Why Trade?

Davis Baird
University of South Carolina

Mark S. Cohen
UCLA School of Medicine

According to Peter Galison (1997), science has a highly fractionated structure with multiple sub-sub-disciplines, each with its own agenda. Cooperative trading between groups is necessary for most scientific work to move forward, and it is this trading that preserves the stability of science. We argue that it is not trading per se*, but trading in a gift (as opposed to a commodity) economy that guarantees stability. We support our claims with an examination of contemporary work on magnetic resonance imaging instrumentation. Specifically, we consider: (1) How a feature improvement, intended to reduce scan time, led to substantial medical mis-diagnosis; (2) How a technical error, when corrected, created a consumer crisis in which radiologists preferred technically flawed instruments; (3) How new magnetic resonance theory radically altered the physical interpretation of MRI images; (4) How the MRI instrument at first was financially supported by, and—ironically—ultimately invalidated, the accepted understanding of the nature, source and management of chronic back pain. Ultimately there are three reasons stability requires gifting. First, without a general sense of shared purpose traders will not be committed to mutual engagement; profit does not provide an adequate shared purpose for the MRI community. Second, stability requires trust, and profits are not an adequate foundation for trust. Finally, knowledge is a gift that will not keep on giving if treated simply as a source of profit.*

1. Introduction

The concept of a "trading zone" is a central contribution of Peter Galison's *Image and Logic* (Galison 1997). He describes physics in this century as a complex interaction of numerous sub-cultures of the physics community. These different sub-cultures, broadly categorized under "theoretical," "experimental" and "instrumental" headings, each have pursued their inter-

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ests in largely autonomous ways. But, they interact, and trading zones are the sites for these interactions. Galison borrows the concept from anthropology as a model for the interaction of different (sub)cultures. To motivate the analogy, he considers an example: the monetary interactions of peasants and landowners in the southern Cauco valley of Colombia. The two groups engage in many levels of monetary exchange, and there are mutually agreed upon behavioral patterns that govern these exchanges. But they are understood differently:

> For the landowners, money is "neutral" and has a variety of natural properties; for example, it can accumulate into capital—money begets money. For the peasants, funds obtained in certain ways have intention, purpose, and moral properties, ... So when we narrow our gaze to the peasant buying eggs in a landowners's shop we may see two people harmoniously exchanging items. ... Out of our narrow view, however, are two vastly different symbolic and cultural systems, embedding two incompatible valuations and understandings of the objects exchanged (p. 804).

This is the picture Galison urges for twentieth-century physics. It includes many sub-cultures with individually autonomous and jointly incompatible valuations and understandings. Yet, these sub-cultures can trade with each other in much the same way that these two Colombian cultures trade with each other.

And herein is a long story with many examples, presented in great detail, of how different sub-cultures become trading partners. Galison is concerned primarily with epistemic trading: How do different sub-cultures trade knowledge with each other when they have radically different methodologies, criteria for accepting "results," and indeed different ways of expressing their results? Galison again turns to anthropology, taking the concept of mediating "interlanguages"—pidgins and Creoles—to characterize the media of exchange. *Image and Logic* details extensively how such sub-cultures have worked out languages of exchange, languages that, of necessity, abandon or remain neutral with respect to the different "valuations" (which can include a host of commitments, from theoretical presuppositions to preferred instruments) of the different sub-cultures.

Galison employs this image of physics made up of individually autonomous trading sub-cultures to explain the stability of physics. Here he responds to the post-positivistic image of science where radical changes can produce "incommensurable theories." We cannot say new science is better than old science because, on this view, the two are incommensurable. Galison maintains that this image is wrong. Radical changes do not produce such incommensurability and instability. As he argues, while one sub-culture may undergo radical changes, other trading partners of this sub-culture carry on without a break. Individual autonomy plus joint trading produces stability.

Galison does not take up the question posed in the title of the present paper—or rather, the many questions posed in the title of this paper. Taken one way—What is the underlying motivation of different scientists or sub-cultures to trade?—Galison may be right to beg off. Part of his point is that different groups can give different meanings to their exchanges: "And with the anthropologists, it is crucial to note that nothing in the notion of trade presupposes some universal notion of a neutral currency. Quite the opposite, much of the interest of the category of trade is that things can be coordinated … without reference to some external gauge" (p. 803). However, there is another way to take our question. We ask for the function or telos of the trading which Galison documents. We argue that the answer to this question is central to the stability that Galison documents.

In particular, we have in mind another distinction developed by anthropologists, that between *gift* and *commodity* approaches to trading. Gift economies are archaic, and arguably predate any widespread form of commodity economy. Yet they remain essential—if under-appreciated—aspects of exchange in many domains of modern life. Gift economies have attracted the attention of anthropologists and sociologists (Zelizer 1979; Caplow 1982; Gregory 1982; Cheal 1988; Mauss 1990; Carrier 1995) and they are central to Friedrich Nietzsche's *Thus Spoke Zarathustra* (Nietzsche 1982; Shapiro 1991).

Lewis Hyde presents a theory of gifts and gift exchange in his marvelous book, *The Gift: Imagination and the Erotic Life of Property* (Hyde 1979). He argues that artists and their works must live in a world of gifts and gift exchange: "[W]orks of art exist simultaneously in two 'economies,' a market economy and a gift economy. Only one of these is essential, however: a work of art can survive without the market, but where there is no gift there is no art" (p. xi). Elsewhere one of us has argued for the same point with respect to scientific knowledge—epistemic trading (Baird 1997). Here we propose that participation in a gift economy is a central feature of the stability Galison explains by means of autonomous trading sub-cultures. The telos of the trading is to create something transcending each trading partner, something beyond the many sub-cultures of physics: the culture of physics. This more general community is established and maintained by a gift economy, and would be lost were trading understood by those involved in terms of commodity exchange.

