# BOOKS *et al.*

NEUROSCIENCE

## A Framework for Vision's Bag of Tricks

**Vincent A. Billock**

Every researcher working on perception has a mental catalog of interesting visual phenomena. Several years ago, Dale Purves, an eminent neurobiologist, began revisiting many of these classics and questioning the standard explanations for them. This research was guided by what Purves and his colleagues call "an empirical theory of perception." They posit that visual mechanisms evolve and develop to exploit statistical likelihoods in natural images. Neural activity is thus shaped by the prior successes and failures of visually guided behaviors responding to similar retinal stimulation (empirical feedback). Consequently, what we see accords with what prior images evoking similar neural activity usually turned out to be.

**Why We See What We Do**
**An Empirical Theory of Vision**
*by Dale Purves and R. Beau Lotto*
Sinauer Associates, Sunderland, MA, 2003. 272 pp. Paper, $42.95. ISBN 0-87893-752-8.

*Why We See What We Do*, Purves and R. Beau Lotto's new book on this theory, will remind vision researchers of James Gibson's and David Marr's seminal efforts, and it may prove as influential. Gibson introduced the ecological approach, which focused on the analysis of invariant features of information in the optical stimulus while ignoring neural processing (*1*, *2*). The approach led to many insights but was limited by a reluctance to broaden its interests or to incorporate other advances in perception and neuroscience. Its dismissal of numerous visual illusions and phenomena as "unecological" contributed to an unfortunate estrangement from the rest of the vision community. Marr's computational theory of vision was more ecumenical (*3*). He began by asking, what information is essential for solving a particular visual problem? Insights derived from that analysis then had to be turned into algorithmic or neural models—a tricky process that Marr tried to facilitate by offering several problematic rules.

Purves and Lotto take an approach superficially closer to that of Gibson, with its emphasis on perception-action interactions and regularities of information in optical stimuli. However, their empirical theory regards optical information per se as often ambiguous. Rather than resonating to Gibson's optical invariants, the visual system (partially hardwired by evolution and modified during individual development) makes reflexive decisions based on probability. In this regard, the empirical theory is more simpatico with Marr, whose binocular vision models use probabilistic assumptions about correspondences between points stimulated in both eyes.

After Marr and Gibson, many vision researchers despaired of finding an elegant theory of vision. For example, V. S. Ramachandran compared the evolution of visual mechanisms to the improvisations of hackers and described the visual system as "a bag of tricks." (*4*). Purves and Lotto neither defy this insight nor wallow in it. Their empirical approach accepts the modularity of vision and the ad hoc nature of each mechanism's development. They rely on (though do not model) the ability of trainable neural networks to capture image regularities and likelihoods, which they analyze in novel and ingenious ways. Crucially, they embrace visual illusions as clues to the probabilistic biases wired into the system. For example, they take three important two-dimensional contrast illusions and show that each corresponds to the pattern of stimulation induced by illumination of a more common three-dimensional, real world stimulus. The authors apply this approach to a variety of problems in the perception of contrast, form, motion, color, and depth. Their casebook presentation keeps the work accessible by imparting a sense of the approach without imposing a rigid set of rules.

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**Same shades of gray.** Mutually consistent information indicates that the top surface is in intense light and the front surface is in deep shadow. This leads to dramatic perceptual differences between equiluminant gray patches.

The authors' perspective yields some interesting insights. Consider an atypical example from color vision (an interest of mine): Humans have two color-opponent mechanisms: one signals red or green, the other signals blue or yellow. I could offer explanations for the detailed properties of these mechanisms, explanations based on the necessity of sampling and transmitting the spectral variance of natural images using the least neural bandwidth. Purves and Lotto emphasize that two color-opponent channels give rise to four well-spaced opponent hues and that four such labels are the minimal requirement to solve the problem of segmenting a surface (the famous four-color map problem). I am enthusiastic about this idea not because it displaces anything else I know about color, but because it provokes new lines of thought (such as implications about the number of spatial mechanisms necessary to segment a scene by texture and the use of graph theory in the design of plates for clinical tests of deficiencies in color vision).

Purves and Lotto do not attempt to account for every nuance of the perceptual phenomena they study, and they make only a sketchy effort to tie the explanations they derive to actual or inferred neural mechanisms (a surprising choice, given their backgrounds). For example, in discussing why chromatic brightness should differ from luminance, they ignore models of how brightness is generated (by nonlinear summation between luminance and color mechanisms) and why it varies (because the relative weights in the summation may be softwired). This work seems ideal for Purves and Lotto to incorporate (by making the summation parameters a function of experience). I suspect that the authors eschew such modeling because they are influenced by trainable neural networks whose hidden layers are seldom so interpretable.

Specialists without such inhibitions may implement some of Purves and Lotto's theories as algorithmic or neural models. Considerable work could also be done on the more generic aspects of their theory. The book's influence may be enhanced because it arrives just when much of the research needed to flesh out an empirical theory has become available. There is a growing literature on the multiscale statistics of natural images, and there has been much recent progress on incorporating Bayesian decision-making into visual models. Similarly, rigorous treatments of the interactions between perception and action, the dynamics of neural activity patterns, and the dependence on the system's prior history are hallmarks of recent work in sensorimotor research and complexity theory.

Purves and Lotto, although clearly aware of many of these developments, have not yet attempted to fully incorporate these findings in their own approach. A book that did so would appeal to a smaller (and more mathe-

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matically inclined) audience. The real test of *Why We See What We Do* will be whether it inspires specialists (with the ability to integrate work across these areas) to create fully fleshed-out models.


