I will be able to go into here (see Lynch 1985b, 1990a). For present purposes, I will focus on the following three features:

(1) The arrangement preserves a *moral* segregation between manually and mechanically reproduced surfaces, while at the same time it establishes a set of detailed correspondences between them. In order to grasp the combination of moral and epistemic implications of the segregation, consider the accusation of fraud raised by Gould (1981, pp. 171ff.) when he discovered that Goddard's exemplary photographs of members of the Kallikak family were *retouched* in order to visibly exhibit the "feeblemindedness" allegedly running in that family. An unknown artist's hand apparently distorted the symmetry and shape of the children's eyes and mouths to denote moronic expressions. The discovery of the artist's handiwork undermined the authority of the document. The discredited photograph no longer occupied a privileged space as a stand-in for the "original" object. Moreover, the fraud was exposed as a *deliberate* misstatement within the "pure deictic language" of the photograph. It was not akin to Hartsoeker's diagrammatic hallucination (Figure 1), which is generally regarded as an excusable projection error, embedded within the continuous field of visual and conceptual order in the hand-drawn image. The re-touched photograph was less excusable; the "touch" intruded upon a surface not of its own making. Gould debunked the myth of the Kallikaks, along with the spurious genetic theory the myth supported, and he attributed this myth not to an innocent projection error, but to a much more malevolent kind of "conscious skulduggery".

An apparently rigorous separation between manually and mechanically reproduced imagery exhibits an *inspectable* correspondence between the two. The drawing is checked against the photograph, while the merely singular and contingent features of the photographic field are selectively modified into the more schematic and semiotic details of the diagram. The distance between

drawing and mechanical reproduction enables the photograph to stand for the original object the diagram analyzes. In other words, the photo-diagram pairing *brings-out* an order of signifiers and signifieds, and supports a *correspondence theory of representation* in the face of the threat posed to it by mechanical reproduction. Where mechanical reproduction threatens to swamp any particular sense of an original "reality" by dispensing a profusion of visible details, no single aspect of which stands for an unequivocal and authoritative object, the photograph/diagram pairing affixes a "sense" to the photograph's surplus detail. Within this pair-structure, the photograph acts as raw material for the diagram's rendering.[4] It becomes the richly textured, singular, and hyper-realistic field from which the diagram selectively draws-out a set of formal relations. Once drawn-out in this way, diagrammatic features retain a visible correspondence to their less precisely demarcated, blurrier, perspectival and unlabeled counterparts in the photograph. A viewer can go back-and-forth between the two without either collapsing the pair and losing a sense of the "mystique" of the photogrph *or* divorcing the conceptual apparatus of the diagram from the hyper-realism of the mechanical reproduction.

(2) The pairing performs gestalt functions. These include such familiar themes as highlighting relevant details, bleaching out backgrounds, and sharpening edges; or completing outlines to enhance figure-ground contrast and produce a sense of object constancy. These operations are performed as manipulations within a pictorial space. They are matters of art as much as psychology, and they are produced by drawing upon the surface of a figure rather than by cognitively processing "raw" visual information. These practices skew the figure in the direction of an intelligible reading of what the figure shows. Where a visual psychology text uses a repertoire of illusions to demonstrate cognitive operations, an analysis of the composition and sequential ordering of illustrations in a scientific demonstration exposes the "card tricks" through which an *order* of reality is fashioned (cf. Bjelic and Lynch, in press). To clarify this point, consider the familiar gestalt figure of the "duck-rabbit" (Figure 3).

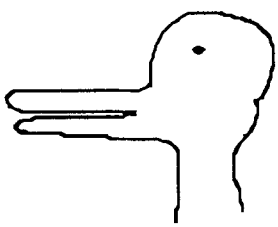

Fig. 3. Duck rabbit.

Typically, figures such as the duck-rabbit (or Hanson's (1958) bird-antelope) are used to demonstrate that a figure we see *as* a duck can be seen a moment later *as* a rabbit. The duck's "bill" becomes the rabbit's "ears," when we visualize the figure in accordance with the gestalt shift. The ambiguous figure thereby becomes an exemplar for an argument about how observation can be structured and guided by conceptual suggestion and instruction. A different appreciation of the demonstration is conveyed by the following series of transformations (Figure 4).

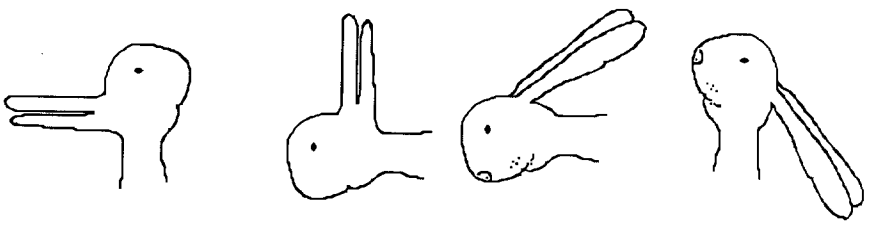

Fig. 4. Figural metamorphoses.