We argue our case by looking at the development of magnetic resonance imaging instrumentation that has occurred largely outside of a gift economy. Existing in a commodity economy, MRI exhibits differences and instabilities that do not appear in the cases Galison considers.

Here, we supply illustrative examples drawn from medical magnetic resonance imaging (MRI). Specifically, we consider:

1. How a feature improvement, intended to reduce scan time led to substantial medical mis-diagnosis.
2. How a technical error (in translating known physical principles to instrumental design) when corrected, created a consumer crisis in which the radiologist consumer preferred the theoretically flawed instrument, and how this knowledge percolated among the many communities that make MRI possible.
3. How basic, and fundamental, new magnetic resonance theory altered radically the physical interpretation of the medical images and was embraced quickly by the medical consumer.
4. How the MRI instrument was at first supported by, and ultimately invalidated a major medical paradigm: the nature, source and management of chronic back pain.

2. Magnetic Resonance Imaging

Nuclear Magnetic Resonance

It was the physical predictions of quantum physics, made by E. Schrödinger, I. I. Rabi and others that led to the recognition of nuclear spin and the magnetic moment of certain atomic nuclei (e.g., Rabi, Zacharias et al. 1992). While the quantum properties of single atoms generally are not visible, they can be probed effectively in large ensembles. In 1946, Felix Bloch was able to demonstrate directly the phenomenon of nuclear induction, by which Larmor precession—which atomic nuclei undergo when placed in a magnetic field—can be re-oriented through the application of a radio frequency electromagnetic pulse (Bloch 1946; Bloch, Hansen et al. 1946). Further, these experiments were able to elicit macroscopically detectable radio signals. The effect was predicted by theory, and tested by the development of a specialized instrument. The first applications were to spectroscopy—the study of the atomic constituents of molecules as predicted by tiny changes in the effective frequencies of the radio energy. NMR reflects quantum physical properties on a very large scale.

Galison points out, in his discussion of Julian Schwinger's studies at the M.I.T. Radiation Laboratory, that the engineer usually has to go about his or her work reducing the complete mathematical descriptions of objects to simplified generalizations (Galison 1997, pp. 820-27). Such certainly is the case with nuclear magnetic resonance ("NMR") where the statistical mechanics are well beyond the reach of the average biologist, chemist or engineer. In the particular case of NMR, the basic principles are much easier to grasp using classical mechanics, and for this reason researchers seldom traffic in discretized representations (e.g., Farrar and Becker 1971; Fukushima and Roeder 1981; Brown and Semelka 1995).

MRI

In 1973, twenty-seven years after this initial experimentation with NMR, Paul Lauterbur demonstrated that one could take advantage of the purely classical properties of the NMR phenomenon to form two-dimensional images (Lauterbur 1973). While these first images represented local nuclear spin density, already researchers recognized that the rates of magnetization of the nuclei (chiefly T1 and T2[1]) varied according to their local chemical and molecular environment. Today's magnetic resonance imaging ("MRI") pictures are two-dimensional maps of these magnetization rates within slices of tissue.

It is worth noting that in making his image forming apparatus, Lauterbur only needed to accept Bloch's instrument, not its underlying theory (although Lauterbur did need one of the classical results—namely that the spin frequency is a function of magnetic field strength). The medical industry needed to know virtually none of this. The corporate engineers who, in under seven years, transformed Lauterbur's bench-top demonstration device to a massive and complex medical instrument, effectively hid the principles of operation from the medical consumer.

Due to its extraordinary ability to form images of the inside of the body, based on passive recordings, and while avoiding exposure to hazards such as ionizing radiation, MRI has become an immensely popular clinical tool. As of 1998, industry estimates suggest there are over 3,500 installed units in the United States alone. The capital investment in these instruments is overwhelming. The average installed instrument costs about 1.5 million dollars at delivery and is serviced by about $100,000 in upgrades each year (for example, one of the largest manufacturers, General Electric, recommends that their customers set aside an additional 10% of the instrument cost annually for upgrades). More than 5 billion dollars have been spent on installations and $350 million is spent yearly for upgrades. Why? Because for an incredible number of diseases, MRI is considered the definitive diagnosis, justifying a cost-per-use of $500-$1,000.

1. T1 and T2 refer to magnetization rates that are understood to be intrinsic properties of materials exposed to magnetic fields. Specifically, T1 reflects the rate at which substances approach magnetic thermal equilibrium, and T2 reflects the rate at which spin phase coherence decays following nuclear magnetic resonance induction.

3. Who is in the Zone?

Already it is clear that MRI instrumentation presents a complex confluence of different sub-cultures. At least five general groups can be identified, each further divisible into sub-groups.

Physicists

There are physicists, and here we have all three of Galison's sub-cultures represented. There are quantum theoreticians, experimentalists and instrument makers. A closer look into the details of the development of NMR would likely reveal a story little different in character from those in *Image and Logic*. Articles in the leading topical journals, such as *Magnetic Resonance in Medicine*, *Journal of Magnetic Resonance*, *Magnetic Resonance Imaging*, *Computer Assisted Tomography* and *Radiology* each have a distinct character that comes, in significant part, from the varied background and focus of these researchers, running the gamut from basic physics to almost pure clinical applications.

