1. Dr. Purves is the lead editor of the textbook *Neuroscience* published by Sinauer Associates. The fourth edition was released in 2008. (Other editors are: George J. Augustine, David Fitzpatrick, William C. Hall, Anthony-Samuel La Mantia, James O. McNamara, and S. Mark Williams.)

   With R. Beau Lotto of University College, London, Dr. Purves has written a book called *Why We See What We Do*, (2003, Sinauer Associates), which, in a much more scholarly fashion, covers much of the same material as this film.

   Dr. Purves's website, www.purveslab.net, has interactive demonstrations, some of which we use in this film. We highly recommend having your students visit the site and try their own hand at examining the material there; it is both instructive and fun!

   For your further investigation, Dr. Purves has posted all of his papers on his website and can be downloaded.

   Dr. Lotto's website, http://www.lottolab.org contains some of the demonstrations shown in the film and more.

   Another site (unrelated to this film) that has many examples of visual illusions is www.michaelbach.de/ot/index.html. Like Dr Purves, Dr. Bach sees these as demonstrations of how the visual system works, and not tricks, as the term "optical illusion" implies.

2. This film assumes that students know the rudiments of the human visual system. It reviews some of the anatomy and physiology involved, but its aim is to move them beyond the basics into an appreciation of the fact that we do not perceive exactly what is "out there," a concept that is strongly counter-intuitive.

3. ***The British Empiricist School***: George Berkeley (1685–1783), John Locke (1632–1704), and David Hume (1711–1776). You may need to remind some of your students that "school" in this sense is not a building, but a group of like-minded thinkers. John Locke is probably the most familiar of these figures. The expression "tabula rasa" (blank slate) is associated with him as he proposed that all knowledge came from experience, as opposed to thinkers like Descartes, who viewed much human mental activity as being innate. George Berkeley was an Anglican bishop and, with David Hume, took Locke's ideas even further.

   Of course, the idea that we do not perceive what is truly "out there" goes all the way back to Plato and his cave analogy. A key point in this history, and the basis for much of the discussion in the film, is that the senses do not allow us to get at the world directly. In both science and philosophy, this obstacle is referred to as the "inverse problem."

4. ***Perspective***: This is probably the easiest way for students to grasp that what we perceive is not how things really are. A tree on a hillside far away looks much smaller than the physically similar tree we are sitting under. Students who have taken art history classes can contribute to a discussion of how before the Italian Renaissance, most pictorial art portrayed people in the background as the same size or even larger than ones in the foreground, who reason indicated were the same size. The orange man demonstration in this film is available on the Purves website.

5. ***Visual perception in animals***: As the film indicates, cats and other nocturnal hunting animals such as owls, have better night vision than humans do, but they have more limited color vision. Some birds that forage in the daytime (for instance, hummingbirds), have access to colors in the ultraviolent

spectrum that we cannot imagine, and have four types of cones in their retinas as opposed to our three. It is impossible for us humans to envision (and that word is used purposely) the colors perceived by fellow creatures that we are unable to see. An interesting article on this subject can be found at www.sciencedaily.com/releases/2008/05/080512113508.htm.

6. ***Ventral and dorsal visual pathways***: In a companion film in this series, *Human Brain Development: Nurture and Nature* with Helen Neville, PhD of the University of Oregon, there is a discussion of the two visual streams: the ventral and dorsal. Dr. Neville's research indicates that people who are deaf from birth have enhanced dorsal stream function (motion perception and peripheral vision and attention) in comparison to people who are born with normal hearing. But the ventral pathway function in deaf people shows no parallel enhancement. Dr. Neville uses this information to show how some systems of the brain, i.e. the dorsal visual pathway, are plastic and changed by the experience of being deaf, whereas others are more constrained in their plasticity, such as the ventral stream. She goes on to point out that highly plastic systems can also lead to vulnerabilities; dyslexics tend to have poorer peripheral vision than people who read normally.

7. ***Receptive field characteristics***: These have been the subject of much research in vision and other sensory studies as can be seen by Googling the topic. Which stimuli cause neurons to fire respond by increasing or decreasing baseline activity? It would be easy to think that there is a one-to-one correspondence between a stimulus and its responses in terms of the perception created, but the evidence described in this film shows that vision doesn't work that way.

