数字图像处理
(Digital Image Processing)

视觉感知基础

第二章 数字图像基础

- 人眼结构
- 人眼感知视觉过程
- 人眼特性

2.1 视觉感知基础

为什么要研究人类视觉?

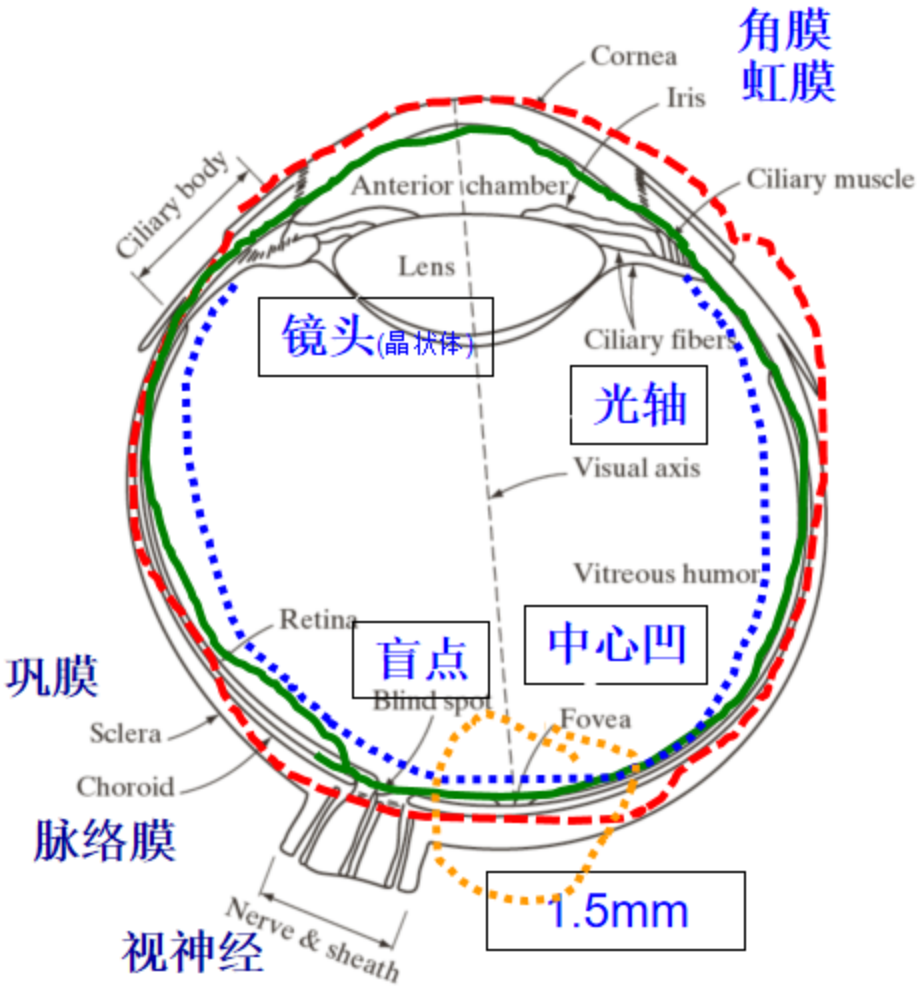
1) 数字图像处理的质量评价多由人眼主观评价;

2) 许多图像处理相关技术要根据人眼特性设计;如电视图像场频率、屏幕刷新频率、图像量化级别、立体显示(双目视觉)、图像压缩

3) 根据人类认知图像内容的机制可以研究出新的图像处理算法

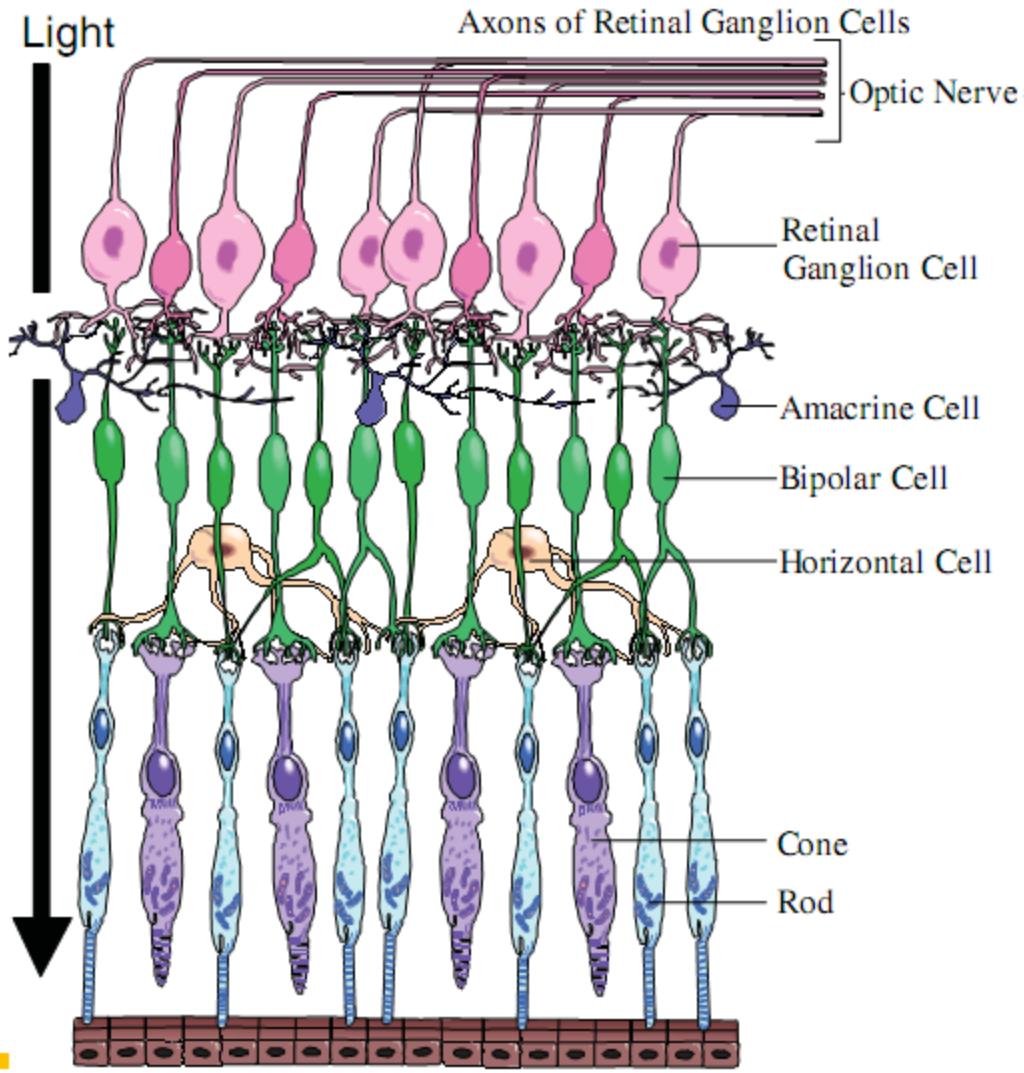
人眼结构

- 人眼:近似球体,平均直径约为**20mm,** 眼球壁由三层膜构成
  1. 角膜和巩膜
  2. 脉络膜 睫状体 虹膜
  3. 视网膜
- 眼球内部主要是晶状体和玻璃体
- 眼球分为屈光系统和感光系统两部分



Lens (透镜), Iris [‘aiəris] (虹膜), Retina [‘retinə] 视网膜, Fovea [‘fəuviə]小凹(尤指视网膜的中央凹), cornea [kɔniə] 角膜, sclera 巩膜,

人眼结构



感光系统的作用是将光刺激转换为神经刺激,送入大脑神经系统. 主要由视网膜组成.

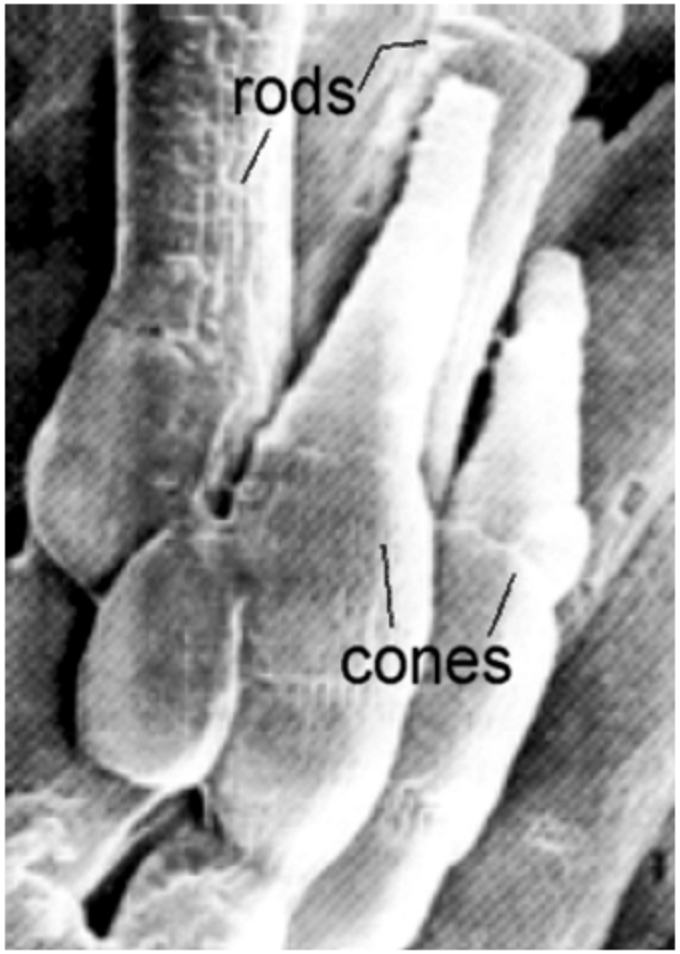
视网膜是倒置结构, 由外到里由三层细胞构成

神经节细胞层: 神经节细胞,与视神经相连,传递神经刺激

双极细胞层: 双极细胞,连接视细胞和神经节细胞.