Instrument Manufacturers

But MRI quickly moves into the commercial sphere, and the various elements of the corporate world also engage in MRI trading. There are corporate engineers—instrument makers—to be sure, but there are also marketing people, finance people, people involved with installation and trouble-shooting. Within a corporation such as Siemens, General Electric, Picker, Philips or Varian, all of these people have to engage each other about the MRI instrumentation they are developing, manufacturing, selling, installing and trouble-shooting. But they also have to engage the various physics communities, on the one side, and their customers, on the other side. One mechanism for trade, of course, is the peer-reviewed literature. There are many tricks to making high quality images; while some appear in that literature, a surprising number do not.

Clinicians

MRI instrumentation typically is purchased by hospitals and/or private consortia of physicians who then sell the services of their instrument and their expertise in using it. The knowledge base required to invent and to understand the MRI instrument generally is obscure to the average clinician. These clinicians, however, have formed "meta-analyses" or "clinical interpretations" of the human data they collect with their instruments that are correspondingly beyond the reach of the physicists or engineers who designed the instruments.

Consumers

In the end, of course, there are consumers, patients and insurance carriers who pay the substantial price for this instrumentation. These people neither need nor commonly have the expertise of the instrument makers or the clinical users of the instrument. They do need to have some reason to believe that the instrument is a valuable tool for medical diagnosis.

Researchers

Although their direct involvement in the capital transactions in MRI is minor (barely a single pixel in the overall cash economy of MRI instrumentation), applications researchers, conducting their experiments on humans and animals, represent an essential and large component of the information and 'gift' economy of MRI. Clinical consumers and manufacturers are avid readers of the scientific literature; clinicians are quick to demand, and manufacturers quick to implement, the latest ideas in improving the MRI study. We have experienced personally the astonishing rate at which new ideas in fast imaging (Cohen and Weisskoff 1991) and so-called functional MRI (the study of brain function by MRI) (Belliveau, Kennedy Jr. et al. 1991; Kwong, Belliveau et al. 1992; Cohen and Bookheimer 1994) have been translated to commercial hardware and clinical practice.

Many Zones

It would be wrong to suggest that there is a single trading zone here. Confirming the general spirit of Galison's book, MRI instrumentation provides a central node around which many different sub-cultures swirl. As need arises, different groups learn to communicate with one another. Thus, only rarely would the initial experimenters who developed the prototype instrumentation need to communicate—trade—with the consumers or even the clinician users of MRI. Often they lack sufficient common language to do so. Major MRI meetings, for example, are frequently fractionated (and fractious). It is common that parallel sessions are held in "clinical applications," "physics" and "instrumentation" (e.g., see the meeting schedules posted at www.ismrm.org, the web site for the major MRI-in-medicine meetings). Usually, this is because only a small minority of the attendees would wish to attend all three. On the other hand, there is much room for communicative error resulting from the complexity of interactions that the knot of interests in MRI produces. We note that, while Galison's model (and his figure 9.5, p. 799) imply an essentially laminar structure to trading, in which whole communities serve as trading zones, at least with MRI, trading zones occur between groups at most levels: physicians with physicists, physicists with engineers, engineers with marketing, marketing with consumers, etc....

4. Pidgins, Instrumental Artifacts and Coke Classic

There have been several by now celebrated cases where incomplete communication has led to serious consequences. Here are two of our favorites.

Gibbs Ringing Artifact

In the vast majority of cases, MRI is performed in Fourier space (Lauterbur 1973; Kumar, Welti et al. 1975; Lauterbur 1981). When the raw data that make up an image are sampled incompletely—which they must be, because the true raw data are infinite in time—a characteristic artifact, known as "Gibbs ringing," occurs at abrupt intensity discontinuities. This artifact appears as a dark band parallel to, but slightly displaced from, a lighter region resulting from a large intensity gradient. Such artifacts are well known to the physicists and engineers who work on MRI instrumentation, as are optimization procedures for their mitigation (Henkelman and Bronskill 1987). Please see figure 1.

There was a period of about three years (1987-1990), however, when it became fashionable for physicians to reduce the rather long MR imaging times by using anisotropically shaped (i.e., non-square) imaging pixels in studies of the spine. As it turned out, this resulted in a prominent dark line appearing within the spinal cord. The dark line was a Gibbs ringing artifact. Unfortunately clinicians, not aware of this kind of artifact—for not being conversant with the mathematics used to transform the instrument signal into an image—at times interpreted this artifact as a disease process: a fluid filled lesion known as a "syrinx" requiring aggressive medical treatment. Ultimately, the artifact was detected and explained by an individual (Bronskill, McVeigh et al. 1988) whose knowledge bridged medicine and physics. Unfortunately, this did not happen until a great many patients had been misdiagnosed and treated. Once the nature of the artifact was recognized, and its implications appreciated, later researchers identified it too as the cause of misdiagnosis of different disorders, for example, spinal cord atrophy (Yousem, Janick et al. 1990).

Water, Fat and "Coke Classic"

Here is a second example. Since the very early days of spectroscopy using NMR, it has been known that the resonance frequency of fat differs from that of water. Because MRI using the Lauterbur method capitalizes on the resonance frequency of the signal to determine spatial location, a so-called "chemical shift difference" between fat and water results in a spatial dis-

