

EE6310: Image and Video Processing Spring 2023

The Human Visual System



भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

Image and Video Processing

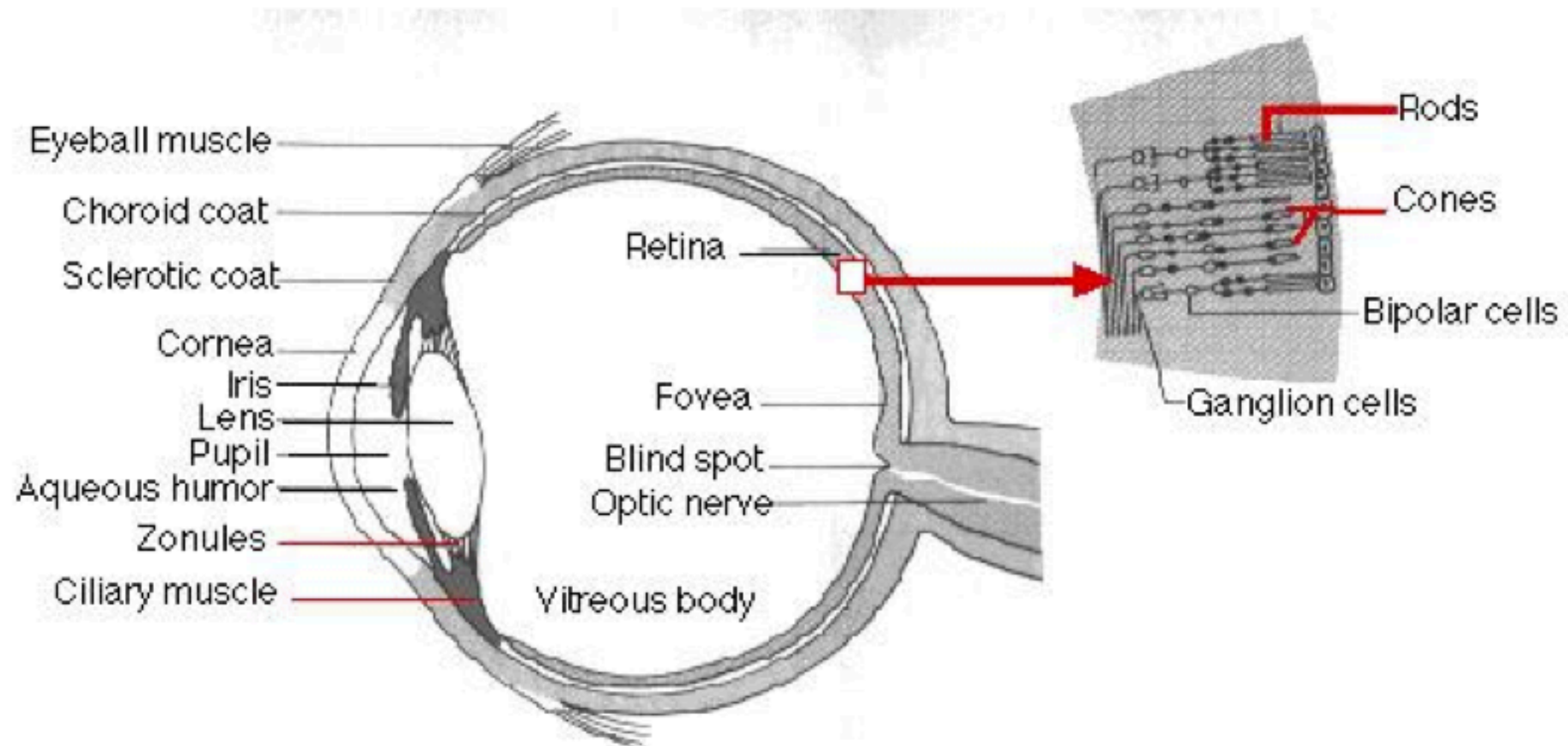
A multidisciplinary area:

- Mathematics
- Optics
- Visual psychophysics
- Computer vision, AI
- Surface physics
- Computer graphics
- Scientific visualization
- Medical diagnosis
-

Myriad Applications

- Multimedia communications
- Astronomy
- Meteorology
- Biomedical imaging
- Terrain mapping
- Quality inspection and control
- Military
- Microscopy
- Compression
- ...