Following the series from left to right, the first "duck-rabbit" (with a "duck" orientation) becomes progressively transformed into a "rabbit". Shifting its orientation on the page, filling a bit of interior detail, and changing the angle of the bill/ears progressively eliminates the figure's "duckness". Rather than using a systematically ambiguous figure to exhibit an alternating perceptual structure, the figural metamorphosis shuts-down the initial alternative of "duck" and skews the figure's details into those of "rabbit". The alternating figure of the duck-rabbit is isolated as a figural trick making use of a drawing's surface features. The perceptual demonstration relies upon an art that *solicits* the visual ambiguity; and this art is itself exposed by surrounding the figure with dis-ambiguated alternatives. A gestalt shift of another kind has been accomplished: the optical illusion exposing a deep perceptual structure (Figure 3) is shown to require a delicate contexture of details on a visible surface (Figure 4).

The gestalt themes associated with figural continuity and figure-background contrast are similarly transformed when we consider them as matters of the alignment, shading, and orientation of a drawn figure on a sheet of paper. A diagram highlights figural contrasts and continuities and draws them out from the surplus details in which a photograph embeds them. The "conceptual hallucination" is framed against a backdrop of surplus details, which act as a check against the artist's free hand. While a viewer's perceptual competency is reciprocally implicated, the figure's surface provides the proximal site of the transformation.

(3) The pair sets up further analytical operations by aligning and attuning the composition to the requirements of labeling, encoding, and measuring. As shown in Figure 2, the diagram schematizes the details of the photograph, making entities stand out by drawing discrete borders, homogenizing textures within the boundaries of coherent things, and resolving points of overlap and ambiguity. The particular way in which this is done can set up a kind of internal "conversation" between photograph and diagram with the viewer as "overseer" and the text's discursive references articulating the upshot.[5] Further operations can align figural profiles with rectilinear matrices, setting up a transformation of pictorial space into graphic space (Lynch 1985b, 1990a).

The device of juxtaposing photographs and diagrams appears in some of the earliest uses of photographs in biological research. Darwin (1955) uses both photographs and drawings to represent exemplary facial expressions and postures.[6] For many of these photos he enlisted the services of professional actors and he had them strike stereotypical poses for the camera. The photos sometimes appeared blurred and stilted, given the necessity for the actors to hold their poses while the image was shot. Darwin sometimes used drawings of the actors' faces to give a sharper image of their expressive lines and creases. Stereotypic animal postures represented in Darwin's text also tended to be drawn, perhaps due to the difficulties of inducing an animal to hold a paradigmatic pose while the photograph was set up.

The use of diagrams to work-over and bring-out the details of photographic evidence is not a particularly sophisticated or uniquely scientific device. Its established use in science is less a product of scientific innovation than an appropriation of an intuitively 'natural' use of different orders of textual reproduction. Photo-diagram pairs are rarely used as proofs or compelling evidence in biology texts, and there are no guarantees associated with their use. They might better be considered as part of an array of visual/rhetorical tropes used in scientific texts. In other words, the pair device is one of many pictorial modes of argumentative persuasion.

POST-MECHANICAL REPRODUCTIONS

The distinction between diagrams and mechanical reproductions is historically-bound. As I mentioned above, photographs were not always viewed simply as pictures of their referents. Early daguerreotypes were viewed as strange and distorted objects, and the institution of the snapshot was established only after cheap and easy-to-use cameras became available. With the proliferation of digital image processing in numerous fields of research, we may have entered another era in imaging technology. Digital imaging and image processing break down the distinction between manual and mechanical reproductions. Diagrams may still be tied to handiwork, but in many cases (such as Figures 1, 3, and 4, which I have "drawn" for this article) it is the hand on the keyboard that does the job (Lynch 1990b). When photographs are digitized, their details are represented