**References**

1. J. J. Gibson, *The Senses Considered as Perceptual Systems* (Houghton Mifflin, Boston, 1966).
2. J. J. Gibson, *The Ecological Approach to Visual Perception* (Houghton Mifflin, Boston, 1979).
3. D. Marr, *Vision: A Computational Investigation into Human Representation and Processing of Visual Information* (W. H. Freeman, San Francisco, 1982).
4. V. S. Ramachandran, in *The Utilitarian Theory of Perception*, C. Blakemore, Ed. (Cambridge Univ. Press, Cambridge, 1990), pp. 346–360.


HISTORY OF SCIENCE

# Vision of the Lynxes

**Giovanni F. Bignami**

The president of the Accademia dei Lincei is still the "Princeps" in official documents, such as the elegant parchment given to new members. The text of these documents is in Latin, of course, because tradition counts: after all, this year marks the 400th anniversary of the creation of the Accademia, the world's oldest scientific society.

**The Eye of the Lynx**
**Galileo, His Friends, and the Beginnings of Modern Natural History**
*by David Freedberg*

University of Chicago, Chicago, 2003. 525 pp., illus. $50, £35.50. ISBN 0-226-26147-6.

The Accademia was founded in the Roman summer of 1603 by young Prince Cesi and a small group of his friends. It was dedicated to understanding and describing nature as a whole—not a small task for four young intellectuals. They likened themselves to lynxes, animals reputed at the time to have especially sharp eyesight (an attribution that modern physiologists of felines, alas, have shown to be incorrect).

In the first decades of the 1600s, the original Lincei grouped around Galileo. He had been admitted in 1611, presumably on the strength of his just-published *Sidereus Nuncius* ("*The Starry Message*," not "*Messenger*" as it is sometimes translated). Galileo's book, a bestseller which sold out its initial print run of 550 copies in a few days, revolutionized astronomy. The subsequent history of the Accademia is also well known. In the 17th century, it published such fundamental works as Galileo's *The Assayer* (1623) and the splendid *Novae Hispaniae, Thesaurus* (1630–1651), a collection of drawings and descriptions of the natural wonders of Mexico (which at the time were as alien and puzzling as NASA's moon rocks were in the 1970s). The Accademia's fortunes rose and fell through the following century until the Lincei were revitalized, with their current name, in 1801. With its location in Rome, various popes tried to appropriate and control the Accademia. Then, in 1871, the "Italians" entered Rome and the Lincei became the official academy of the new state of Italy. It remains so today, after a difficult hiatus during the fascist regime.

This long and tormented history has led to the anniversary now being celebrated in Rome with composed pride and interesting new research. It is thus especially fortunate, and possibly not entirely by chance, that David Freedberg's *The Eye of the Lynx* comes out now. An art historian, Freedberg is the director of the Italian Academy for Advanced Studies in America at Columbia University. His splendid volume is replete with facts, wisdom, and beauty as could only come from pairing history of science with history of art. The visual aspect is of course striking. The book includes many examples from the Lincean Cassiano dal Pozzo's collection of drawings (dated from around 1640), which Freedberg dramatically rediscovered in a forgotten corner of Windsor Castle in 1986. These are a joy to the eye, and the author also masterfully sets them in their scientific and historical contexts.

Also in the context of the early Lincei, Freedberg leads the reader through a skillful representation of the birth of modern astronomy, with Kepler's Nova of 1604 and Galileo's lectures in Padua on the "Nova Stella." Galileo did more than lecture about the nova; Fredberg describes a little-known dialogue, anonymous but attributed with certainty to Galileo, that tells in a delightful way the story of the new star. Equally delightful are Freedberg's original translations of a few passages from the dialogue—all the more remarkable because the original text is in a 16th-century Paduan dialect, which Galileo used to give a special direct robustness to his characters. (Only the historian of science Stillman Drake has tried similar translations before, and he did not do better.) In another fascinating aside, Freedberg discusses the microscope and its first scientific use, by Francesco Stelluti, to study the anatomy of bees. This work was carried out within the delicate relationship between the Lincei and Pope Urban VIII Barberini, whose coat of arms included three bees. Urban VIII represented a great hope for Galileo and the Lincei when he was raised to the Pontifical seat in 1623, but later he would force Galileo to recant. My own discussion of Stelluti's pioneering microscopy (*1*) mentions the rest of the story of the coat of arms: the bees were originally horseflies, because the noble Barberinis started as horse-traders.

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**"Sweet 'pregnant' orange."** Vincenzo Leonardi's sensitivity to color and texture and his skill in watercolor produced the finest drawings in Cassiano's "paper museum," including a spectacular series depicting citrus fruits.

When, in his seventies, Giovanni Battista della Porta became the fifth member of the Lincei, he was known throughout Europe for his work in a multitude of fields. His influential books on physiognomy and phytognomy embodied the view that the surface appearances of things reflect their true inner nature. The pairings of animal and human physiognomies in della Porta's original drawings link *The Eye of the Lynx* with Irene Baldriga's *L'Occhio della Lince* (*2*), also a fascinating read. That both books have the same title speaks of the fascination historians of art and science alike have for the Accademia, its associates, and their encyclopedic culture. This University of Chicago volume excels in the splendor of its reproductions and the clarity of its English text. The more modest, black-and-white Italian book is also recommended, especially for its wealth of original quotations. Though these will require readers to be versant in Latin and old Italian.


**References**

1. G. F. Bignami, *Nature* **405**, 999 (2000).
2. I. Baldriga, *L'Occhio della Lince, I primi lincei tra arte, scienza e collezionismo* (Accademia Nazionale dei Lincei, Roma, 2002).


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