感光细胞层:两种视细胞,锥状细胞 杆状细胞,感受光线的明暗和颜色刺激

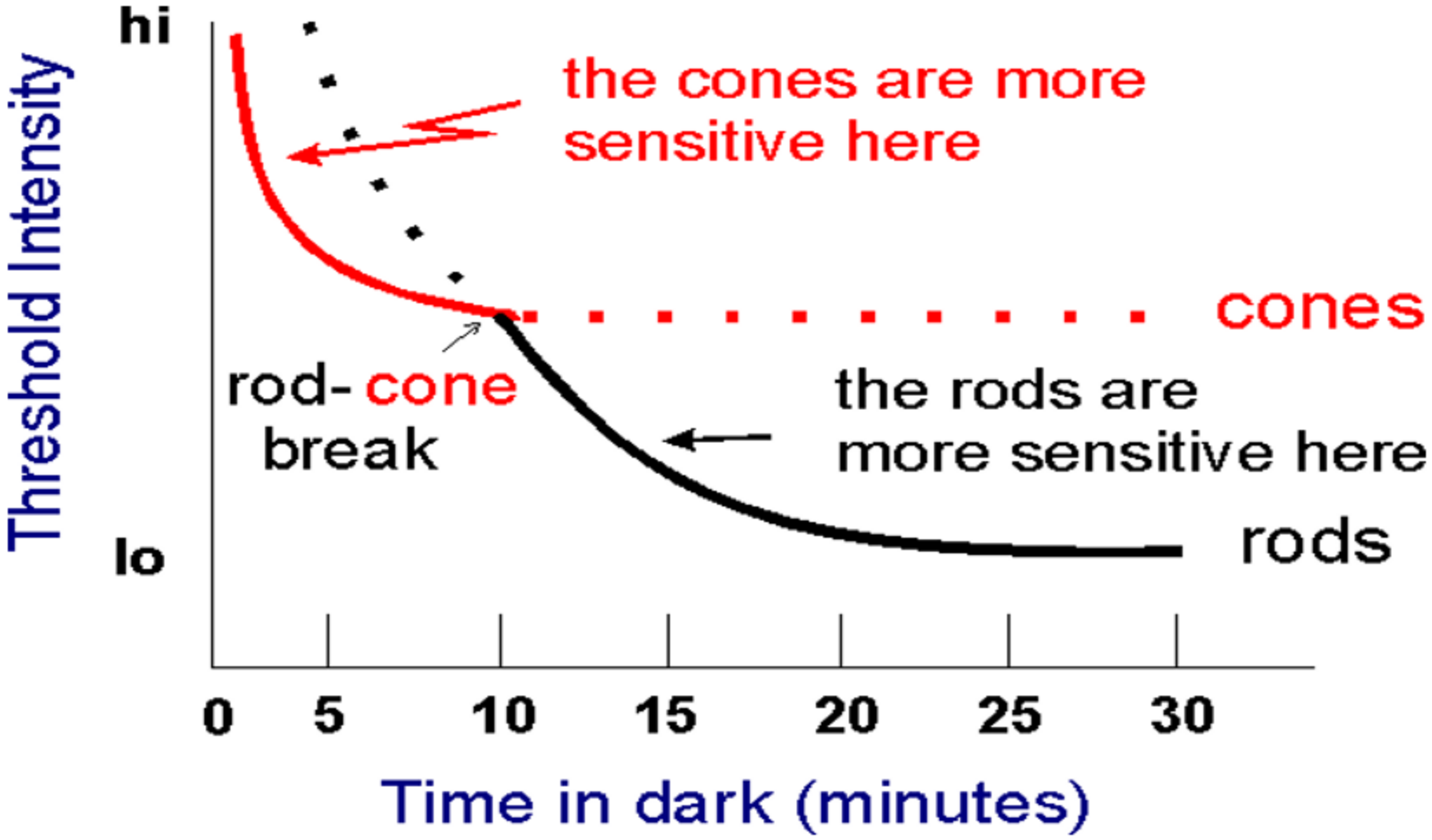
人眼结构



- **锥状细胞Cones**
  - 数目:600~700万, 位于中心凹附近
  - 每个锥状细胞连接到单独一个双极性细胞
  - 空间分辨率高, 对颜色敏感度高
  - 感光灵敏度低,锥状视觉称为“明视觉”
- **杆状细胞Rods**
  - 数目:7500万~1.5亿
  - 几个杆状细胞连接到同一个双极性细胞
  - 空间分辨率低,没有色彩感觉
  - 感光灵敏度高,杆状视觉称为“暗视觉”

Light Adaptation 亮度适应

Dark Adaptation Function

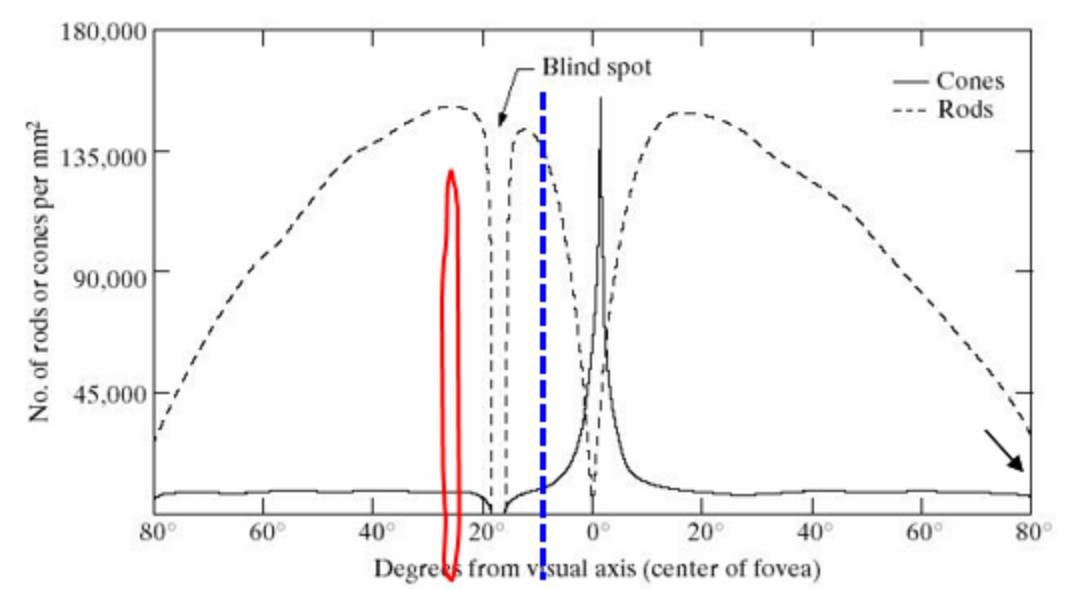


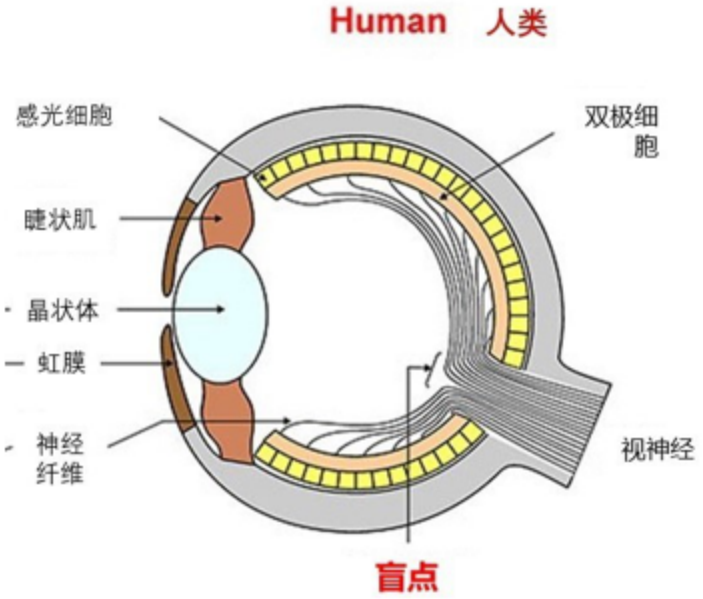
For approximately the first 10 minutes in the dark, the cones require less light to reach a threshold response than do the rods. Thereafter, the rods require less light.

The point at which the rods become more sensitive is called the rod-cone break.

