Metaphors
Ladders of Innovation

by David Gray and Michele Macready

Though often dismissed as mere rhetorical window dressing, metaphors play an important role in innovative thinking. In particular, the *cognitive* use of metaphor can reveal potentially fruitful connections and novel ways of seeing that lead to new insight. There are many modes of metaphorical thinking, and an analysis of its operation in science, as in other domains, requires attention to the intention of the metaphor, its essential structures, and the different types of impact it can produce.

A Necessary Ladder

A two-day workshop organized by SFI and the Strategy Institute of the Boston Consulting Group (BCG) last April brought together practitioners and academics from a number of fields with a common interest in the topic of metaphor. SFI participants Walter Fontana, José Lobo, and Jim Rutt gave presentations on the use of metaphor in their respective areas of chemistry, economics, and business. Paul Humphreys and

Nicholas de Monchaux of the University of Virginia presented, respectively, a philosophical account of metaphor and its use in shaping visions in architecture. Tiha von Ghyczy of University of Virginia's business school and the BCG Strategy Institute, together with Michele Macready and David Gray, also of BCG, reported on the Strategy Institute's effort to build an online "gallery" of multi-disciplinary metaphors to inspire business thinkers, and reflected on the potential of employing large sets of metaphors as aids to creative thinking. The meeting explored the use of the cognitive metaphor as an important element in innovation in all these disciplines. The road to novel theoretical work consistently winds through a forest of metaphors.

Complexity science is premised on the assumption that seemingly disparate phenomena, both natural and social, evolved and constructed, can be understood using a common conceptual framework. The signature concepts used to talk about complex systems—emergence,

adaptation, networks, evolvability, phase transitions, self-organized criticality, fitness landscapes, robustness, learning, edge of chaos, even the very notion of complexity itself—remain more metaphorical and suggestive than definitional and precise. And how else could physicists, biologists, chemists, economists, anthropologists, ecologists, computer scientists and historians engage in meaningful scientific dialogue without the ferocious exchange of metaphors?

Reliance on metaphors is by no means unique to complexity science, of course, but is instead prevalent in every field of scientific inquiry, especially in its early stages. Nor is the importance of metaphors confined to rarefied reasoning: the use of metaphors shapes our basic perception and understanding of the world. And yet scientists often distrust metaphors. Metaphors are not models and are thus not susceptible to the sort of direct application and rigorous testing that are the gold standard of scientific verification. As such, metaphors are sometimes viewed as incomplete—or worse, shoddy thinking. While acknowledging their appeal, many regard metaphors merely as ladders which, to paraphrase Ludwig Wittgenstein (no slouch himself when it came to the use of metaphors), once used to climb to a conceptually novel place must then be discarded.

At SFI, concerns for the proper role of metaphors and a respect for the difficulties in transitioning from metaphors to models have been present from the beginning and continue to animate discussion, from the 1992 "Integrative Themes Workshop"[1] to a recent workshop on the "Robustness of Coupled Natural and Human Systems." Plenty of Wittgensteinian ladders continue to be erected and kicked away in complexity science. At the Strategy Institute the cognitive use of metaphors in developing innovative strategies has been at the center of recent work.[2] The insights gained have already started to make an impact on practical work for clients.

Yet, the prevailing view systematically under-appreciates the critical operation of metaphor in cognition—whether in science, the arts, or in business. A metaphor is not merely a flawed and fuzzy model. Nor is it a final answer. A useful metaphor is an *invitation to hard work* that can be indispensable to innovation. Metaphors and models are not locked in a battle for relevance but can be seen as successive ladders, stacked one upon the other, which continue to underpin good thinking. W. Brian Arthur acknowledged this state of affairs at an SFI conference a few years ago when he said: "I have a very strong belief that science and thinking progresses not so much by theorems but by metaphors. Metaphors are what we absorb, that go in deep, that we digest, perhaps also consciously forget. But two years later you start to write about evolution in the economy and (suddenly you find yourself) deeply informed about how it takes place."