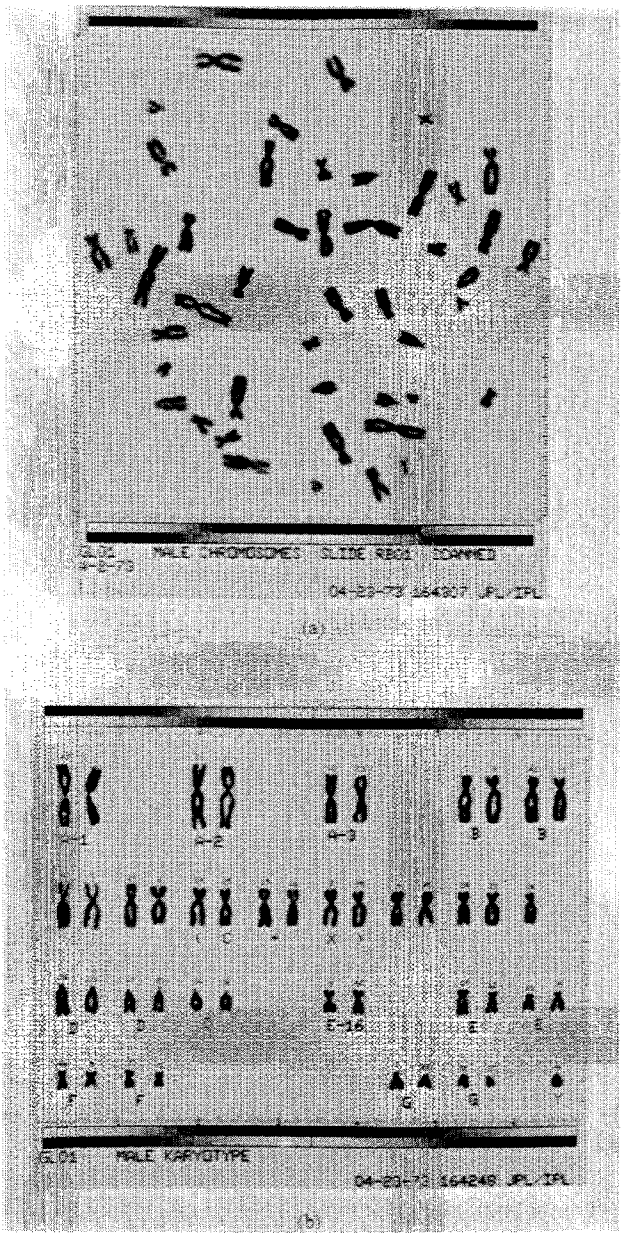

Fig. 5. Human chromosomes: (a) original; (b) karyotype. (From Kenneth R. Castleman (1979, p. 341), *Digital Image Processing*. Englewood Cliffs: Prentice-Hall.)

as arrays of pixels (picture elements) that can be transformed through continual keyboard manipulations. Contrasts can be enhanced or muted, false color arrays can be selected from a "palette", degraded data can be restored, different picture frames can be added together; etc. and etc. And, as Figure 5 illustrates, a photograph can be developed into a 'diagram' by using available computer programs.

Both the "original" and the "karyotype" in Figure 5 are digitized images, only the karyotype has been sharpened and arranged through application of software programs. Much of what was said above about the primitive persuasive device holds here also, except that the diagram has been divorced from the "low" manual labor of drawing. With the touch of a few keys, the "original" can be transformed into an endless series of pictures, graphs, maps, three-dimensional simulations, tables, arrays of numbers, and formulae. Distinctions between diagrams, photographs, numerical tables, and models break down as images become interchangeable displays of numerical data. It is now more obvious than ever that no single visible rendering "stands for" the original object. Instead, complex series of images are composed and re-arranged in a syntax we have yet to decipher. Consequently, the moral and epistemic qualities assigned to an "original" representation may undergo yet another transformation. The "raw data" collected by taking a photograph or micrograph can be "improved upon," not by re-drawing or re-touching the original, but by subjecting it to mathematical transformations that subtract noise or otherwise create a mechanically "improved" or "enhanced" image. Assuming that the software functions are justified by accepted mathematics and physics, the processed image can be held to provide more "trustworthy" or "authentic" evidence than the raw data. In a digital image, many of the surplus details in a raw data frame become "noise" to be eliminated rather than guarantors of the authenticity of the product.

CONCLUSION

I have argued that the rhetorical device of photo-diagram pairing exploits two distinctive modes of representational realism. Where the photograph evokes an unmediated presence to an original thing or scene, the diagram exhibits analytic handiwork, showing a conceptualized version of the original. The drawing skews the sense of the original in a discursive and often a mathematical direction, as its handiwork subtly shifts the reproduction into congruence with a textual argument. The diagram thus acts to bridge the "mystique" of the photograph with the literary and mathematical analysis in a text. Diagramming provides the intermediary between an original field and a final analysis. The "original" is enframed as the "authentic" or "real" phenomenon discussed and analyzed in the text, and its represents the "raw data" that are subsequently processed to expose phenomena hidden within the surplus details of those data.