人眼结构

视网膜上锥状细胞和杆状细胞分布密度



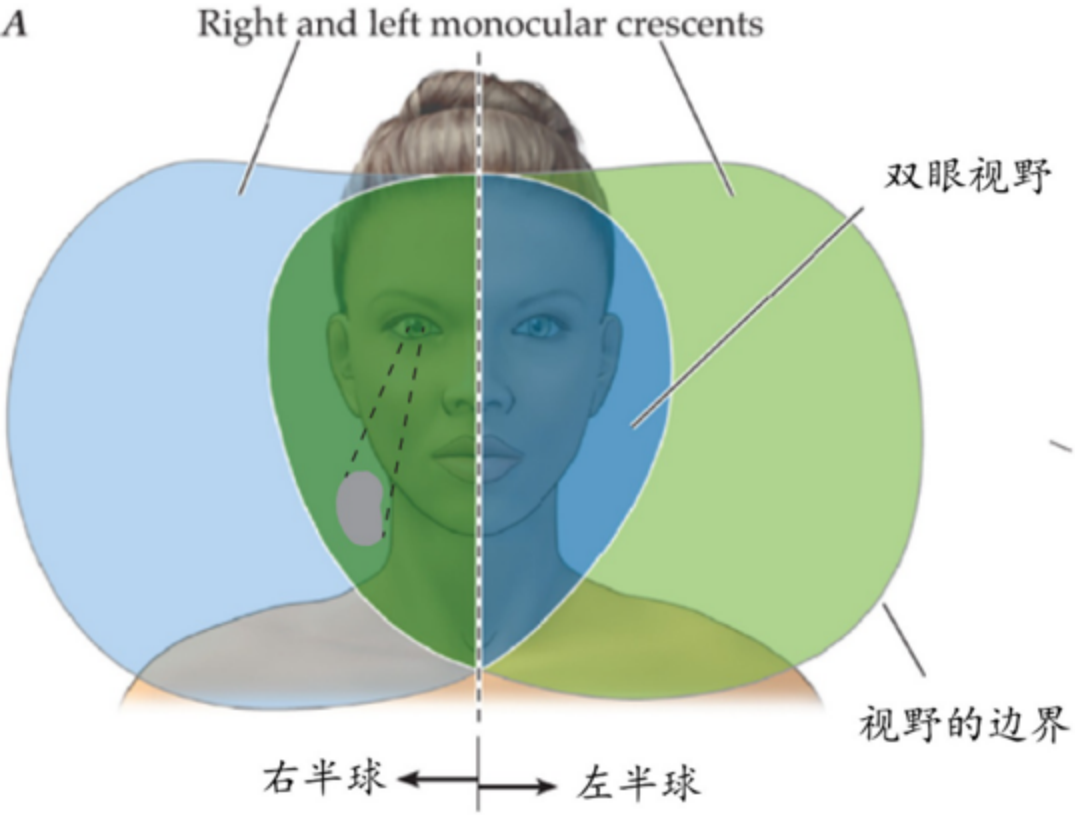


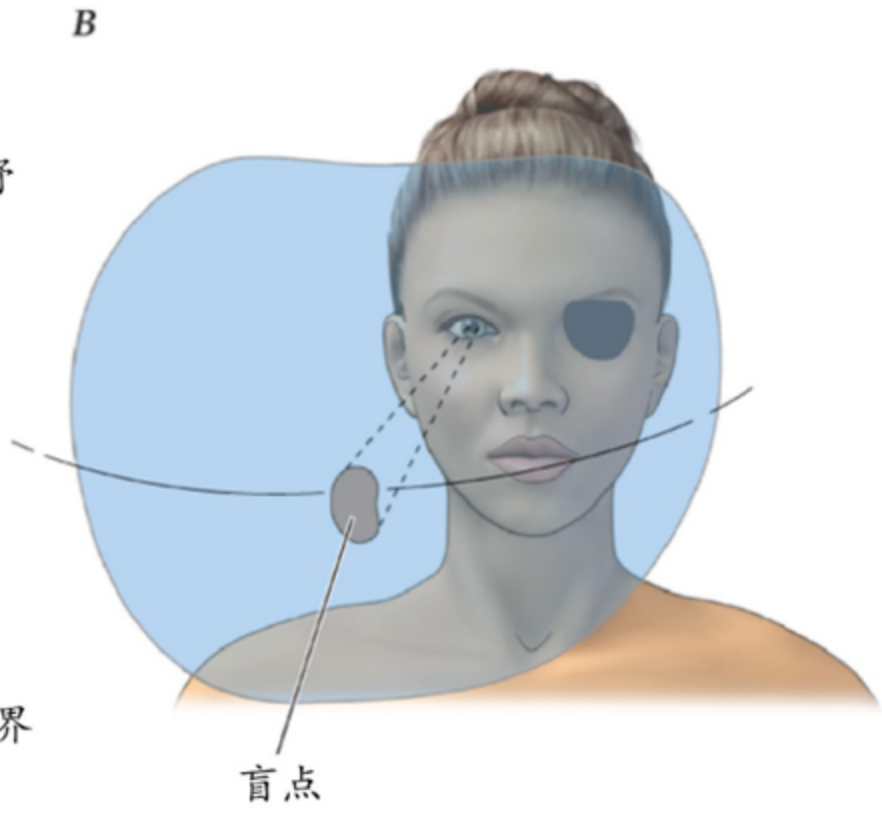
Cone vision (bright-light vision)

Rod vision (dam-light vision)