One goal of the April workshop was to discern some of the essential aspects of metaphors that make such unlikely, playful connections so highly productive. What constitutes the "appropriateness" of a metaphor, and where do good metaphors come from? More fundamentally, are there ways to improve our prowess as metaphorical thinkers, and can the novel topologies created by the mixing of metaphors, such as occurs regularly in cross-disciplinary work at both institutes, increase their power? This paper is an attempt to address some of these thorny questions and draws heavily upon conference presentations for insights and examples.
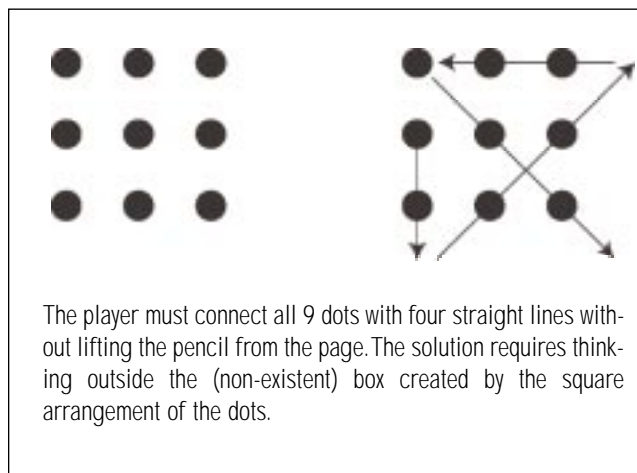
Metaphorical Reasoning

Metaphors appear almost everywhere in our conscious experience. While the classical use of the term applies primarily to a literary device, metaphors can also be visual or even auditory or olfactory (say, comparing something to the aroma of baking bread or apple pie). The organization of the PC "desktop," with its folders and file cabinets, is built on a metaphor. And what are we to make of so-called "metaphors of use" that let us see that, for certain purposes, a dime is a screwdriver? What is it that makes all these things potential metaphors?

"A metaphor," writes philosopher Nelson Goodman, "is an affair between a predicate with a past and an object that yields while protesting."[3] This rather louche, metaphorical definition highlights an essential feature of the metaphor: an intrusion from one domain into another. The metaphor borrows language, symbols, logic, and associations from one field and imposes them upon another to which they do not properly belong. Thus, the notion of a "war on poverty" suggests a transfer of structures and associations from

the military domain to the social. The fit may be uncomfortable and endured only under protest, as Goodman notes. It is the incommensurability of the metaphor that is often its salient characteristic: if taken literally, all metaphors are patently false if not absurd. Melville's declaration that "Christ was a chronometer"[4] is a stark example. A liaison that does not involve some transgression of boundaries is no metaphor.

Thus the fit of the metaphor will always be inexact, and it is around these jagged edges that much of its innovative potential lies. A metaphorical intrusion smoothed by time and long wear is apt to become a dead metaphor or cliché: "Achilles heel" no longer jangles with associations of its original source but is used quite unreflectively to denote a fatal weakness. For most in the business world, the exhortation to "think outside the box" evokes no connection to the brain-teaser that spawned the phrase. These metaphors have died into literalness and thus lost their power to catalyze thinking.

The player must connect all 9 dots with four straight lines without lifting the pencil from the page. The solution requires thinking outside the (non-existent) box created by the square arrangement of the dots.

We should note that language is thick with the corpses of dead and dying metaphors. Scratching the etymological surface of most words reveals their metaphorical roots: the "corporation" derives from the *corpus*—a living body, and "strategy" from *strategos*—a military general. We are quite justified in using words literally without constantly acknowledging the underlying metaphors, but unearthing these foundations can sometimes be revealing. Unquestioned, implicit metaphors continue to exert a strong effect on the structure of language and thus on the structure of thought itself. For instance, bringing to light the mechanical metaphor implicitly embedded in a lot of

business thinking (which continues to spawn new sub-metaphors, like "alignment," "toolkits," and "reengineering") can cause us to reconsider whether we are operating with the right picture in mind. Attention to metaphor allows us to engage in a useful archeology of clichés.