The Human Eye



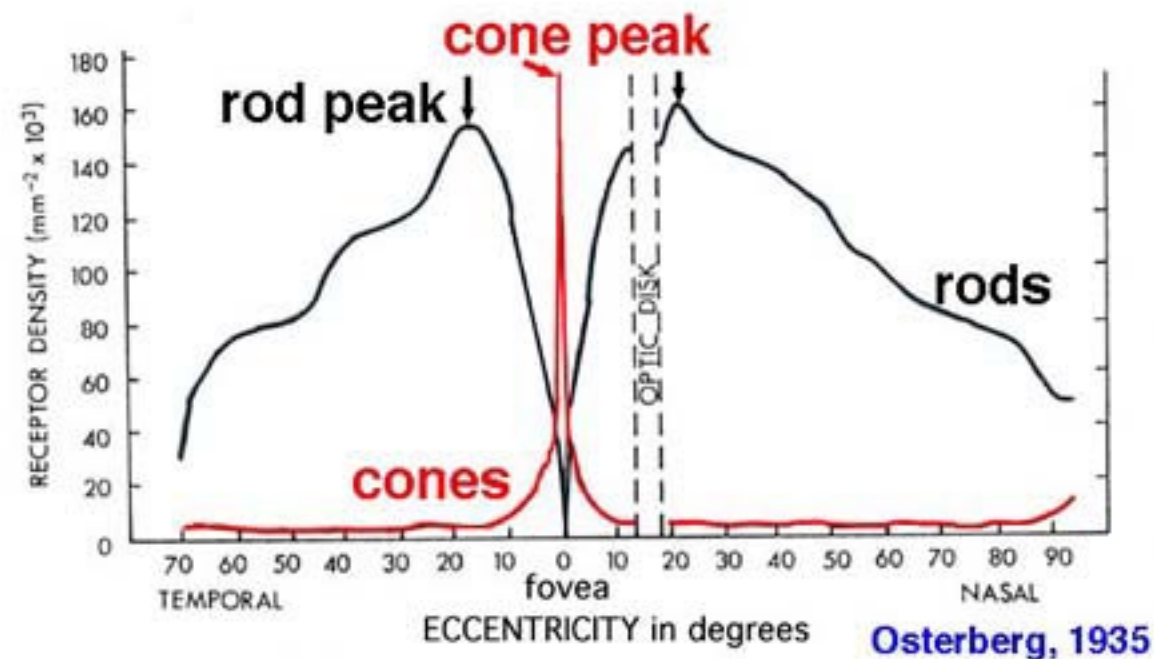
The Human Eye - Basic Physiology

- **Cornea:** tough, transparent anterior cover
- **Sclera:** opaque posterior cover
- **Choroid:** network of blood vessels – nutrition to eye, heavily pigmented, very sensitive
- **Ciliary muscles:** extension of the choroid
- **Iris:** extension of choroid, controls light entering eye
- **Pupil:** central opening of iris
- **Retina:** receptor area lining the entire posterior eye wall

The Human Eye - Basic Physiology

- **Cones:** sensitive to color, resolve fine details, photopic vision
- **Rods:** sensitive to illumination, coarse details, scotopic vision
- **Blind spot:** absence of receptors
- **Lens:** 60 – 70% water, 6% fat, and protein