空间上的离散化

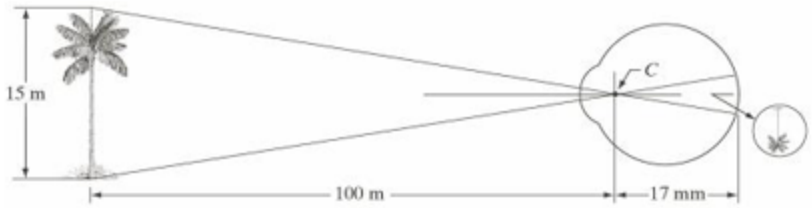
人眼结构

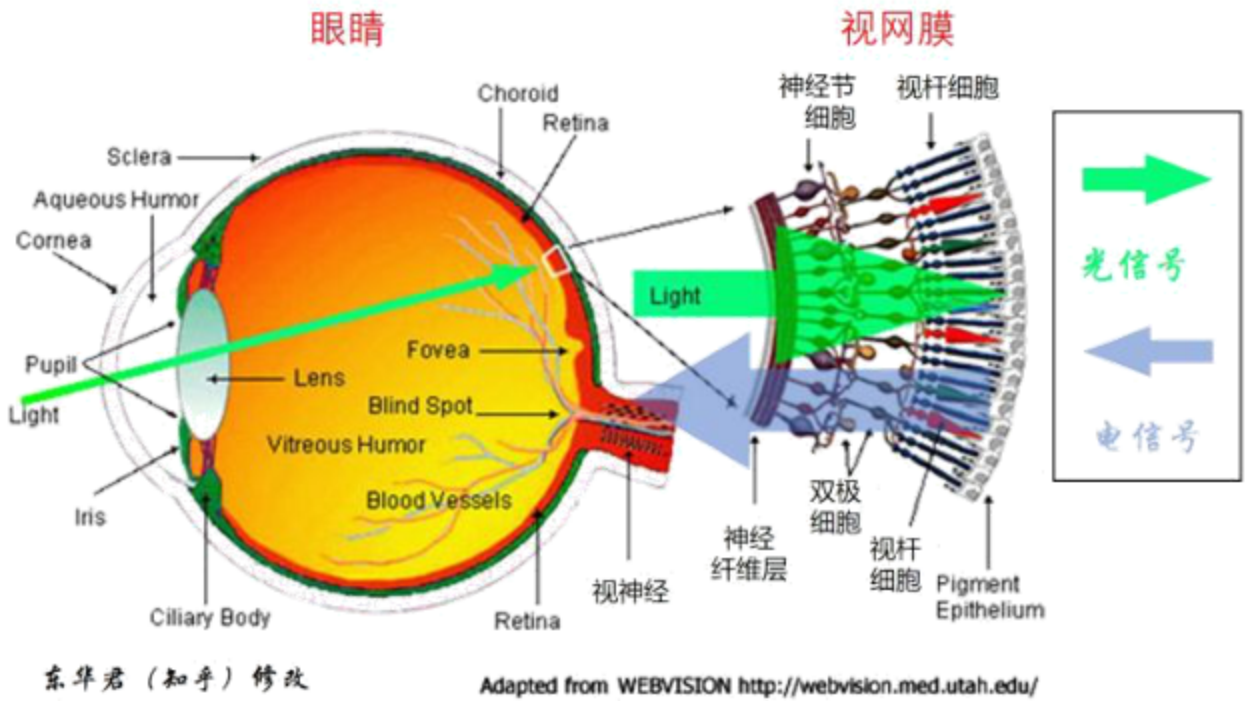




东华君（知乎）修改

人眼感知图像的过程





东华君（知乎）修改

Adapted from WEBVISION http://webvision.med.utah.edu/

成像过程：

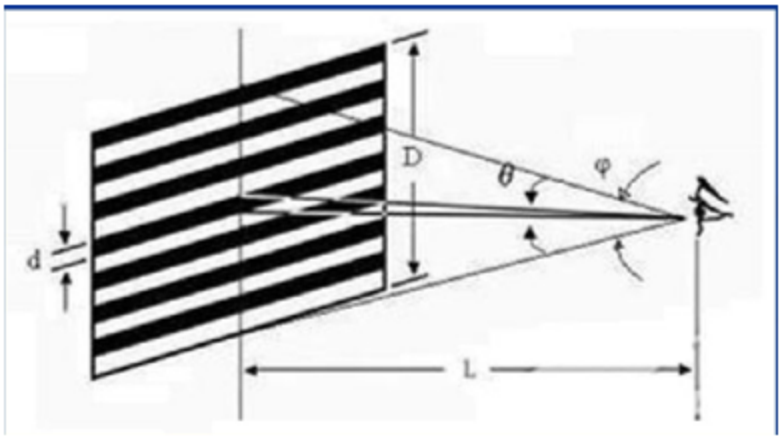
1.视网膜图像主要反射在中心凹；

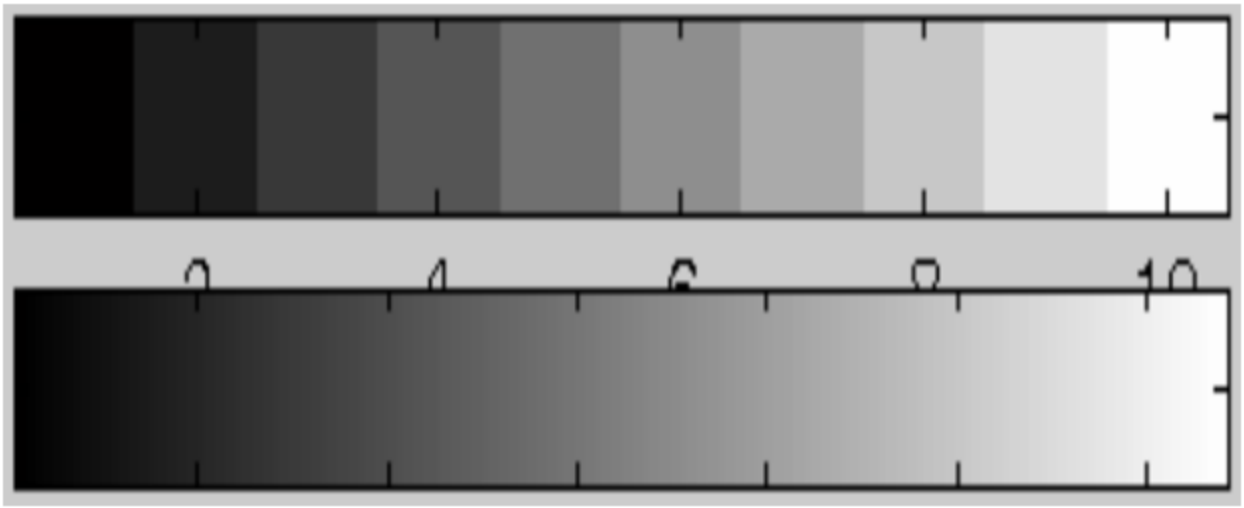
2.光敏细胞产生神经刺激

3.视觉神经将神经刺激转换为电脉冲，最后由大脑解码

人眼特性-空间分辨率

- 人眼视觉的空间特性
  - 空间分辨率为1′
  - 灰度分辨能力为64级





10个灰度级

128个灰度级

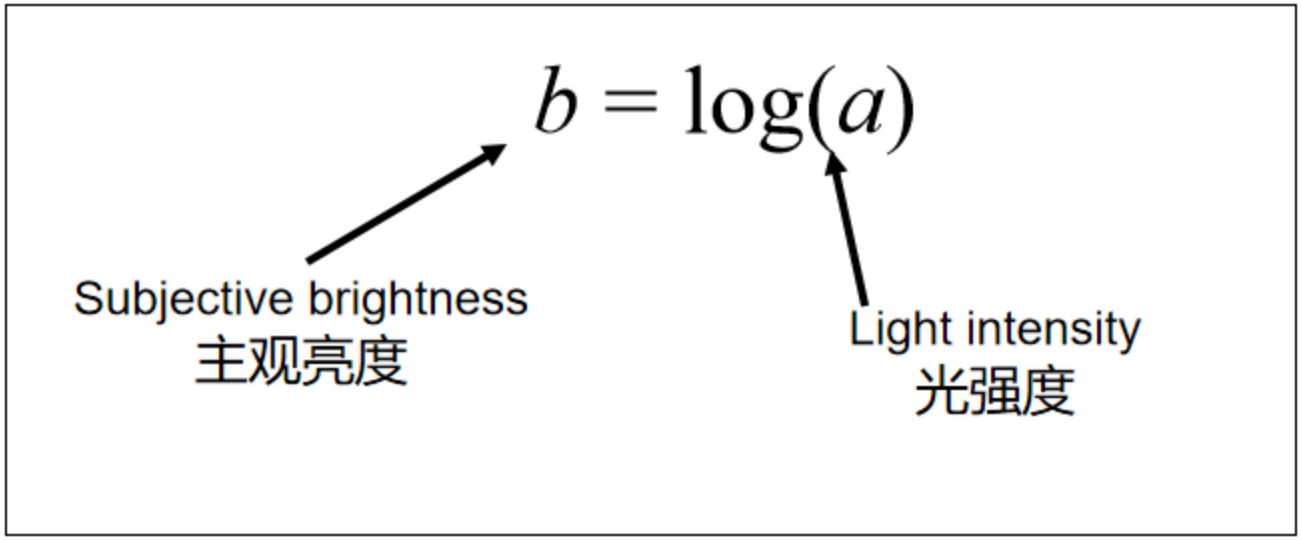
人眼特性-时间分辨率

- 视觉的时间特性
  - 活动图像的帧率至少15 fps时,人眼才有图像连续的感觉
  - 活动图像帧率在25 fps时, 人眼感受不到闪烁感
  - 监控视频 15fps, 电影 24fps, 电视 25fps, DVD 30 fps 电脑屏幕 60fps

人眼特性-亮度适应和辨别

(bright adaptation and discrimination)

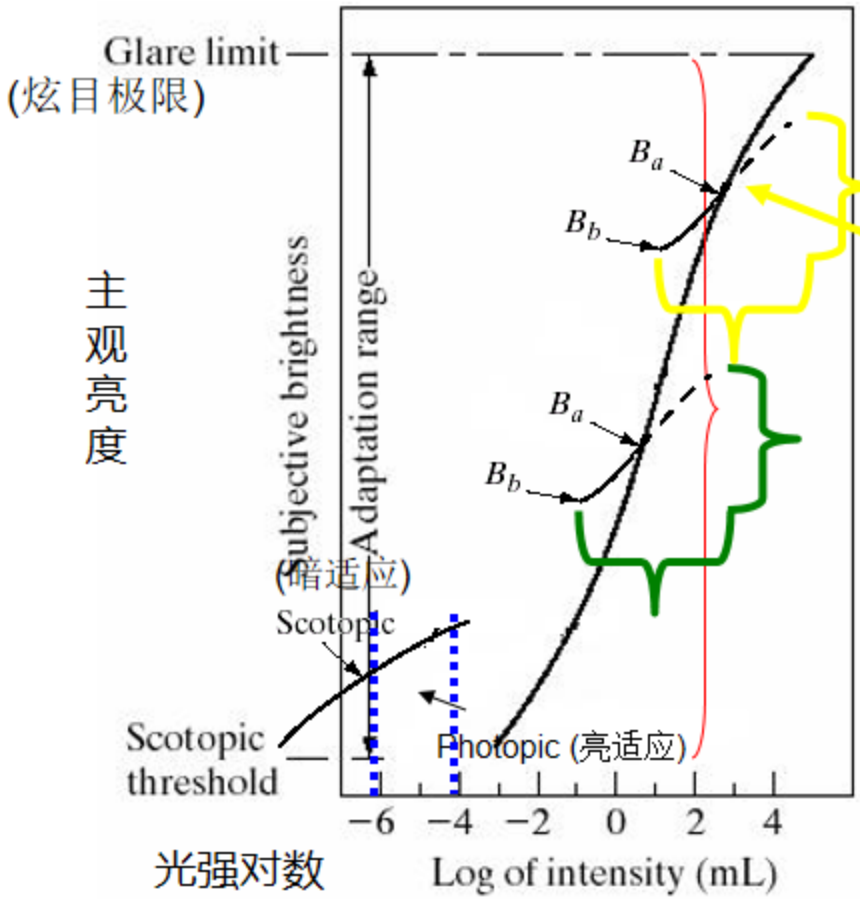
- **Subjective brightness vs. light intensity**
  主观亮度 vs. 光强度



亮度适应和辨别

➢Brightness adaptation(亮度适应)