Anatomy of a Metaphor

Linguists use the terms *source* and *target* to designate the linked domains of the metaphor. The target is the main topic of discourse (e.g., the development of scientific ideas)—the thing we wish to understand—and the source is the interpretive device that sheds light on the target (e.g., political revolutions). Typically, we would expect the source domain to be the more familiar to us, the one closer to understanding or intuition, which therefore allows it to elucidate the more obscure target.

Many metaphors, however, draw upon source domains of considerable complexity: for example, laminar flow as a metaphor for business supply chains. Among business practitioners the invocation of laminar flow is likely to produce a lot of blank faces, while the supply chain (itself a metaphor!) will be quite familiar. In this case, the effectiveness of the metaphor is not immediate but requires a great deal of education to make it work.

The example highlights an important feature of metaphor--its power to *defamiliarize* the familiar. We think we know something about supply chains: the interlinked system of companies, individuals, and goods that provides inputs to manufactured products. The effectiveness of the metaphor borrowed from physics lies in its power to unhinge this knowledge--is it a chain? or is it more like a smooth flow of liquid? or is it a web?--in a way that allows new thinking to penetrate. We need not discard the existing picture, but the effective metaphor causes us to add new dimensions to the conceptual space. We may, therefore, wish to replace the notions of "familiar" and "unfamiliar," substituting "known" and "unknown." In some sense, the cognitive flow of the metaphor will always be from a domain of knowledge to one of nescience, but this does not necessarily correspond to the intuitive familiarity of these realms.

We should note that the transfer (the word *metaphor*

itself comes from the Greek roots meaning "to carry across," i.e., transfer) can work in both directions. The linking of neurophysiology and computation is a commonly cited example of such a "boomerang" metaphor. While the initial borrowing of language and concepts flowed from brains to computers, the favor has been returned in the form of computer theory as a source of metaphors for neurological processing and, more generally, for information processing in biological processes. It may be more proper to speak of "ricochet" metaphors--once fired off, the trajectory and related combustions touched off by the cognitive metaphor may be difficult to predict! Darwin was clearly influenced by the works of political economists like Malthus and Smith in developing his principle of natural selection. A century and a half later we see the emergence of an army of researchers eagerly applying biological insights to the workings of markets. Likewise, the authors of a new book [6] relating the strategic insights of military theorist Carl von Clausewitz to business note that they are merely returning the metaphor: Clausewitz himself proposed that war could best be compared with commerce, since both are social conflicts of human interests and activities.
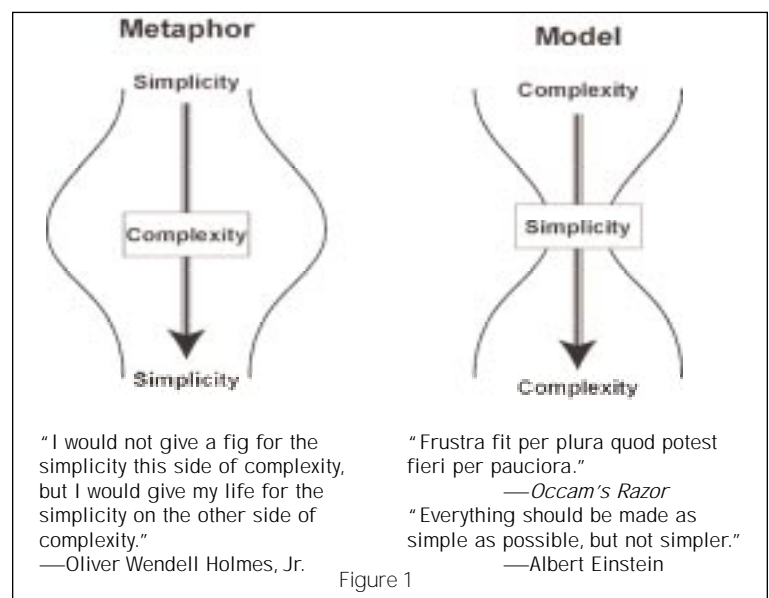
Metaphor and Analogy