8. ***Lightness/darkness compared to light intensity***: Light intensity (luminance) can be measured by a photometer. Lightness and darkness, on the other hand, are subjective experiences. Students will probably recognize the demonstration with the gray patch on white and black paper, but the other demonstrations will most likely be new to them. More such demonstrations can be found on Dr. Purves' website. The pedestal demonstration in the film is especially worth discussing. We are so attuned to see areas in shadow or indirect light as being darker that it is disconcerting to discover that the gray on the rise of the step and the gray on the top of the step are actually the same shade of gray.

9. ***Color perception***: The experience of color is initiated by the capture of light waves by the cones in a retina. The idea that the colors we see are the result of subsequent brain activity, and not the property of objects, is very counter-intuitive. Many of us remember childhood discussions wondering, "Am I seeing the same color as you when I look at this sky or is your blue different?" There is no way of knowing that, as we can't get inside another's head. Color only exists in the brain of a perceiver, and not in the world.

   Students will be able to relate many stories of colors "changing" (color contrast) given the environment in which they are seen; women especially can tell tales of clothes or make-up whose colors looked great in a store, but not in a different light.

   The cubes in the film, and more color demonstrations, are available on the Purves website.

10. ***Perception of form***: The demonstrations in this section of the film should be familiar to most students. The discussion of the misperception of line lengths in a fan-like display leads to the discussion of how we make sense of visual information, and why our perceptions can be at odds with measured qualities of the physical world, in this case, line length.

11. ***Graphs***: The first McDonald's-arches-like graph shows how subjects in psychological testing situations are biased to see lines oriented about 75% of the way up from the horizontal being longer than a horizontal or vertical line of the same length.

    The second graph is based on research that used a laser range scanner to determine the location, in three-dimensional space, of every pixel in the thousands of natural scene images. Catherine Howe and Dale Purves carried out this study in 2002. A full explanation of this and related phenomena can be found in a small book by Howe and Purves, called *Perceiving Geometry* (Springer, 2002), or in the original papers on the Purves website.

    A less technical explanation can be found at: www.hhmi.org/bulletin/pdf/june2003/Illusions.pdf

12. ***Laser range scanner***: This scanner can be thought of as being visual radar. It sends out a beam, and returns data indicating the distance of objects—in the case of the demonstration in the film, a fireplace in a room at the University of North Carolina, Chapel Hill. Dr. Lars Nyland, who is seen operating the scanner in the film, has a most interesting website with links to various projects involving the scanner, including an analysis of Jefferson's Monticello and forensic uses (blood splatter, anyone?). http://www.cs.unc.edu/~nyland

13. ***Evolution***. This may prove a controversial topic for some of your students. A quick discussion on the evolution of the eye with video can be found at: www.pbs.org/wgbh/evolution/library/01/1/l_011_01.html. The accompanying text makes the point that our eyes are not perfectly designed as would most likely be proposed by a believer in intelligent design. The position implicit in the Purves film is that our visual systems have evolved through random mutations that have led to better visual circuitry in individuals, who in turn passed these characteristics to their offspring. An interesting article on the evolution of color vision is at: http://www.talkorigins.org/faqs/vision.html

14. "***Optical illusions***:" In this film, Dr. Purves uses demonstrations to point out the many discrepancies between the measured properties of objects or a visual stimulus, and what we actually see. Instead of being "tricks," these demonstrations are cues about how our visual system works, interpreting retinal images to perceptions that are useful in getting around in, and acting on, the physical world, despite the fact that we have no direct access to this world through the senses.

15. ***The other senses***: Dr. Purves suggests that the other senses can be understood in empirical terms similar to vision. His lab is currently doing some very interesting work on why we hear as we do, relating musical tones to the tones of human speech. There is a demonstration of this on his website.

Related Films Also Available from Davidson Films

This is one of four films in Davidson Films' "Neuroscience" series. The other titles are:

- ***Discovering the Human Brain: New Pathways to Neuroscience*** (2006) 29 Minutes
- ***Human Brain Development: Nature and Nurture*** (2007) 30 Minutes
- ***The Emotional Brain: An Introduction to Affective Neuroscience*** (2009) 33 Minutes