视觉系统不能同时在一个范围内工作，通过改变其灵敏度来完成不同强度级别的适应。

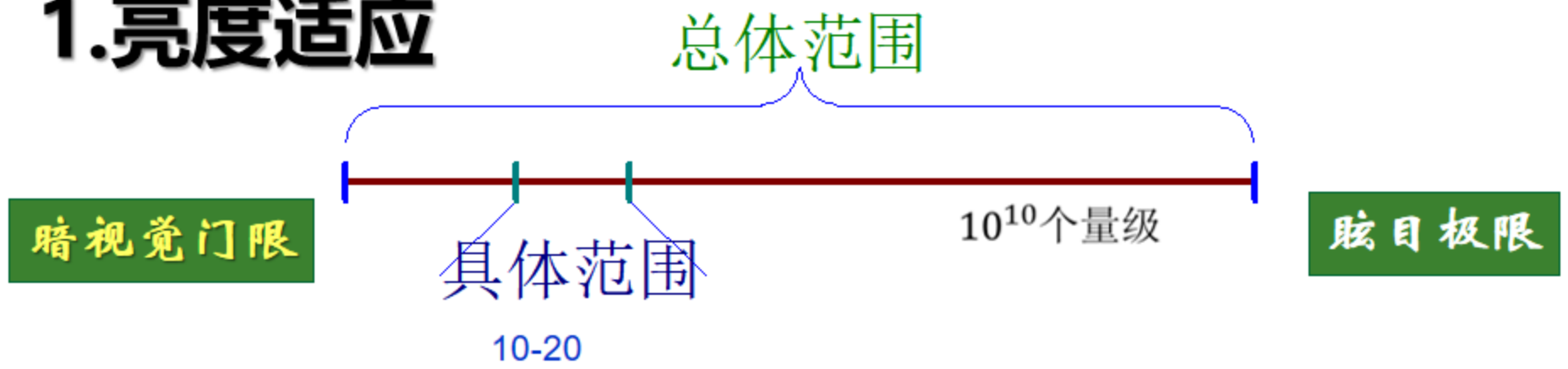


Brightness adaptation level
亮度适应级
视觉系统当前的灵敏度级别

Brightness adaptation level
亮度适应现象

亮度适应和辨别

1.亮度适应

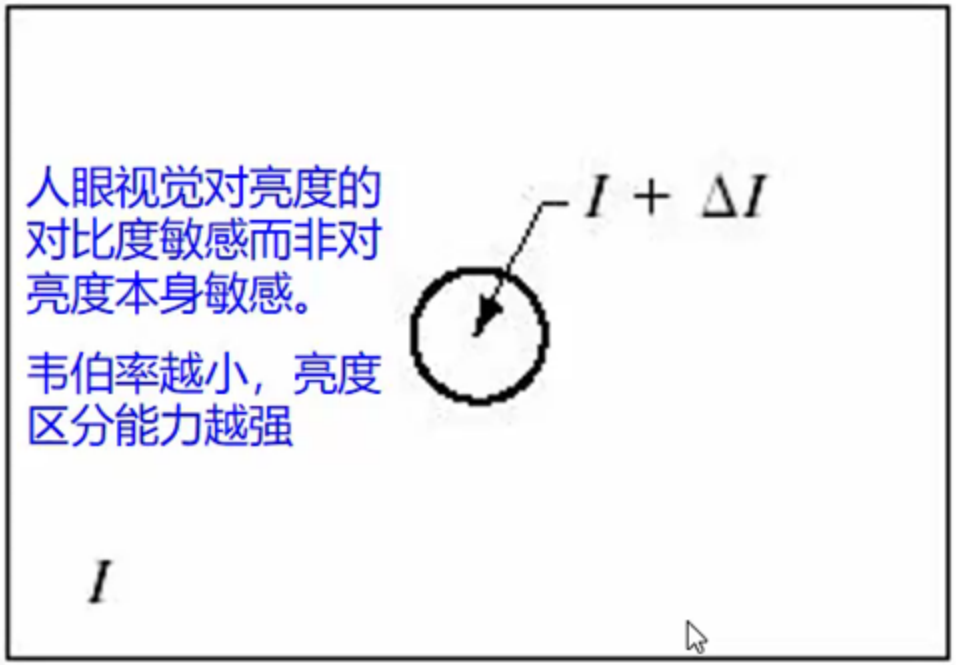


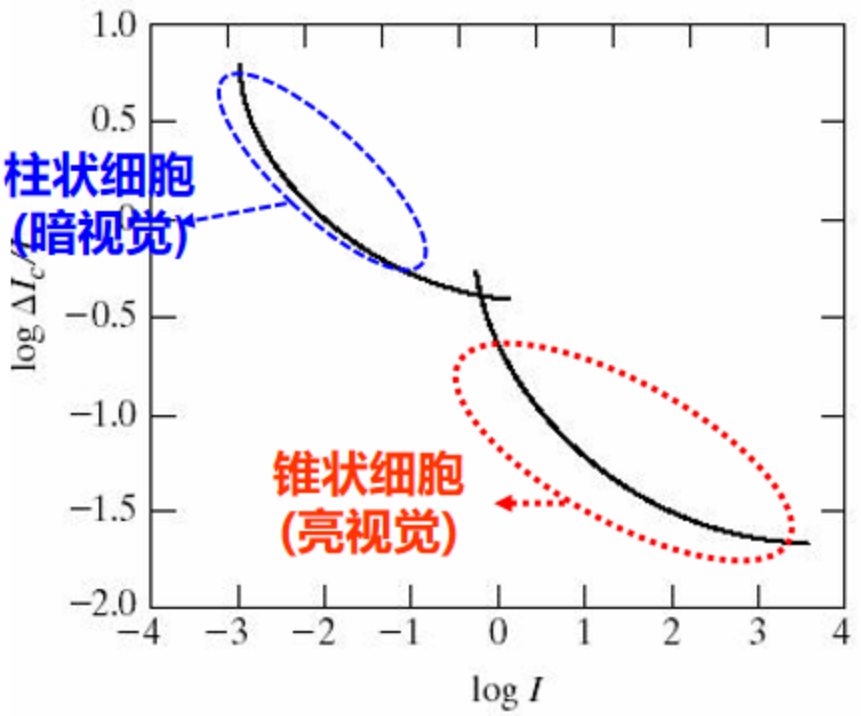
- 同一时刻所能区分的具体范围远小于总体范围
- 以适应级为中心的小范围区别能力为10-20个亮度级变化
- 实际眼睛遍历观看图像时，在各个不同适应级上变化，实际区分能力要多许多—视觉适应性
- 韦伯实验：人类视觉系统亮度辨别能力

亮度适应和辨别

Brightness discrimination (亮度区分)

你能看出亮度变化量ΔI?





当背景光保持恒定时，改变中间光源强度，从不能感觉到可以感觉间变化，一般可观测到12-24级不同强度变化

低照度，韦伯比高，亮度辨别能力差
高照度，韦伯比低，亮度辨别能力强

亮度适应和辨别

May our eyes deceive us?

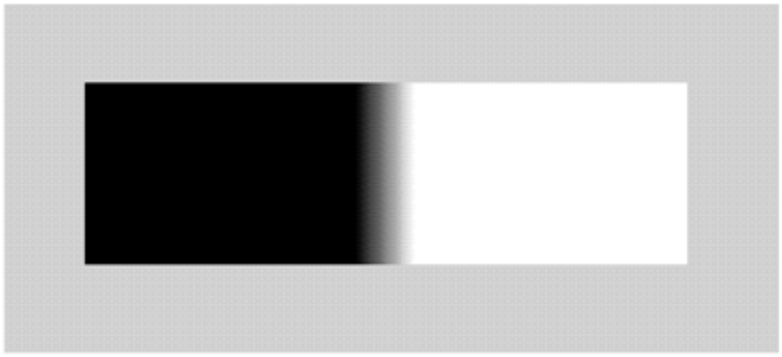
主观亮度不是光强的简单函数

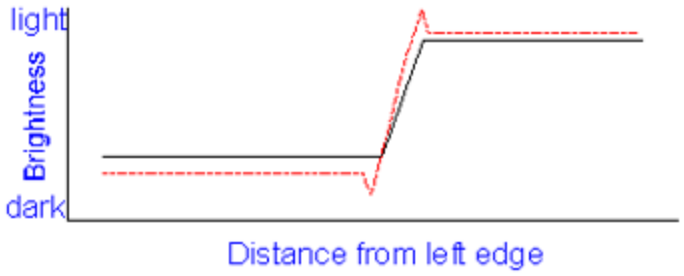
视觉系统往往会在不同强度区域的边界出出现“下冲”或“上冲”现象。

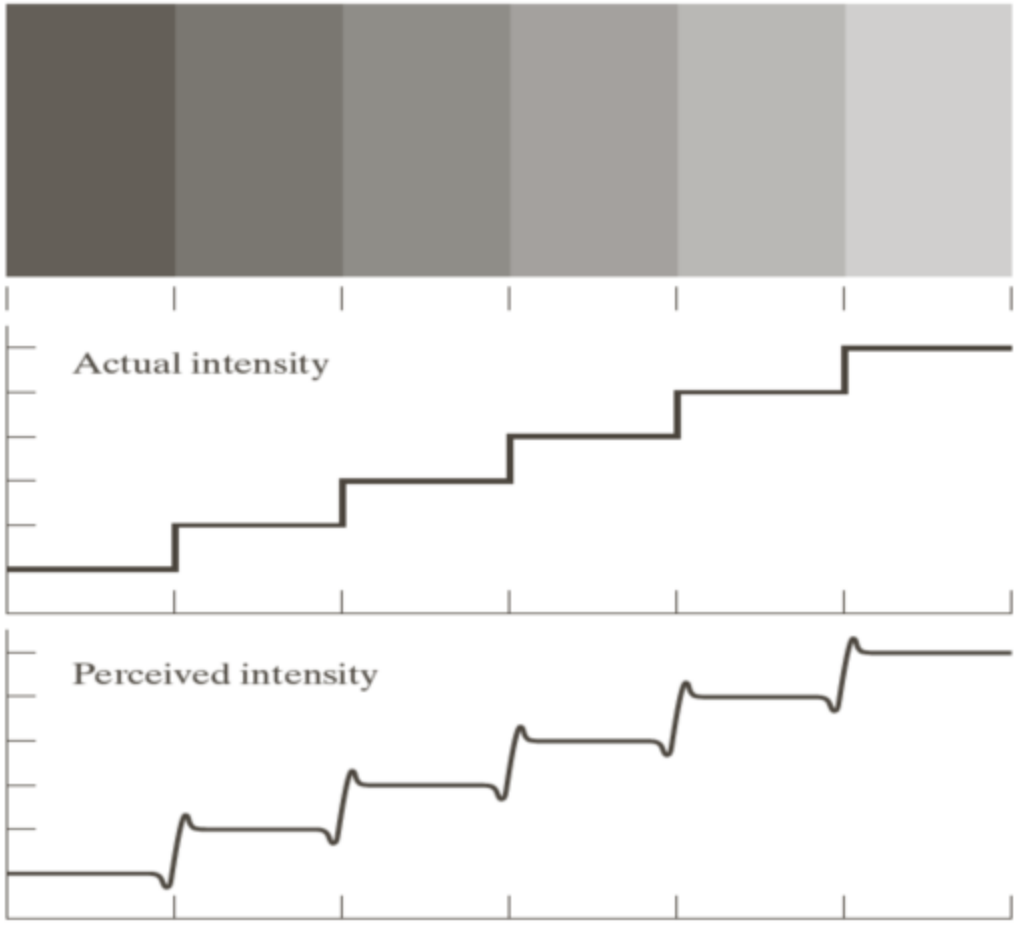
同时对比现象，即感知区域的亮度并不简单地取决于其强度，与其周围环境或区域亮度有关系。