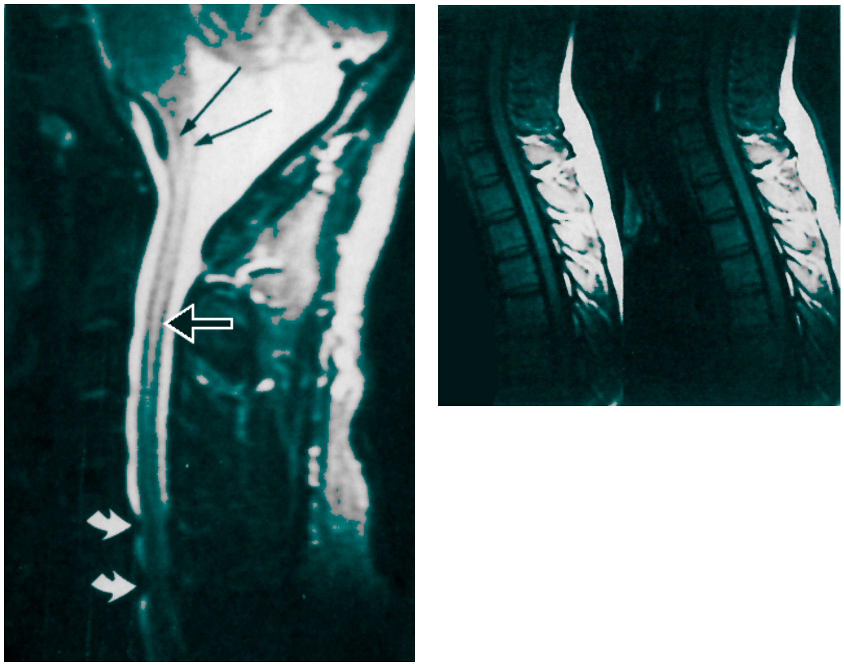

Figure 1. (reprinted from Bronskill, McVeigh et al. 1988). These clinical MR images show the presence of an artifact caused by Fourier truncation, which appears to the clinician as a medical condition: a fluid filled cavity in the spinal cord called a syrinx. In the image on the left, this appears as a bright line in the center of the spinal cord (outline arrow). White arrows indicate the clinical condition of cervical spondylosis. Interestingly, the artifact does not appear in these locations. On the right, from the same article, successive images from the same patient show the syrinx-like artifact (this time as a dark line in the center of the cord), and its amelioration (right) by a change in scanning parameters.

placement of fat and water signals. From the very earliest days of practical medical instrument design (1981 or 1982), minimization of the "chemical shift difference" artifact has been an important goal. Instrument engineers took this artifact to be a major design constraint that ultimately would limit the effective signal to noise ratio and perhaps resolution of the instrument (Hoult and Richards 1976; Hoult, Chen et al. 1986; Henkelman and Bronskill 1987).

Surprisingly, given the care with which instrument engineers had worked on the chemical shift difference, a highly visible error surfaced in 1990. General Electric, one of the leading instrument manufacturers, noted a flaw

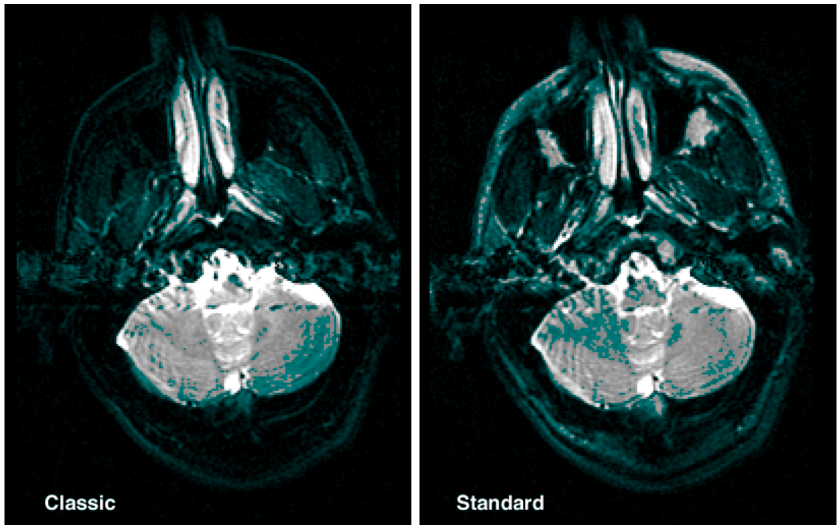

Figure 2. "The Classic Difference." Engineers at General Electric detected a flaw in the control software that runs their MR scanner and resulted in the images having contrast that does not conform to theoretical expectations. These scans compare images acquired before (left) and after (right) the software modification, and are quite grossly different. By the time, however, that the "bug" was detected, some physicians had learned to prefer the original contrast behavior. The company elected to provide both versions of the control software labeling the original method "classic" and the new method "standard."

in some of their most commonly used data acquisition programs (known in the field as "pulse sequences"). Generally two or more radio fre- quency pulses are used to form the signal that makes up a MR image. In order to avoid or minimize an artifact known as a stimulated echo, as well as other problems with "eddy currents," the instruments produced by General Electric (since at least 1985) had applied each of the two image forming pulses to a different spatial location—one for aqueous tissue and another for lipid (fat-containing) tissue. The result was an image with a depleted fat signal. From the theoretician's perspective, this was a serious error.

When the flaw was recognized, General Electric fixed the software and sent the new version along with a clear description of the problem to the user base. Now a marketing problem arose. Many physicians, having become used to the presentation provided by the original—flawed—software, did not like the new—corrected—software. Not only were images on individual patients made with the new software incommensurate with the prior exam images on the same patients, but also the physicians were more familiar with and better able to interpret images from the original software (Figure 2). In a textbook, only-in-America response, General Electric decided to offer both variants. By pressing a button labeled "Classic" clinicians could make the instrument use the older, flawed, software. Quoting from the software manual (General Electric Medical Systems 1993):

> **The Classic Difference**
>
> The Signa Advantage system offers you two types of 2D Spin Echo Imaging: standard and classic. The difference is most obvious in late echoes with 1.5T systems.
>
> Standard 2D Spin Echo is recommended for T2 studies. It offers greater signal-to-noise and is less sensitive to center frequency adjustment. Its late echoes will be more uniform, and will demonstrate images with more shades of gray than classic.
>
> Classic 2D Spin Echo SNR is lower. It's recommended when you're looking for a larger variance between muscle and fat signal. To use it, touch the [classic] soft key on the imaging parameters screen. Its effects can be emphasized via center frequency adjustment. Classic images are annotated with a "CL."