The Human Eye - Receptor Distribution

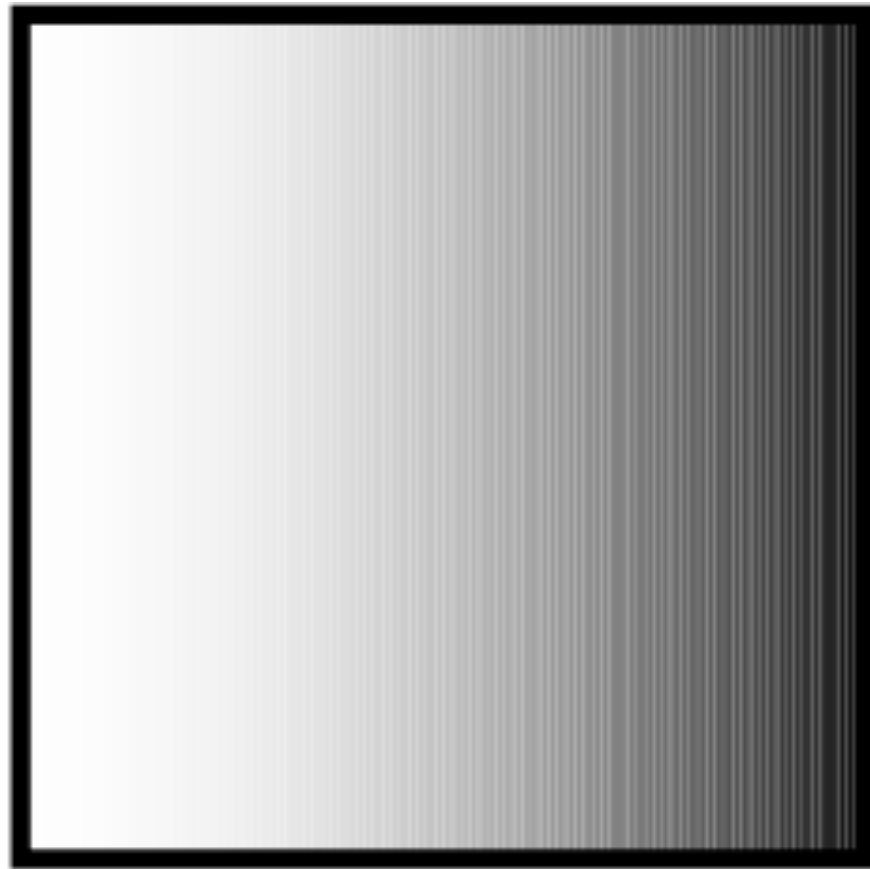


- **Fovea:** central portion of retina where cone distribution peak
- **Visual axis:** line from the center of the lens to the fovea
- Distribution of receptors a function of the angle from the visual axis
- Image source: http://www.phys.ufl.edu/~avery/course/3400/gallery/gallery_vision.html

The Human Eye - Brightness Response

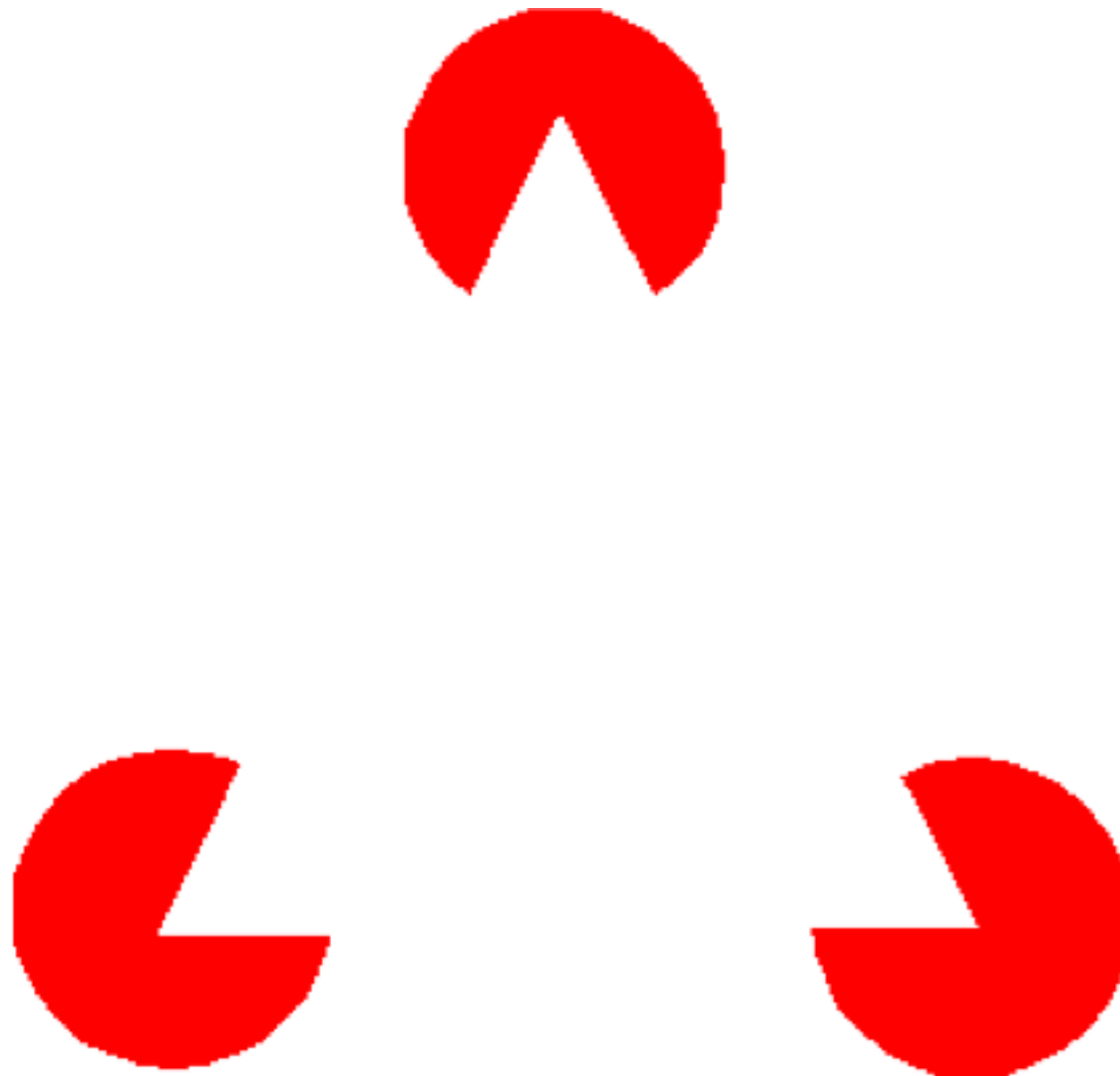
- Adapts to a wide range of brightness levels - bright day to moonless night
- Does not operate over the entire range simultaneously - driving at night
- Brightness adaptation: achieves this range by adjusting sensitivity
- Discriminating changes in intensity an important feature
- Experiment: background intensity I with a flashing dot with intensity $I + \Delta I$
- Weber ratio: $\Delta I/I$ such that intensity is detected 50% of the time
- Weber ratio: a measure of intensity discriminability