Analogy is closely linked with metaphor and, indeed, we may think of these two notions as interchangeable: both point out likenesses in particulars between things that are otherwise dissimilar. In the way we propose to use the term, analogy is a *component* of metaphor that refers to the correspondences between domains—the structures or associations that form the core of the link between source and target. Without some degree of analogical mapping, the metaphor will be stillborn. A metaphor, however, goes beyond analogy by including all the ill-fitting facets of the linked entities—the fractures and fault lines—in the picture. The metaphor comes to life where analogy leaves off.

At this point, we raise again the vexed question of metaphors and models. In some cases we want to make a sharp distinction between these two things, while in others they seem to live in harmony. The question

arises with particular force in the sciences where metaphors (e.g., plum puddings or solar systems as images of the atom) seem to shade into models that shape experimental design. The metaphorical origins of scientific models have been long noted: "Perhaps every science must start with metaphor and end with algebra, and perhaps without the metaphor there would have been no algebra."

Yet models have certain recognizable properties distinct from metaphors, most notably a degree of formalization that the metaphor lacks. We want models for specific purposes and we demand of them a certain rigidity that preserves the essential relationships between the model and the modeled. We might ask whether the mechanism of the model necessarily involves an appeal to the formalization of mathematics. A ship model, for example, provides a formal mapping to the actual bark by means of a mathematical correspondence, say 1 cm = 1 meter. A financial model similarly purports to capture the essential activities of a firm and their relations to one another using the formal structures of mathematics.

Figure 1 below illustrates the differing intentions of model and metaphor. The widening body on the left represents the "complexification" accomplished by the metaphor. For example, "…Juliet is the sun" brings in a host of potential structures and associations (e.g., of light, warmth, rising and setting, perhaps also eclipse?) that vastly complicate our picture of an otherwise unremarkable teenager from Verona and leaves that object forever altered in our understand-

"I would not give a fig for the simplicity this side of complexity, but I would give my life for the simplicity on the other side of complexity."
—Oliver Wendell Holmes, Jr.

"Frustra fit per plura quod potest fieri per pauciora."
—*Occam's Razor*
"Everything should be made as simple as possible, but not simpler."
—Albert Einstein

Figure 1

ing. The pinched figure on the right represents the opposed mechanism of the model that seeks to make tractable a potentially vast body of inputs and data through necessary simplification. This simplification is far from the final word, however, as analysis of results gives birth to new types of complexity.

This picture may seem to imply a fundamental opposition between metaphor and model. But this need not be so. One attempt to cut this Gordian Knot is simply to identify models with analogy, which would lead us to say that a model is a special kind of metaphor--one that has been pared down to the hard core of direct correspondence we can map between the two domains. This leaves the door open to further revision of the model through a metaphorical process but also lets us make formal demands of the model that may lead to its "falsification" or rejection if it fails to deliver on its promised correspondence to reality. Figure 2 is an attempted illustration of this relationship that stresses the analogical properties of the model while allowing for an ongoing reciprocity between model and metaphor.

Figure 2: Metaphor and Model
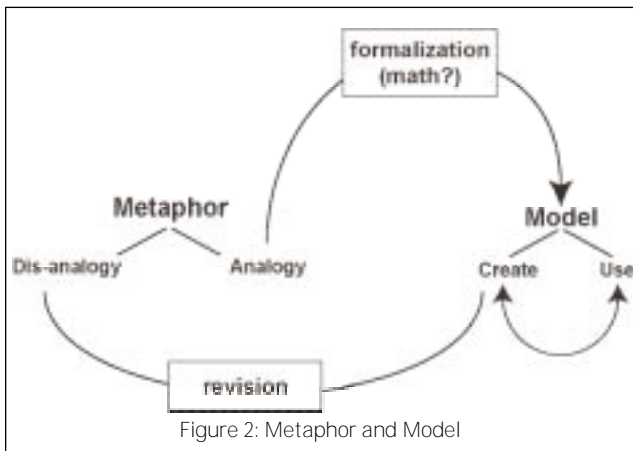
DIALECTICAL TAXONOMY

The metaphor appears in so many guises and incarnations that a formal representation of its workings would seem very nearly futile. Instead, our analysis leaves intact all the inherent tensions. This description incorporates a sort of dialectical pairing of aspects of metaphor without attempting an ultimate synthesis. The progression is described in three stages: the intention, the structure, and the impact of the metaphor.