马赫带效应

感觉亮度不是简单的强度函数的；视觉系统有趋于过高或过低估计不同亮度区域边界值的效应。



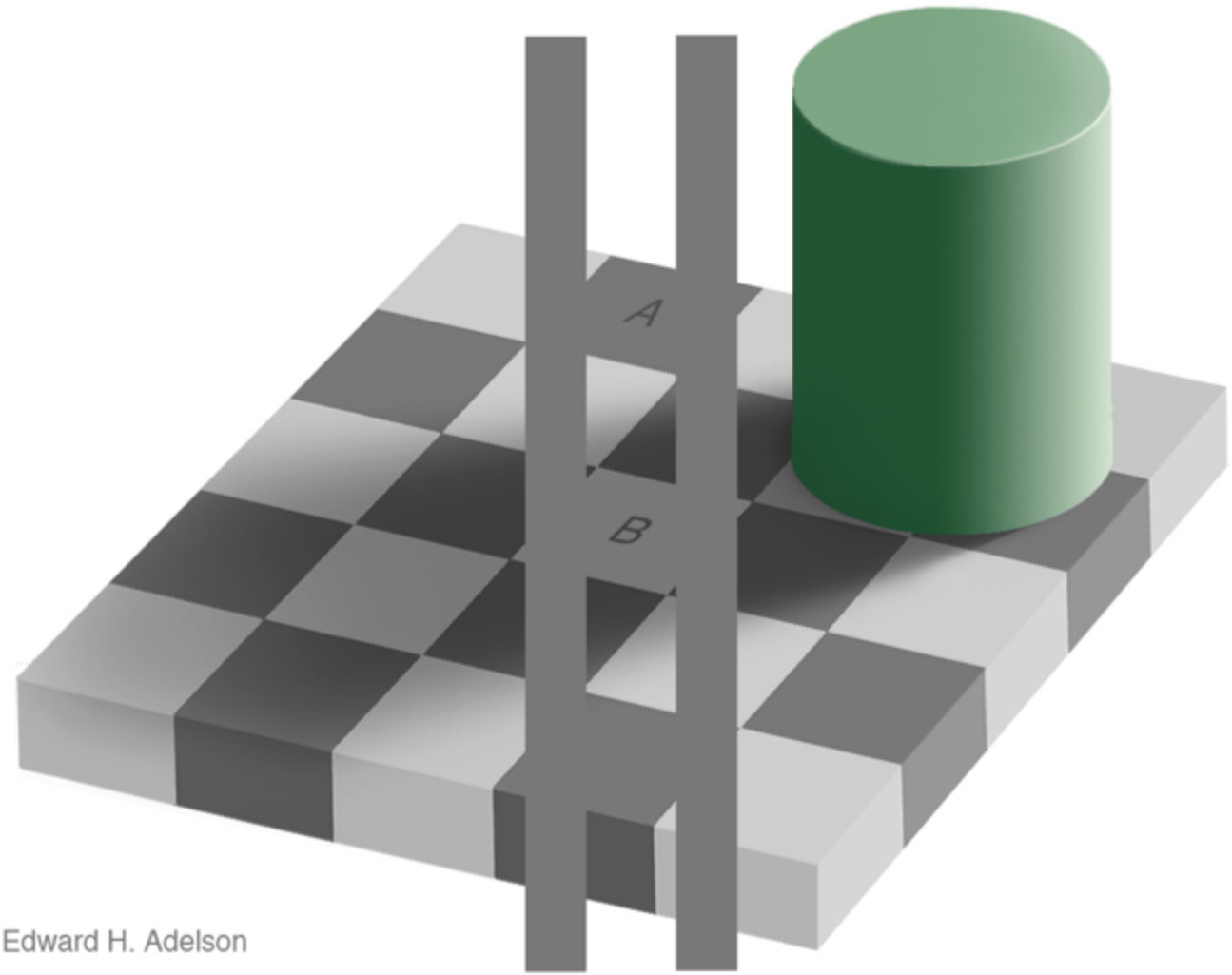




同时对比现象

- 人眼对某个区域感觉的亮度（主观亮度）不仅依赖于他自身的亮度，还与它的背景有关。

同时对比现象

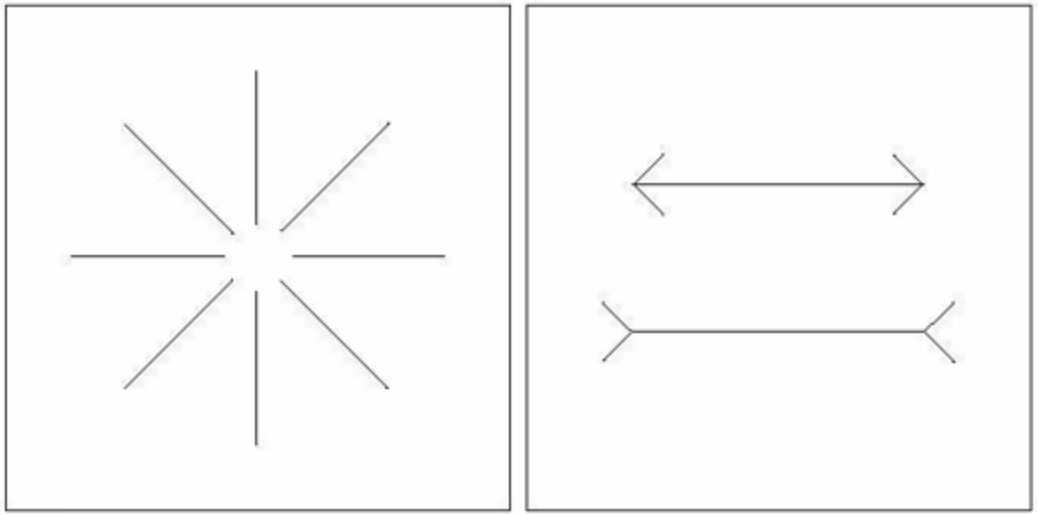


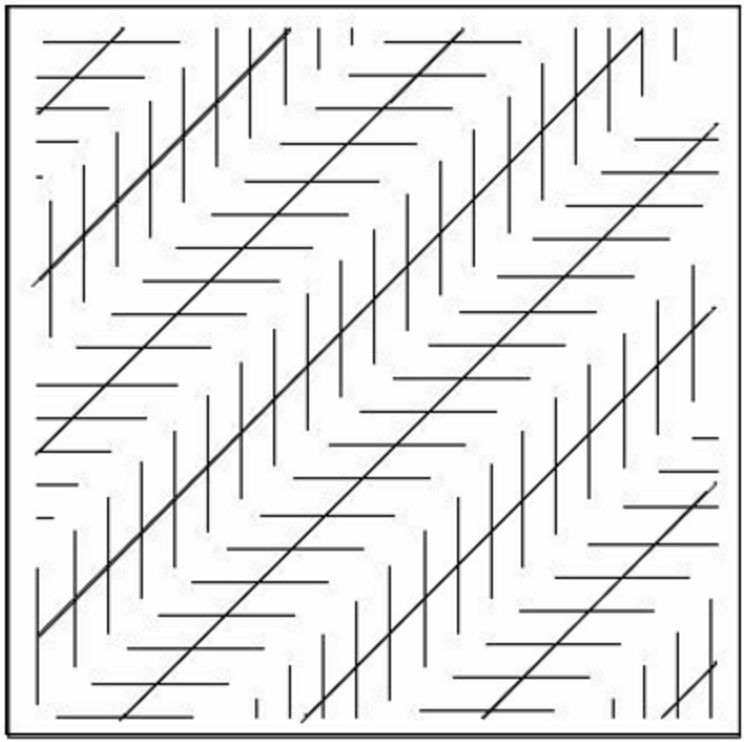
Edward H. Adelson

For more great illusion examples take a look at: http://web.mit.edu/persci/gaz/

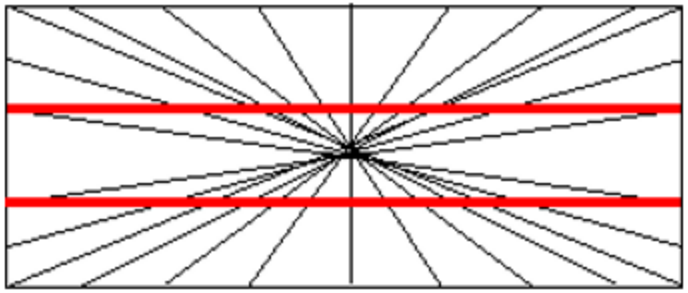
视错觉

- May our eyes deceive us?