Fortunately, this only led to modest health care errors—the effects were limited to a slightly reduced diagnostic sensitivity, and over time radiologists have become familiar with images made by the new software.

Image as Pidgin

These examples make clear that the space in which clinicians work and interact with MRI instrumentation differs from the space in which MRI instrument engineers work. They share the MR image; this is the pidgin of their trading zone. But the image has diagnostic meaning for the clinician that it does not have for the engineer. Conversely, for the engineer, the image represents a complicated algorithm, incorporating a variety of tradeoffs in dealing with the kind of signal NMR provides.

It is not obviously wrong for the clinicians to prefer "MRI classic." Humans have a remarkable ability to interpret sensory input—such as provided by MRI instruments—and coordinate it with other data. A picture is not simply context-free information. Context, which in this case can include prior MRI images of the same person and other diagnostic information, clarifies the meaning of the picture. On the other hand, when other inputs are limited or ambiguous, genuine misinterpretations can arise from a limited understanding of the theory behind the production of the picture—as in the first example above.

An "instrumental artifact" is not a cut and dried category. In both of these cases, from the engineer's perspective the instrument was producing artifacts. In the first case, the artifacts clearly led to misdiagnoses and treatments. In the second case, however, from a clinician's perspective switching from "MRI classic" to "MRI perfected" could lead also to misdiagnoses due to interpretive errors based on contextual expectations.

These examples also make clear the need for persons who bridge instrument engineering and clinical uses of MRI instrumentation. It was because of Bronskill's unique position that the Gibbs ringing artifact was explained. But who is going to pay for this bridging work? Given the relatively limited number of instrument makers and the large number of installed instrument users, it seems most likely this work will fall on the manufacturer. And for this reason, it seems very likely that marketing will get mixed in with this bridging work. Indeed, it was a bit of marketing genius that resolved clinician dissatisfaction with the new MRI software, by offering MRI classic. But this brings us to our next section.

5. Pursuing the Market

Magnetization Transfer

As we have learned more about how human tissue produces MR signals, both our understanding of the images we can produce and our understanding of the diagnostic possibilities of these images have improved. In 1989 several investigators, notably Robert Balaban at the National Heart Lung and Blood Institute, demonstrated that the magnetization of a sample can be transferred across molecules (Wolff and Balaban 1989; Balaban, Chesnick et al. 1991). This is the result of Van der Waals interactions producing close physical coupling of nuclear spins in a local region. The nature of the MRI pulsing sequences is such that these magnetization transfer effects may produce significant shifts in image contrast that depend on factors long presumed to be independent of contrast, including image slice location, number of slice locations and a litany of other factors. This new understanding of magnetization transfer substantially altered our understanding of the theory behind the instrument. Our understanding of the physical properties that make up the MR signal, and the MR image, was qualitatively and quantitatively changed.

How did the user community react? Remarkably, the applications engineers and physicians moved quickly to exploit this new contrast mechanism. In the space of less than two years, the "magnetization transfer effect" moved from laboratory curiosity to medical practice, helping to improve the radiologist's view of blood vessels in the brain and tumors in the leg (Wolff, Chesnick et al. 1991; Scholz, Ceckler et al. 1993; Wolff and Balaban 1994). Clinical researchers realized, for example, that the magnetization transfer effect could be used to selectively suppress the signal from stationary brain, and thus facilitate the collection of images of the blood supply (angiograms) (Edelman, Ahn et al. 1992); it can be used to enhance contrast between tissues in the joint spaces in the knee (Wolff, Chesnick et al. 1991), and it can be used to improve the conspicuity of small features of the eye (Ceckler, Karino et al. 1991), to name but a few examples.

Back Pain

A much more challenging, and vastly more expensive, failure of communication between instrument engineer and medical clinician relating to MR images is now being played out. Back pain currently is the single most important medical condition leading to lost work time in this country. The economic consequences of back pain are staggering, and yet we have only the vaguest sense of its causes (Gawande 1998).

When clinical MRI first appeared, its applications were mostly inside the head, where the skull has always rendered the brain nearly invisible to x-ray methods. While the brain has remained a major focus of clinical applications, by 1986, MR imaging of the spine consumed about 50% of scanner time, brain about 35% and the rest of the body about 15%.[2] MR images of the spine were showing a tremendous incidence of disk prolapse; the disks, which separate and cushion the bones of the spine, were bulging into the space that should be occupied by the spinal cord and nerves. The conventional wisdom with respect to pain, at the time, was that inflammation of the spinal nerves would lead to pain.

Seeing the intense interest from the referring physicians (and lawyers), MR imaging centers pushed hard for manufacturers to develop improved tools to study the spine. Physicians complained vigorously that the manufacturers were dragging their feet on this pressing medical problem. The demand became so great that the large instrument vendors—enormous companies like General Electric, Philips and Siemens—lost significant sales to small startup companies that could bring one such tool—called a "surface coil"—to market more quickly. A complete spine exam would cost insurance companies (or the unfortunate patient) about

2. (*Siemens Medical Systems* marketing material—Author's personal communications.)