The pair relationship is *not* invariably a matter of degrading the original through the diagram's partial, interested, and simplified account of it. Although

particular diagrams can be liable to such degradation, the primitive persuasive device works to bolster the diagram's conceptual analysis by placing it within a visible order of correspondences upheld by a moral segregation of the paired representations. Borrowing terms from the analysis of conversation (Sacks et al., 1974) the primitive persuasive device works through a "conditionally relevant" pairing of the photograph and diagram. The photograph comes first, since it furnishes an open texture of relevancies from which the diagram selects. The diagram capitalizes upon the surplus details of the photography by drawing upon their plenitude and retaining them as a visible warrant for the analysis. Unlike speech, the primitive persuasive device is produced through textual placement and displacement. It comprises a synchronic order of juxtaposition, rather than a diachronic order of utterances. The relationship is directionally ordered; the photograph's "pure deictic" evocation of the original object acts as a primary point of reference for the diagrammatic copy. The transition between first and second "pair parts" is an order of transference (Foucault 1983); of similitudes transferred across an epistemic threshold. The analogy with conversation can be taken further: just as paired structures provide an organizational basis for a range of pragmatic actions in conversation – greetings-and-return-greeting, requests-and-responses, question-answer sequences – so the primitive persuasive pairing of distinct representations provides a condition for a variety of actions achieved through sequences of documentary renderings. Some of these are exhibited in published textual illustrations, but many more are produced in laboratory researchers' progressive transformations of "raw data" into "processed images". These transformations include such actions as 'cleaning' the data and 'correcting' for instrumental artifacts,sharpening figural contrasts and upgrading figural identies, making the data look natural, plotting data on graphs and coding them, curve fitting, and selecting "good" illustrations for publication.

Pairing a diagram with a photograph constitutes the mechanical reproduction *as* the original, while at the same time it confines the singularity and surplus detail of the photograph by aligning it within a relational order. That order can activate a variety of readings, depending upon how the diagram plays off of the photograph. It does not necessarily simplify the photograph in a more "abstract" direction, since it can clean and naturalize the photograph's surplus detail. The diagram elucidates an intentional structure in the way it renders the photographic field, while at the same time the photograph retains an authoritative backdrop for that work. Realist and constructivist implications become locked into a kind of symbiotic embrace. Both the excesses of hyper-realism and the extremes of conceptual hallucination are kept at bay by the internal dialogue between the paired representations. This guarantees nothing about any relation to an "external reality," but it offers a textually confined simulacrum of a transition from raw data to conceptual understanding.

NOTES

[1] Readers who are familiar with sociology will recognize that "epistemic sociology" weaves together themes from the sociology of knowledge and ethnomethodology. My own commitments are closest to those of ethnomethodology (Garfinkel 1967; Garfinkel et al. 1981; Morrison 1981; Lynch et al. 1983; Lynch 1985a; Livingston 1986). Several recent publications from other traditions in sociology, history, and philosophy also testify to a growing multidisciplinary interest in tools, skills, representational devices, and experimental practices (Latour and Woolgar 1979; Knorr-Cetina 1981; Hacking 1983; Collins 1985; Shapin and Schaffer 1985; Rudwick 1985; Pickering 1986; Galison 1987; Latour 1987, 1990; Gerson and Star 1987; Law and Whittaker 1988; Amann and Knorr Cetina 1990; Woolgar 1990; Myers 1990; Star, forthcoming). For many of these as well as other studies on visual representation, see edited volumes by Latour and De Noblette (1985); Fyfe and Law (1988); Gooding, Pinch and Schaffer (1989); Lynch and Woolgar (1990); and Clarke and Fujimura (in press).

[2] Readers familiar with Benjamin's (1969) essay should note that I am not applying his distinction in a literal way. Benjamin draws a contrast between the "original" work of art, and the reproduction of it. A mechanical reproduction produces an exact copy, thereby devaluing the role of the original in the economy of art. Consistent with Benjamin's account, a diagram can be subject to mechanical reproduction by using any of the available technologies for copying it (i.e., print, engraving, xeroxing, etc.). As I use it, the contrast between "original" and "copy" applies to the relationship between the visible scene and the picture of it. A diagram is explicitly mediated by handiwork, whereas the handiwork of mechanical reproduction effaces itself, and the picture is presumed to be an unmediated trace of the original object.

[3] Social psychological research on the accuracy of a witness' memory for events (Loftus 1979) uses a contrast between a photograph's depiction of a scene and what a witness recalls some time afterwards. Implicit in the experimental procedure is the unquestioned use of the photograph as a stable record of the actual event in contrast to the witness' degraded and distorted memory image.

[4] The idea of a "pair structure" derives from Garfinkel (Garfinkel et al. 1989), and is also given original development in Livingston's (1986) study of mathematicians' work.

[5] David Bogen (pers. comm.) suggested this image of a "conversation" between the members of the pair.

[6] Eileen Crist (pers. comm.) alerted me to these aspects of Darwin's text.

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