The Human Eye - Brightness Response

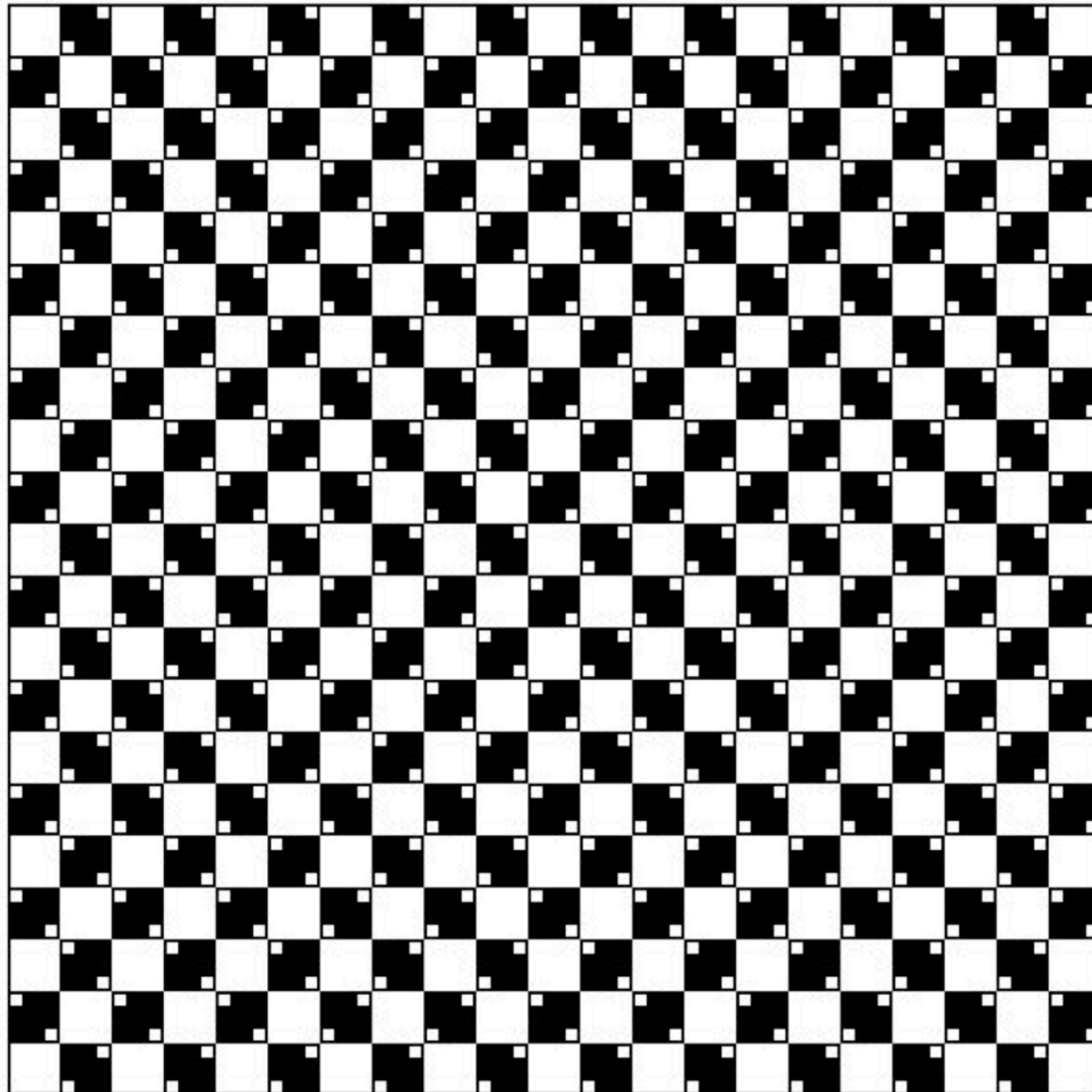


- Mach bands: overshoot/undershoot at intensity boundaries
- Simultaneous contrast: same intensity perceived differently based on background