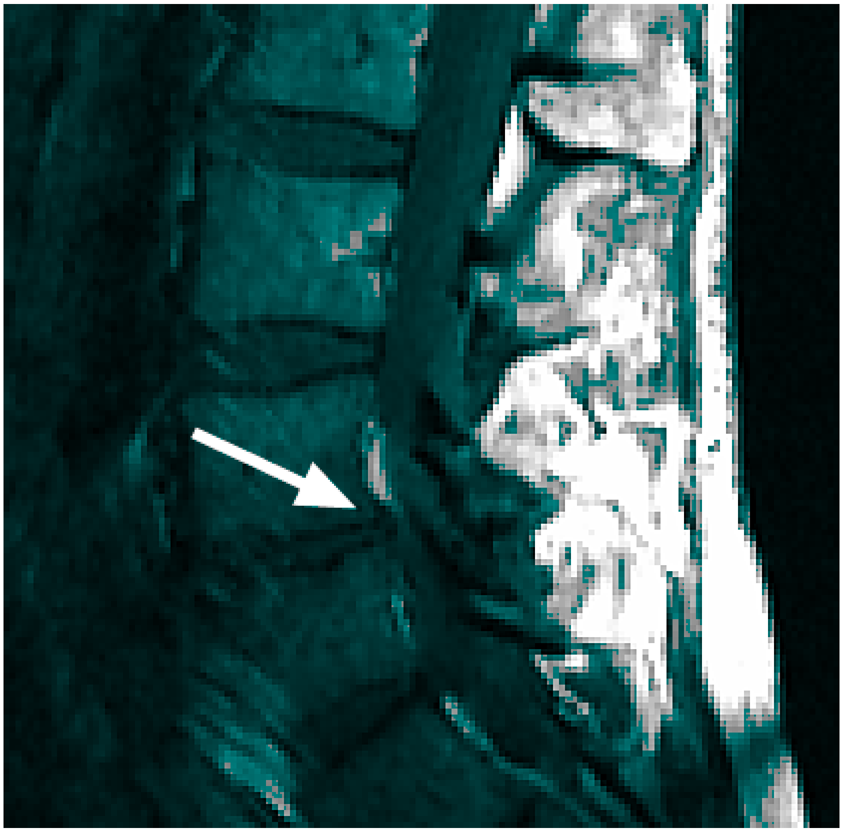

Figure 3. From its very early years, medical MRI was heralded for its sensitivity in the detection of very small lesions in the spine. This image shows a small (<3mm) bulge (arrow) of an intervertebral disc into the thecal sac, which encloses the spinal cord. It was thought that such bulges might indicate the source of chronic back pain, as the bulge resulted in compression of the spinal nerves as they exit the cord. Such bulges can be addressed surgically, although many resolve spontaneously or are unrelated to the patient's back pain. We have intentionally preserved the pixelated quality of the images to emphasize their digital rather than photographic nature. When presented to radiologists, however, the images are usually subjected to digital smoothing on the computer that tends to make them appear more photographic.

$1,000, and such exams were performed at the rate of more than 10,000 per day.

Once the disease was identified, the need for therapy began. The spine, unfortunately, is a terribly difficult site for surgery. The bones are large, in many cases deeply buried in muscle tissue, and the putative disease site (the disk) can only be reached after going around the spinal cord and nerves. Nevertheless, the surgeons press on. Alas, the patients did not experience consistent or substantial relief, even after repeated surgeries. It turns out that the visible "abnormalities" shown in the MRI images were not correlated with the pain (Annertz, Wingstrand et al. 1996; Savage, Whitehouse et al. 1997; Rankine, Gill et al. 1998). Patients who refused surgical treatment, or who were treated "conservatively" (i.e., non-surgically), showed a remarkable effect: disk prolapse came and went without any intervention!

This is a case of a clinical artifact. The instrument did not "lie" about the disks. We misunderstood the meaning of disk prolapse. Since we did not have prior experience seeing this phenomenon, and since it "stood to reason" that disk prolapse would cause the reported pain, images were taken to show a diagnostically significant situation, when it was diagnostically insignificant—normal body behavior.

Not surprisingly, the demand for spinal MRI has dropped. This most likely is due to decreasing fiscal reimbursements from the third party HMO payers. But, in large part, this probably is secondary to the inability of the therapeutic establishment to take significant advantage of the MRI findings.

The Market and the Instrument

These examples show how significant marketing pressure has had an impact on the development and use of the instrument. In the first case, the therapeutic possibilities seem to have genuinely expanded. In the second case, this does not seem to be the case. The instrument, however, has gained tremendous momentum. There is a massive, and costly, installed base, representing an enormous investment. This, on its own, presents a significant incentive for both the manufacturers and the clinicians that sell diagnostic images to pay for their instruments to find diagnostic uses for the instrument.

The instrument and the diagnostic images it produces have been turned into commodities. This has a significant impact on the function of trading in the variety of trading zones that center on MRI instrumentation. In order to appreciate the significance of this point we now turn to a discussion of an alternative form of trading, gift economies.

6. Gift Economies[3]

Gift economies function in a wide variety of circumstances. While each has its own specificity, several generalities describe the range of gift practices. Here we sketch two key properties of gift economies that relate to our concerns with trading zones.

Social Ties

The fundamental difference between gift and commodity economies lies in the curious subtitle of Lewis Hyde's book: *The Gift: Imagination and the Erotic Life of Property*. Gift economies serve to bind people together. They create and maintain social groups. All the various rules or expectations which govern gift exchange serve this end. Ralph Waldo Emerson, in his nineteenth century essay, "Gifts" wrote, "The gift, to be true, must be the flowing of the giver unto me, correspondent to my flowing unto him" (1876, p. 163). On being confronted by an angry family member of a disciple, the buddha is said to have responded, "Thank you for the gift of your anger, which I choose not to accept." Seen in a wider social context, gift economies establish social boundaries; one must give to the group in order to be part of the group and receive the groups' gifts in return: property bonding people together, the erotic life of property.