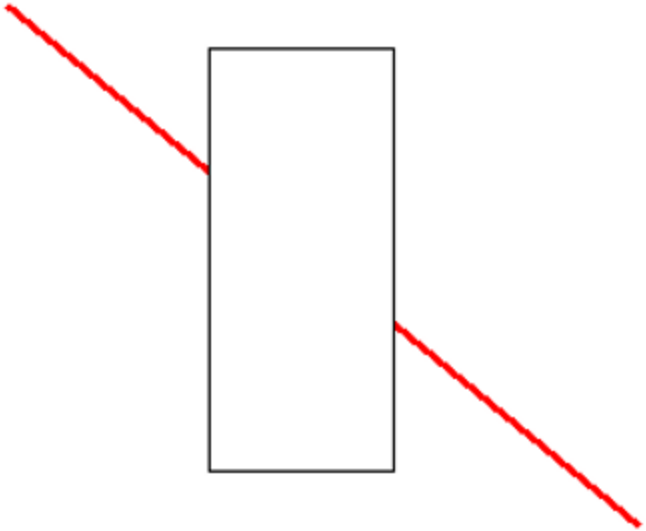




Hering & Pogendorf Illusions



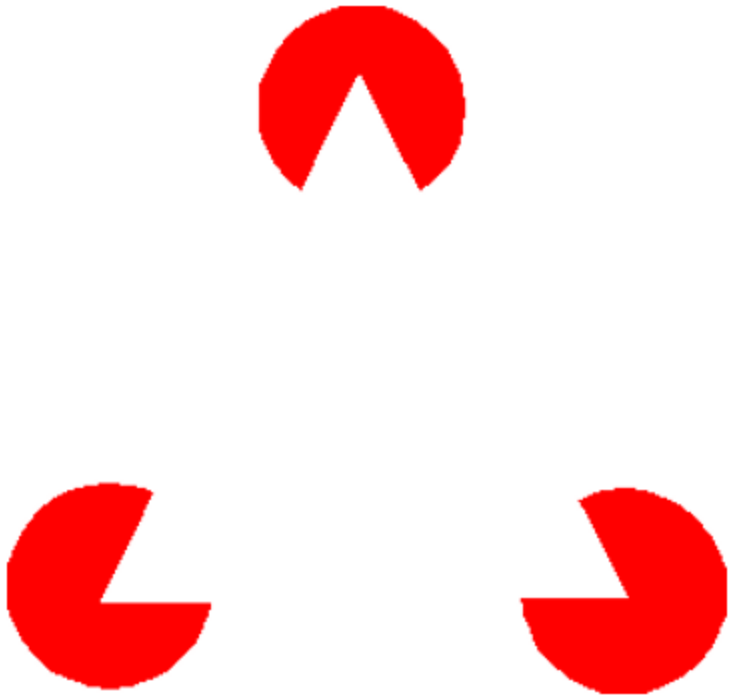
Hering Illusion



Poggendorff Illusion

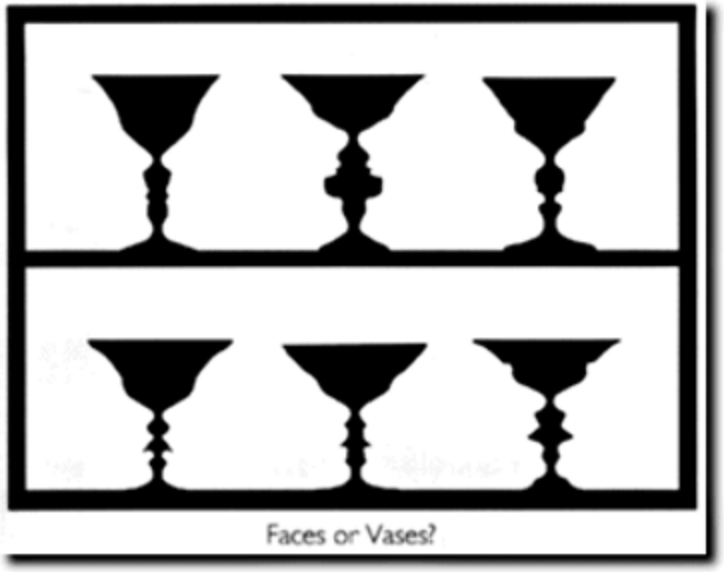
Fun Things

Kanizsa Illusion



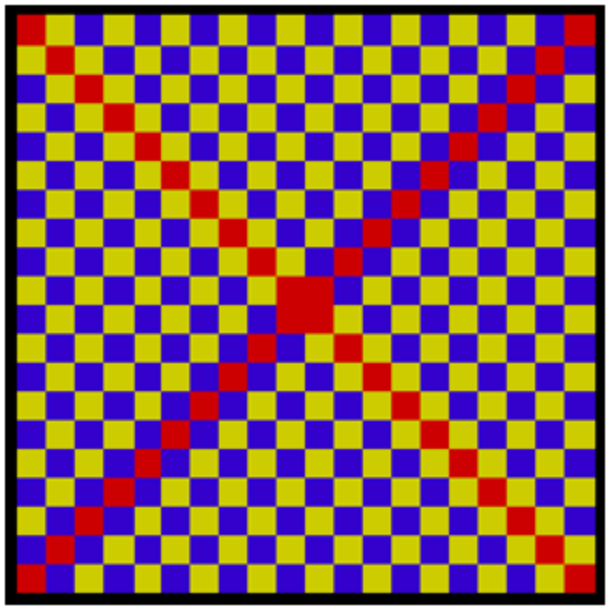
在错觉中，眼睛填上了不存在的信息或错误地感知物体的几何特点。

This is called a Kanizsa figure after the person who invented it. If you look carefully you will probably see the edges of the entire triangle, even though the triangle is defined only by the notches in the red disks.



What do you see in this diagram? In order to find out what people often say they see select possible perceptions.