Intention of the Metaphor

In large part, intention makes the metaphor. There is no reason *a priori* why two such unrelated domains as ant foraging behavior and airline baggage handling should ever meet. The metaphor arises in the deliberate pairing of these two things. Although some things strike us as ìfoundî metaphors, the fact and the nature of the linkage derives more from the intention of the metaphor maker than from inherent structures. Intent must be appropriate to the context in which the metaphor is used and largely determines its success. Thus the particular application of metaphor in the business sphere in which the Strategy Institute operates may differ from its use in the SFI context of scientific research.

Much of the discussion of literary metaphors, going back to Aristotle, deals with them as *rhetorical* devices whose purpose is to convince the reader through an especially apt linkage. The rhetorical metaphor relies on economy of expression and aesthetic impact. The source domain of the rhetorical metaphor should be familiar and intuitive and the analogy between the linked entities immediately compelling. We distinguish from this the *cognitive* use of metaphor that forces a departure from the familiar. The intent of the cognitive metaphor is novelty, and we encounter it primarily as an opening to further inquiry. The linkages may be far from intuitive--for example, a proposed rapport between the intangible structures of proof theory in logic and chemistry[8]. But the intention is to force a cognitive reevaluation that lets us see in new ways and ask different questions.

Thus two alternative intents of the metaphor are revealed: *invitation* and *persuasion.* We are invited by the cognitive metaphor to delve into the intricacies of the source domain, test the strength of the bridge to the target, and hunt for important fractures in the analogy. It is an invitation to become a co-creator of the metaphor. The rhetorical metaphor is more `concerned with persuading us to a certain view.

This points to a further pairing of intentions related to the use of metaphor—*synchronizing* and *disarming.* Metaphors often become shorthand for certain ideas and are thus useful in aligning understanding or expectations. A manager who uses military terminology to describe business situations takes advantage

of the synchronizing power of the metaphor, so that the difference between a "flank maneuver" and a ïfrontal assaultî on a competitor is quickly understood. Alternatively, metaphor can disarm expectationsówe may choose the metaphor of laminar flow or neo-Darwinian evolution precisely because it is unfamiliar. With the metaphor comes an unaccustomed vocabulary for describing phenomena in the target domain that forces a reexamination of what we know.

A final dimension of intention involves the use of the metaphor for *creating* versus *distilling* knowledge. The purpose may be to produce a new lens that allows an alternative view of the area we seek to understand. Here, the disjunctions and fault lines of the metaphor can be especially productive and drive us to search out or create structures that appear to be missing in the mapping between source and target domains. The distilling function of metaphor, on the other hand, is less about creating new knowledge than encapsulating wisdom--often gained through long experience--into a form that can be communicated to others.

These dichotomies reflect two categories of metaphorical intentions: learning and communicating. While the distinction is not absolute--we may learn much in seeking to communicate insights through metaphor--there is a natural split in the foregoing pairings. The learning function of metaphor emphasizes extended engagement with the source domain as a way of shaking up received thinking. It is more likely to focus on the fractured edges of the analogy, seeking novelty in the interstices where the fit is most uncomfortable. Rhetorical, persuasive, synchronizing, and distilling uses of metaphor are more geared toward capturing and communicating subtle insight to others.