Commodity economies work against bonding. The rules and expectations that govern commodity exchange serve to define and delimit mutual responsibility and future obligation between the parties involved. Ideal commodity exchanges occur when the parties involved understand at the outset just what each can expect to give and to receive, and when the interaction is to be concluded.

In a sense, commodity exchanges aim to establish—ideally mutually beneficial—conclusions of interactions. Gift exchanges aim to initiate and maintain interactions. In stark contrast to commodity exchanges, gifts cannot have a dollar-measurable value. Such a value would allow a gift recipient to close the interaction; a gift of equal value could be returned leaving neither party obligated to the other. No further interaction would be necessary. Assigned dollar values work against social bonding.

This erotic life of property is a life of bonding or ensnaring people together. Here is an essential duality of gift economies. Gifts given and gifts received call up the joy of human connection, but also the suffering of obligation: bonding and ensnaring. Nietzsche described the gift giving virtue as the "lust to rule" (Nietzsche 1982, p. 301; Shapiro 1991, p. 17). As commodity economies establish status hierarchies through how much

3. Material in this section is adapted from Baird 1997, Sec 3.

is accumulated, gift economies establish hierarchies through how much one gives. Much literature, following early anthropological work (Lévi-Strauss 1969; Mauss 1990) has characterized gift economies as highly oppressive because of this feature.

Gifts Must Move

Gift economies require a cycle of giving. The racist expression "Indian giver" has its source in this aspect of gift giving. In his 1764 history of the Massachusetts colony, Thomas Hutchinson noted that an, "Indian gift is a proverbial expression signifying a present for which an equivalent return is expected" (quoted in Hyde, p. 3). Hyde goes on to describe how the Massachusetts Indians may have shared a peace pipe with the Puritan settlers, leaving the pipe with the newcomers. But, the Indians expected the pipe to be returned, or better, given to others as part of the socially binding cycle of giving—peace making: "The Indian giver (or the original one, at any rate) understood a cardinal property of the gift: whatever we have been given is supposed to be given away again, not kept. Or if it is kept, something of similar value should move on in its stead" (Hyde, p. 4).

In the section of *Zarathustra*, "On the Gift-Giving Virtue," Nietzsche writes, "One repays a teacher badly if one always remains nothing but a pupil. And why do you not want to pluck at my wreath?" (p. 190). In taking an intellectual gift one incurs a debt to contribute an intellectual gift in return—thereby to pass along or recycle the gift.

Stewardship, not ownership, is a better concept for one's relation to gifts received. For a time, one becomes the keeper of something whose value lies in its movement among those in a gift community. Accumulation, then, provides another stark contrast between gift and commodity economies. Businesses aim to accumulate capital in the form of profits. This capital can then be used in various ways at the discretion of the business managers. Gifts, on the contrary, cannot be accumulated like profits; they must be plowed back into the cycle of gift giving. Gifts received must be given away or they cease to be gifts and the recipient of the gift ceases to belong to the gift group.

Of course, much of the *quid pro quo* is still instantiated in mainstream social intercourse, and can be quite formal even in advanced industrial economies. In present day Japan, for example, the precise details of the wrapping, down to the tying of the ribbon around a gift box, can convey crucial information about the giver, the receiver and the intent. Entire subspecialty economies have evolved to ensure that such gifts are properly chosen and packaged (Vardaman and Vardaman 1994).

7. Why Trade?

Academic Trading

An acid quip of physicist Henry Rowland reveals an uncomfortable boundary between an academic gift economy and the commodity economy corporations typically work in. Rowland, advocate of pure science and contemporary of Thomas Edison, complained that the "spark of Faraday blazes at every street corner" (quoted in Moore 1982, pp. 160–161). Edison, in developing and adapting scientific discoveries into salable commodities from which he gained profit, raised Rowland's ire. Edison availed himself of the gifts of the scientific community, but instead of giving back to that community, he sold his inventions. Edison turned scientific gifts into commercial commodities, and thereby excluded himself from the scientific community.

One of the very time-consuming tasks academics can have is reviewing tenure and promotion files for faculty members at other institutions. While such work usually requires reading numerous articles and/or books and providing a detailed evaluation of the work therein, typically, academics are not paid for this work. Evidently, change is afoot. Fees are being requested for this work.[4] Looked at one way, it is entirely reasonable to expect payment for this work; it is just compensation for time-consuming work that may not be personally professionally rewarding. Yet, there is a long-standing tradition that such work is not done for a fee. Arguably this paradox results from conflicting ways of thinking of academic exchange. It could be thought of in terms of commodity exchange—in which case a fee seems more than appropriate. Alternatively, it could be thought of in terms of a gift exchange—in which case the fellowship of the academic community demands such gifts in exchange for membership in the academic community. The fact that fees are being asked for and that they are seen to be unusual, shows that the nature of the academic economy currently is in play.

At the beginning of the paper we quote Galison, "… money is 'neutral' and has a variety of natural properties; for example, it can accumulate into capital—money begets money" (p. 804).[5] Money is not neutral, and the

4. In a phone call from a member of the Department of French and Classics at the University of South Carolina, Davis Baird was apprised of the fact that outside reviewers for their tenure and promotion files were asking for a fee.

5. Indeed, the very example Galison uses of how the peasants in the southern Cauco valley of Colombia can imbue money with "intention, purpose and moral properties"—which we suppressed in the body of the paper—demonstrates another cardinal point over which gift and commodity economies differ. Galison describes how, when a peasant child is baptized, the godparent holding the child also holds a concealed peso. It is the peso that is

very "natural property" which Galison mentions—that it can accumulate—is one of the cardinal points over which gift and commodity economies differ. Gifts cannot accumulate. Commodity exchanges, as opposed to gift exchanges, aim to separate those involved in the transaction; each could go his or her own way with no further interaction, and all could be well. Not so with gifts. We are not here advocating one kind of trading over another. We note only that they are different and these differences have an impact on expectations for future interactions between the traders. Money is not neutral because monetary transactions understood as commodity transactions separate instead of bind people.