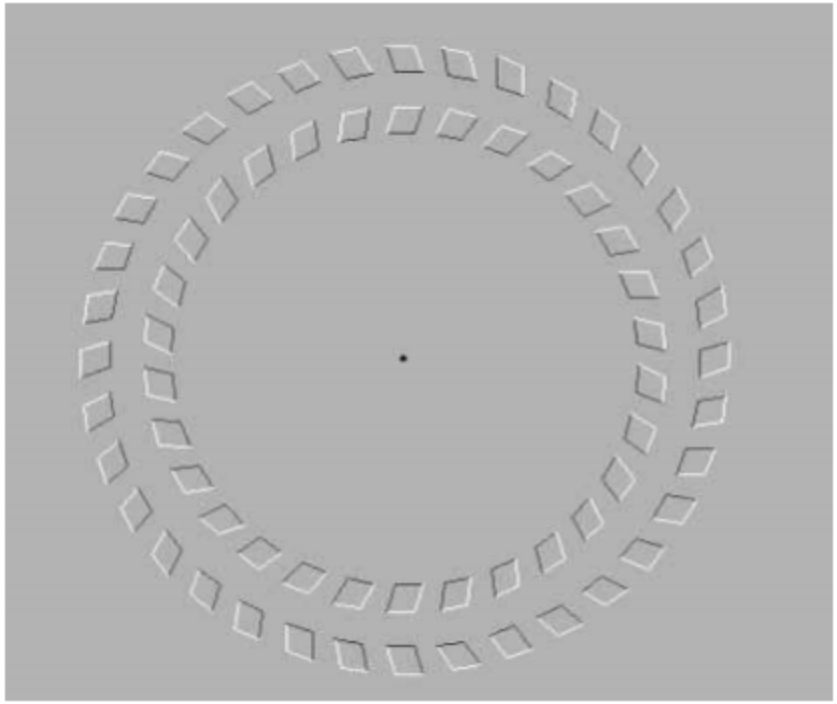
Color Assimilation

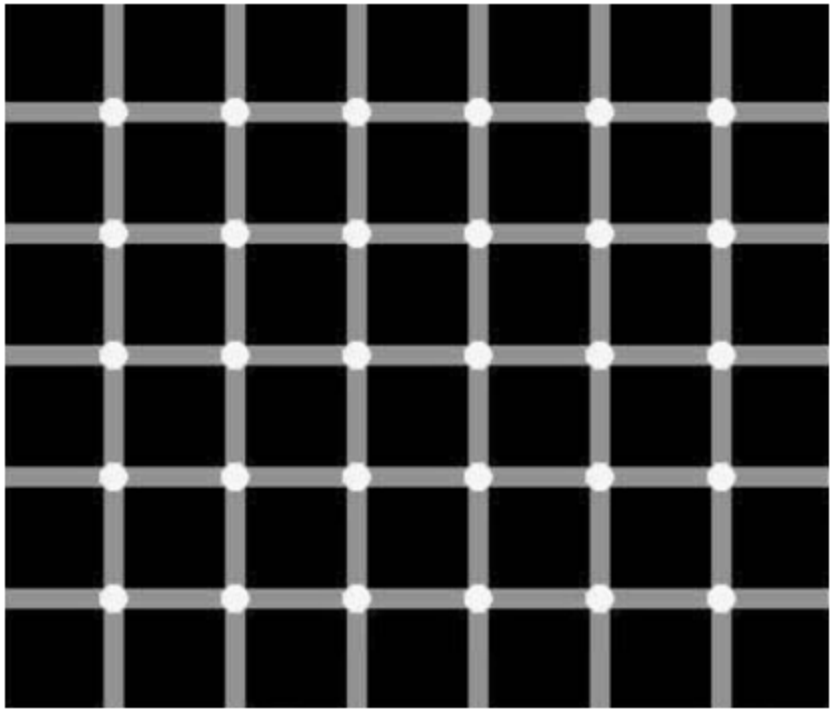


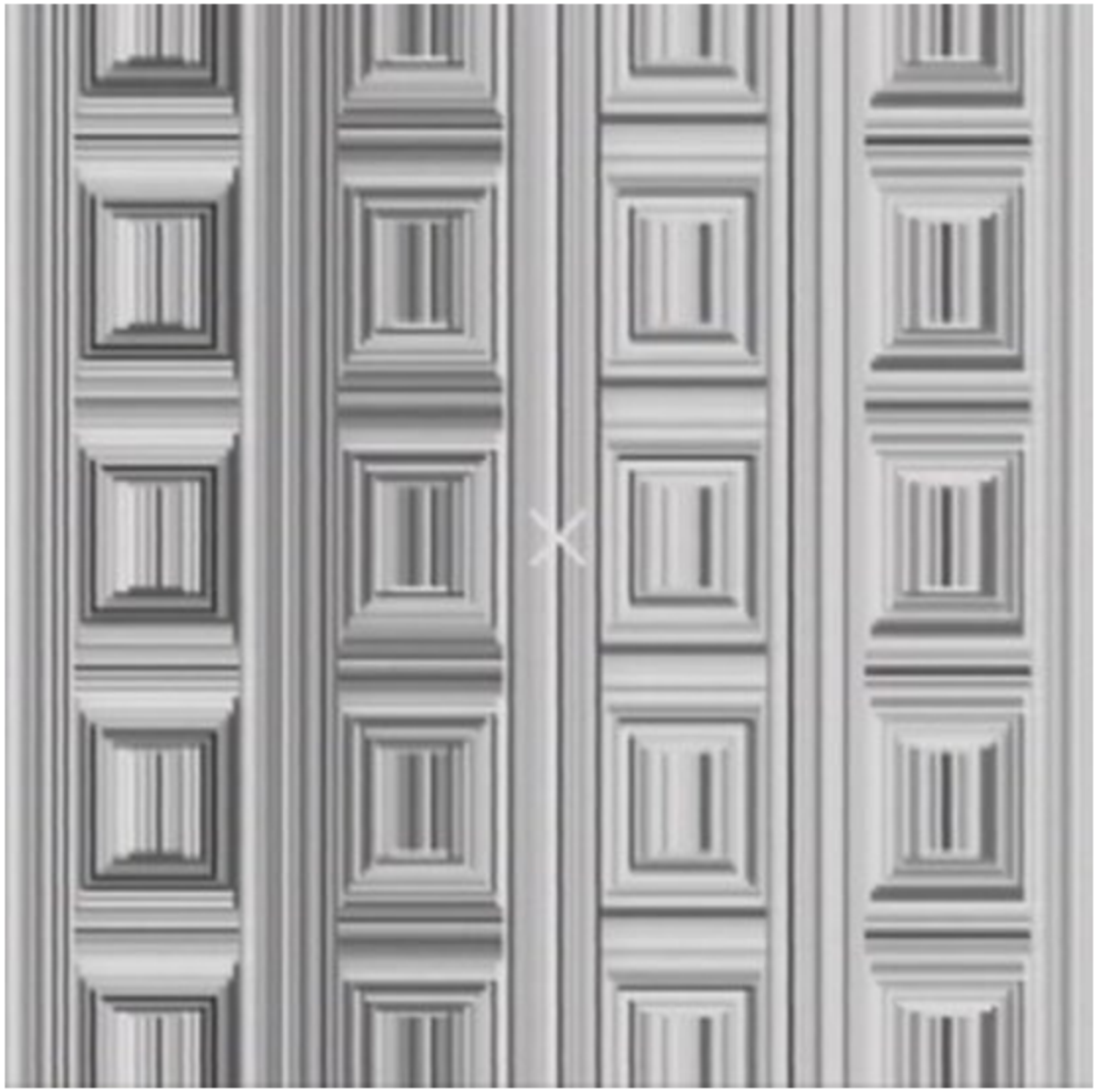
Take two pieces of paper and place their edges as close as possible to both sides of one red diagonal. Note that the red square in the middle is the same as all the other squares on that diagonal. Now move your pieces of paper to expose mainly the red squares on the other diagonal. On this diagonal all the red squares, including the center one, are again the same color red. Because the center square is common to both diagonals this exercise proves that all the red squares in both diagonals are exactly the same red color. Yet, when the pattern is seen as a whole, the two red diagonals appear different from each other

视觉惰性

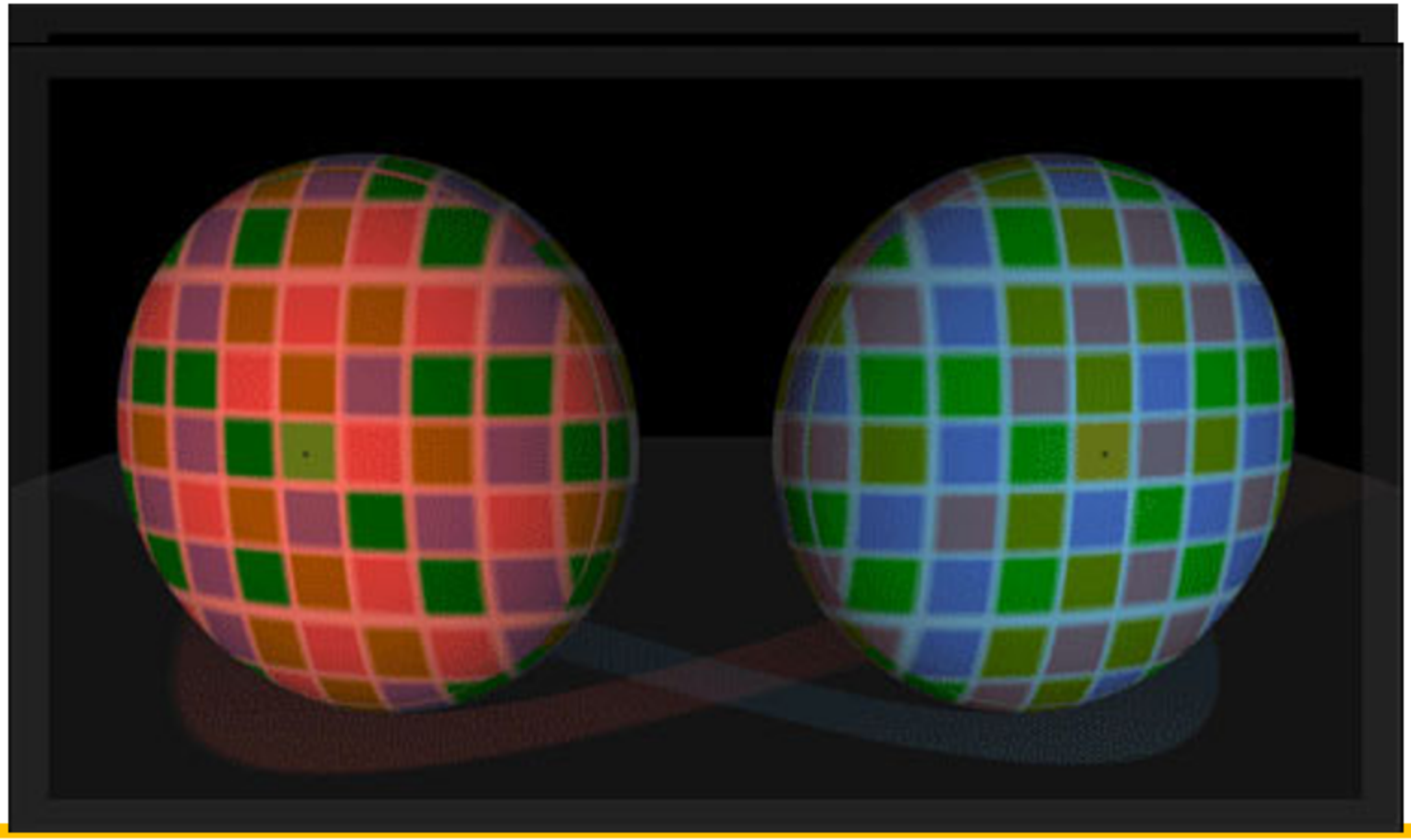
- 视觉惰性：人眼的主观亮度感觉与光的作用时间有关，光像一旦在视网膜上形成，在它消失后，视觉系统将会对这个光像的感觉持续一段时间







Stare at the cross in the middle of the image and think circles



Available here: http://www.lottolab.org/Visual%20Demos/Demo%2015.html

错觉中的视觉真相

TED Ideas worth spreading

Beau Lotto: Optical Illusions Show How We See

http://www.ted.com/talks/lang/eng/beau_lotto_optical_illusions_show_how_we_see.html