Intention

Learn
- Cognitive
- Invitation
- Disarm
- Create

Communicate
- Rhetorical
- Persuasion
- Synchronize
- Distill

Structure of the Metaphor

The building blocks of metaphor--source, target, mapping, analogy, fracture--have been discussed in some detail above. But a number of tensions surrounding the structure of metaphor arise in its application. One such tension pertains to what might be called the "level" of the metaphor: does it act as a *governing* paradigm or in an illustrative, *subsidiary* role? A grand, governing metaphor offers a holistic interpretation of the target domain. Some governing metaphors may be unacknowledged-—though no less extensive or influential for that reason. Implicit images of firms as machines or as organisms are pervasive in business discourse[9] and shape our understanding and expectations of action, authority, and change. But not all metaphors make such claims to completeness. When Wittgenstein uses a toolbox to illustrate the diversity of language, or Adam Smith speaks of the intercession of an invisible hand in the market, our enlightenment does not depend upon acceptance of a larger schema.

Indeed, we often find that effective metaphorical thinking involves not just one *grand schema* but a *mixing of metaphors.* While such promiscuity is deemed poor style in the literary metaphor, its cognitive use is enriched by a proliferation of viewpoints. This raises some fascinating questions about the topology of large sets of metaphors: the strength, valence, mutability of connections among the source domains. The metaphorical space suddenly expands geometrically. What is lost, perhaps, is the coherence that a single schema, rooted in a particular domain, makes possible. Again, the intent of the metaphor--as a discovery device versus a communication tool--may dictate the effective structure.

A final reflection on the structure of metaphor deals with the trade-off between *depth* and *shallowness.* The domain acting as the source for the metaphor is rarely taken in all its complexity but is, at best, a snapshot—a frozen picture that provides the basis for the metaphorical transfer. Thus, the structures of biological evolution have been taken seriously as a metaphor in economics at least since the 1950s but the picture of evolution that economists work with is typically limited.[10] Our understanding of the source can and should be continually revisited and revised. But to be effective for the metaphor it must have an *appropriately moderate* number of dimensions. Too

much complexity renders the metaphor unmanageable. For the pedantic astrophysicist intent on solar flares and burning helium the comparison of Juliet to the sun will be unrevealing. There is a sense in which all metaphors are shallow and must remain so. We can seek expertise in the target domain but, in the metaphor, we approach the source domain as amateurs.

But as curious amateurs! Unlike the model, which demands a degree of closure and completeness, the process of metaphor has no defined terminus. The original evolutionary metaphor in economics may be updated to include empirical manifestations of epistasis in fitness landscapes or insights from the sequencing of the genome. These revisions may provide valuable extensions of the metaphor—although this is by no means guaranteed. The depth of the metaphor lies in its open-endedness.

Impact of the Metaphor

The outcome of a metaphor will partially depend on its original intent. In some cases, the metaphor may prove immediately effective, while in others considerable effort may be required for it to bear fruit. Its impact may come either in "working" the metaphor or in *using* it. To use a metaphor means to apply the insights, language, equivalences, and other associations of the source to shed light on the target. We do this all the time. Generations of physics students have used the familiar notion of water moving through pipes as a way of conceptualizing the much more intangible flow of electrical current. The parallels break down at some point, but it is a useful early device for learning. We use the metaphor as a kind of "wrapper" to give us a mental grip on a slippery substance.

The effect of working the metaphor is rather different. The impact comes more in its creation than in its eventual application. Working the metaphor means plunging into the intricacies of source and target domain and building the bridge between them span by span. The metaphor that emerges may not be intuitive or easily applicable (e.g., *NKC* landscapes as

images of economic ecologies) but the process of generating it may trigger unanticipated insights. The benefit arises from the different perspective one adopts in plumbing the intricacies of the metaphor.

This also raises the question of just who is using or working the metaphor: i.e., the metaphor's community. Is the metaphor the property of an *individual* or of *a group?* Take, for example, a metaphor that publicly shaped U.S. foreign policy for decades: the "domino effect." This theory expressed the fear following World War II that, if one country were to fall to Communism, its neighbors would fall with it (like a row of dominoes). Whatever the merits or limitations of this mechanistic metaphor, there is no doubt that it had many adherents who used it in forming and communicating ideas. Creation and refinement of a metaphor is often the work of a group. The emerging model of

the atom in the first half of the 20th century benefited from the metaphorical contributions of multiple minds: Thomson's plum pudding, Rutherford's solar system, Bohr's water droplet, etc., that invited a whole generation of physicists to continue this theoretical exploration.