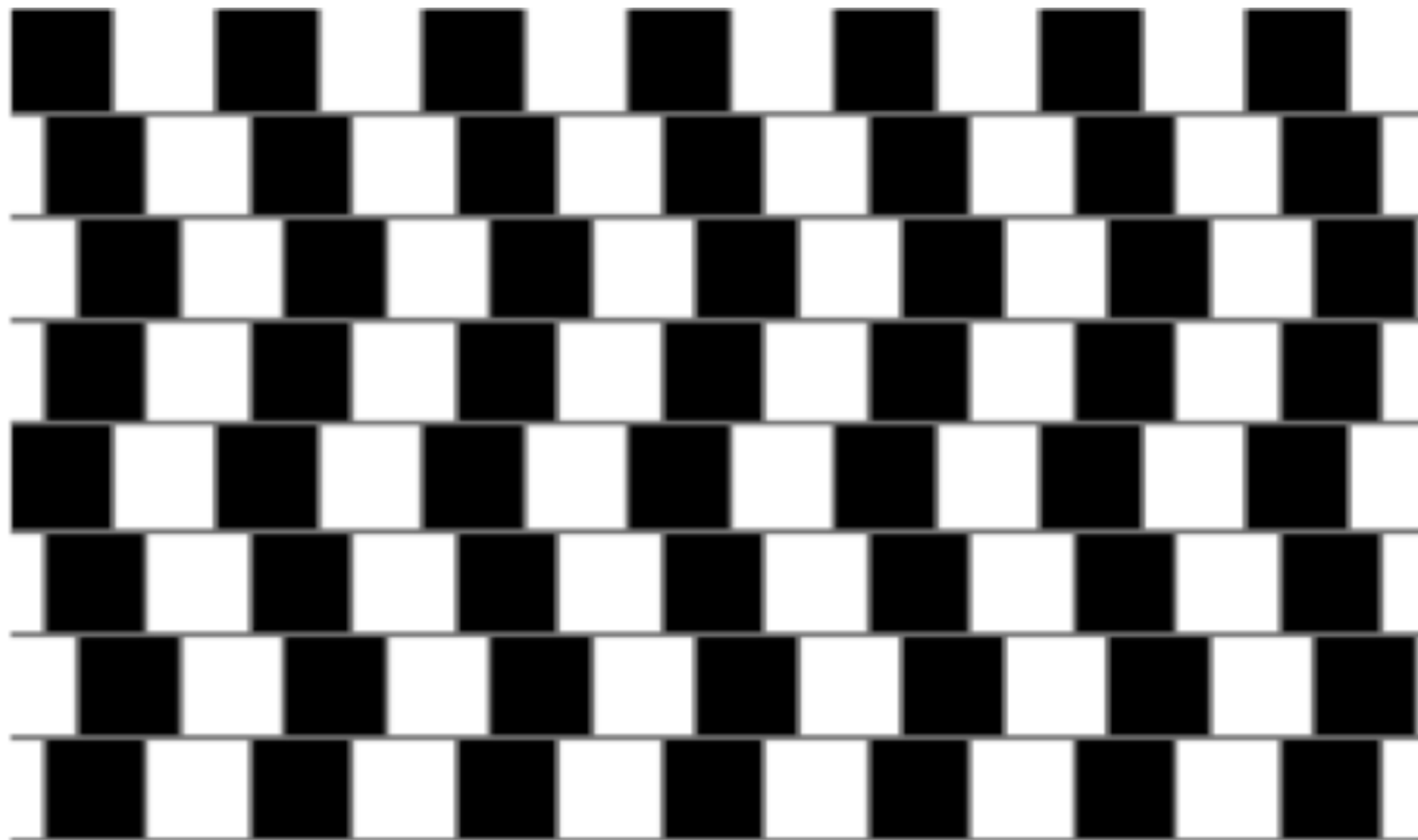
The Human Eye - Optical Illusion



