the author's unpublished work on habitat selection, are full of technical details that will overwhelm the lay reader. Unfortunately, most of the work described is inconclusive; despite the widespread occurrence of melanism, its evolutionary significance is nearly always unknown.

What can one make of all this? Majerus concludes with the usual call for more research, but several lessons are already at hand. First, for the time being we must discard *Biston* as a well-understood example of natural selection in action, although it is clearly a case of evolution. There are many studies more appropriate for use in the classroom, including the classic work of Peter and Rosemary Grant on beak-size evolution in Galapagos finches. It is also worth pondering why there has been general and unquestioned acceptance of Kettlewell's work. Perhaps such powerful stories discourage close scrutiny. Moreover, in evolutionary biology there is little payoff in repeating other people's experiments, and, unlike molecular biology, our field is not self-correcting because few studies depend on the accuracy of earlier ones. Finally, teachers such as myself often neglect original papers in favour of shorter textbook summaries, which bleach the blemishes from complicated experiments.

It is clear that, as with most other work in evolutionary biology, understanding selection in *Biston* will require much more information about the animal's habits. Evolutionists may bridle at such a conclusion, because ecological data are very hard to gather. Nevertheless, there is no other way to unravel the forces changing a character. We must stop pretending that we understand the course of natural selection as soon as we have calculated the relative fitness of different traits. □

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More than meets the eye

Visual Intelligence: How We Create What We See

by Donald D. Hoffman

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John C. Marshall

It sometimes seems that a new visual area is discovered in the primate brain every week. The sheer amount of brain that has purportedly been colonized for vision makes one wonder how we can do anything other than see. It is likewise unclear whether this aggressive drive for *lebensraum* characterizes the biological evolution of the visual system or the cultural evolution of neuroscientists.

Be that as it may, it is quite a relief to see

The "subjective" Necker cube: the black discs can be seen as behind the cube or as holes in front of it.

that Donald Hoffman's riveting introduction to *Visual Intelligence* contains very little about brains. Even when he describes how brain damage can cause loss of colour perception or of motion perception, Hoffman has his eye more on the functional ramifications of the loss than on the neuroanatomical underpinnings. For the most part, then, Hoffman adopts the classical approach of cognitive science and computer science: describe the rules according to which the visual system operates, and let somebody else worry about which neurons are where.

But what is vision? Here Hoffman quotes (and follows) the position originally expounded by David Marr: "Vision is a process that produces from images of the external world a description that is useful to the viewer and not cluttered with irrelevant information . . ." And what in Hoffman's own terms is the fundamental problem of vision? That "the image at the eye has countless possible interpretations". And within which overall framework can the problem be solved? Hoffman sees a strong parallel between Noam Chomsky's arguments for rules of universal grammar and his own rules of universal vision. In both cases, the mature competence that quickly develops is grossly underdetermined by the fragmentary data presented to the senses.

Hoffman accordingly conjectures that "the innate rules of universal vision are part of the child's biology, and allow the child to acquire, through visual experiences that might vary from one culture to another, the rules of visual processing. The rules of visual processing, in turn, allow the visually competent child or adult to construct specific visual scenes by looking." Hoffman is happy to agree with James Gibson that retinal images, above all moving images, are "rich in information". They are just nowhere near rich enough to pick out our visual world from all the "countless possible visual worlds" that are compatible with such images.

Chapter two ("Inflating an artist's sketch") shows most clearly how Hoffman's

strategy operates. The issue tackled is a fundamental puzzle in depth perception: "The image at the eye has two dimensions; therefore it has countless interpretations in three dimensions." Hoffman then solves (most of) the problem of how the visual system comes to the correct interpretation (most of the time) by conjecturing an ordered sequence of visual rules. These range from the simple "Always interpret a straight line in an image as a straight line in 3D" to the considerably less obvious "Interpret each concave point on a bound as a saddle point on a rim".

Hoffman leads the reader through the justification for these maxims by showing with line drawings and other two-dimensional patterns exactly how each rule serves to constrain the percept that we actually derive from the image. In other chapters, Hoffman deploys essentially the same strategy to show how the visual system recovers surfaces, shapes and their parts, colour, and the path of moving objects by "an intelligent process of active construction".

Hoffman's book has many virtues, of which sheer intellectual excitement is the foremost. *Visual Intelligence* has been aimed at the lay reader ("tourists", as Hoffman calls them) and is indeed sufficiently lucid to attract and hold such an audience without insulting their intelligence. Each of the many figures illustrates an argument. And, as so often happens in the theory of perception, Hoffman can show that artists often had an intuitive understanding of principles that the scientists later 'discovered'. From Brunelleschi to Picasso by way of Dürer, painters were using pictorial devices that are only now coming to be formally understood. Hoffman even manages to find palaeolithic cave drawings of bison that show the kinds of subjective contours studied to such great effect by Gaetano Kanizsa.

But this is no 'coffee table book', and I would be surprised if even the most experienced of visual scientists do not learn much from Hoffman's guidance. Even more rare in a book of 'popular science', Hoffman acknowledges the sources of ideas and findings that are not his own work, and gives a full and accurate list of references.

The scattered citations of earlier philosophical understanding (or misunderstanding) of vision include highly appropriate discussions of Berkeley, Locke and Malebranche, although to my considerable surprise Plato's cave has gone missing. If there is one image that sums up the thrust of Hoffman's work, surely it is that dungeon. The moral of *Visual Intelligence* is that we have spent so long in the cave that our brains can now derive what is really out there from the merest flickering of shadows on the wall. □

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