On the other hand, there are private metaphors that lead to insight for one particular mind. An example of this type of heroic metaphor might be Albert Einstein's thought experiment in which he imagined how the world would look to him riding a beam of light (as if it were a train or a horse). The change of perspective that the metaphor allowed made possible the later development of his theories of relativity without demanding, however, that others adopt the light-riding metaphor themselves.

While most of the discussion has been about the logical transfer of structures between target and source domains, an analysis of metaphors that did not take into account the emotional and intellectual associations that attach to them would be incomplete. Metaphors do not come without baggage, and their impact may have as much to do with these ancillary factors as with their formal content. Indeed, it has been proposed that the cascade of associations, both positive and negative, triggered by the metaphor is its content. These associations are not only inescapable but integral to the impact of the metaphor. For example, the effectiveness of military metaphors in business may have primarily to do with the penumbra of associations--camaraderie, loyalty, sacrifice, determination,

etc.--that surrounds warriors. There is thus a dualism between the *logical content* and the *cascade of associations* of the metaphor in assessing its impact.

In highlighting the various strands and tensions of the metaphor, we have raised more questions than we have resolved. At the least, we hope to have made clear how pervasive metaphor is and how multifarious its use. In particular we wish to recognize the essential role of *cognitive* metaphors in creative thinking. As with physical ladders, metaphors must be used with care, planted firmly, and adjusted to the task at hand. And whether we then quietly put them aside or continue to build on these edifices, we will always need to resort to ladders for climbing to new conceptual heights.

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more reading

Metaphor and Knowledge: The Challenges of Writing Science (SUNY Press) is a new book by Ken Baake, assistant professor of technical communication and rhetoric at Texas Tech University. The book offers a history of rhetoric and metaphor in science, delving into questions about how language constitutes knowledge. The book grew out of Baake's 1997 science journalism and technical writing internship at the Institute.

[1] See George Cowan, David Pines, and David Meltzer, eds., *Complexity: Metaphors, Models and Reality* (Addison-Wesley Publishing Company, 1994).

[2] See Tihamer von Ghyczy, "The Fruitful Flaws of Strategy Metaphors," *Harvard Business Review* (September, 2003), 86-94 for a discussion of cognitive metaphors in business innovation.

[3] Nelson Goodman, *Languages of Art. An approach to a theory of symbols* (Indianapolis/Cambridge: Hackett Publishing Company Inc., 1976), 69.

[4] Pierre, "Chronometricals and Horologicals," (Plinlimmonís Pamphlet, 1852).

[5] See Thomas Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, 1962).

[6] See Tiha von Ghyczy, Bolko Oetinger, and Christopher Bassford, eds., *Clausewitz on Strategy: Inspiration and Insight From a Master StrategistóA Publication of the Strategy Institute of the Boston Consulting Group* (New York: John Wiley & Sons, Inc., 2001).

[7] Max Black, "Models and Archetypes," *Models and Metaphors: Studies in Language and Philosophy* (Ithaca, New York: Cornell University Press, 1962).

[8] See Walter Fontana and Leo Buss, "The Barrier of Objects: From Dynamical Systems to Bounded Organizations," *Boundaries and Barriers: On the Limits to Scientific Knowledge*, eds. John Casti and Anders Karlqvist (Addison-Wesley, 1996), 56-116. http://www.santafe.edu/~walter/Papers

[9] See Gareth Morgan, *Images of Organization,* 2nd ed. (Thousand Oaks: Sage Publications, 1997).

[10] Armen Alchian, "Uncertainty, Evolution, and Economic Theory," *The Journal of Political Economy* 58, no. 4 (June 1950): 211-221, is widely regarded as an early influential article in this vein.