Until recently, epistemic—academic—trading typically has taken place in a gift economy. Lewis Hyde argues that this is a consequence of how those involved must think of the inspiration that gives their epistemic gifts life. Where does inspiration or creativity come from? It is a gift, and obligates its recipient to pass along the gift (pp. 143ff). Hyde notes that various developments in modern science have put pressure on the academic gift economy. Writing in 1979, he cites recombinant DNA as one area of research where commodities and gifts are in a state of confusion; matters have only become more complicated (pp. 82ff).

Science since World War II science, particularly "big science," has posed problems for the academic gift community. Big science costs a lot, and consequently, the boundaries between the academic and the commercial have been blurred. In the early post-war period, funding big science through federal grants provided a shield for the gift community. Scientists could continue to treat their work in gift terms because the funds necessary to build the huge instruments or run the huge experiments came from an external source. But federal dollars—alas—are not inexhaustible, and other sources have needed to be tapped.

MRI Trading

MRI instrumentation is—as noted—very expensive. As with the "blaze of Faraday," it is built by private corporations and sold to make a profit. It is a commodity. But, it also is the site for on-going research. We improve our instruments. We learn more about human tissue response to MR probing. We use the instruments to learn more about humans—from brain function to (ultimately!) back pain. But, the largely commercial context for this trading exposes it to pressures that do not exist in gift economies.

Clearly it has been very important for clinicians and instrument engi-

baptized—with the name given to the child. Then, when putting the peso into circulation, the godparent calls its name three times: "the faithful pesos will then return to the owner, accompanied by their kin, usually from the pocket of the recipient" (p. 804). Circulating the peso is essential to this ritual. Gifts must move.

neers to trade. The "Gibbs ringing" artifact would have gone undetected without it. But are clinicians and engineers trading here to "get things right" or to "avoid malpractice lawsuits"? One might dismiss the question: Different people will have their different reasons. But, at a more metaphoric level, the issue is whether trading is taking place as part of a community-forming process, or as part of a community-dividing process. Gift exchange serves the first, commodity exchange the second.

MRI v. Rad Lab

A comparison between MRI and one of the primary examples Galison uses to exemplify the concept of a trading zone—the M.I.T. Radiation Laboratory—should make our point clear. Galison describes at some length how the "Rad Lab" brought together many people not used to working together. Galison shows how theoretical physicists were forced to trade with "production-oriented engineers" (p. 818). This had long-term implications for how theoretical physics was done: Theoreticians were forced through this trading to tie their abstractions to what they wanted to measure; this became the mode for future theoretical physics.

Galison argues that the Rad Lab provides the perfect example of his picture of the intercalated strength of modern physics. Contrary to the positivist picture, the Rad Lab had no "neutral observation language" with which the various scientists and engineers communicated. They all brought their own conceptual baggage to the table, so to speak. Yet, equally contrary to the post-positivist picture, the Rad Lab was not a site of "radical incommensurability," making scientific progress impossible. Despite the conceptual baggage each scientist and engineer brought, they crafted an "interlanguage" with which they could trade. They managed jointly to create a "hybrid of practices that all recognized as 'radar philosophy'" (p. 827). There was no single theory to which all were committed; each worked in his or her own preferred theoretical space. Consequently, theory change did not threaten the joint project. Similarly, changing preferred approaches to instrumentation did not threaten the joint project. The Rad Lab exhibits epistemic strength precisely because of the combination of the autonomous nature of the various trading partners and their shared "radar philosophy."

But, the Rad Lab differs from the diffusion of trading partners involved in creating and exploiting MRI instrumentation. People who worked at the Rad Lab had a clearly defined set of goals. They had to create radar equipment for military use during World War II. They were federally funded, and their work had very high war priority, so they could go about the business of epistemic trading with virtually no need to worry about costs. A gift economy could thrive within the walls of the Rad Lab. We note in passing that this is exactly the reason J. Robert Oppenheimer advocated creating a single facility—Los Alamos—for the bulk of the work needed to develop the atomic bomb.

None of this is true in the case of MRI instrumentation. Very clearly MRI instrumentation is desirable. It allows us to "see inside" without "going inside." This surely accounts for the phenomenal growth in the number of MRI instruments in use. But, clearly if profits were not in the picture, no matter how well the instrumentation allowed us to "see inside," such growth would not have occurred. Once the various aspects of MRI instrumentation are understood primarily as commodities, the various trading partners involved with this instrumentation have primarily profits to motivate them to trade. They are not part of some joint project—to develop radar and save the world from fascism; they are not part of a joint community. If a general *lingua franca* could be said to exist across the many MRI trading partners it would neither be characterized in terms of Creole or pidgin, but in terms of large flows of cash. MRI vendors have recognized competitive advantages quickly by interpreting the needs of clinicians with product advancements and modifications. Thus, if MRI profits were to evaporate, the MRI trading zones would evaporate with them; further progress on this kind of instrumentation would stop. This is not a stable system.

The strength of Galison's intercalated science must flow in part from the fact that the various autonomous trading partners are all contributing to a joint project. While they maintain their autonomy, they also contribute to a shared endeavor. They have to cooperate in creating and maintaining this joint project. They have to have a reason to trade. While each trading partner may have a different reason for trading, trading within a gift economy, because of the nature of gift economies, will produce a stronger result. The strength of Galison's intercalated science rests on gifts.

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