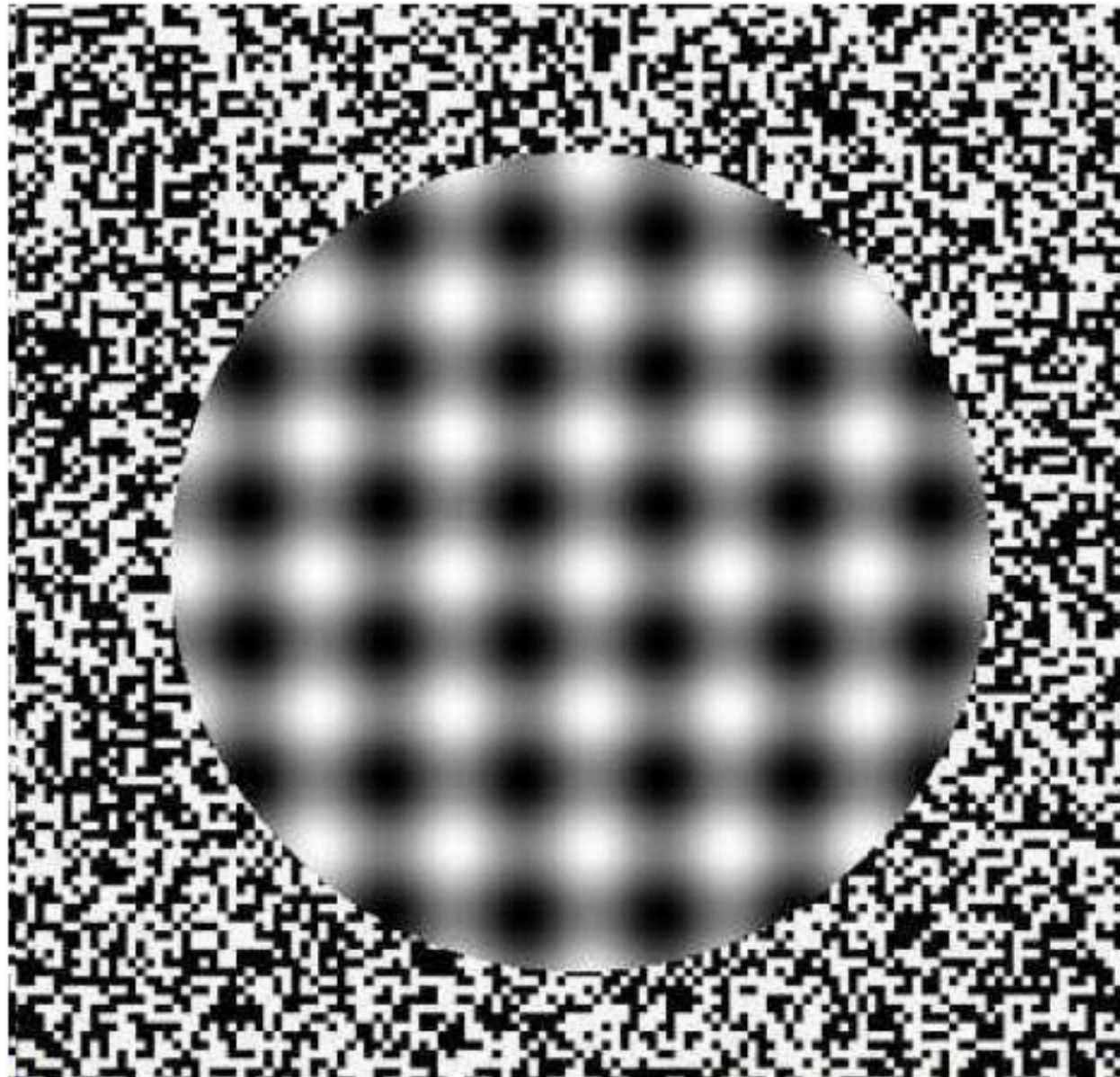
The Human Eye - Optical Illusion



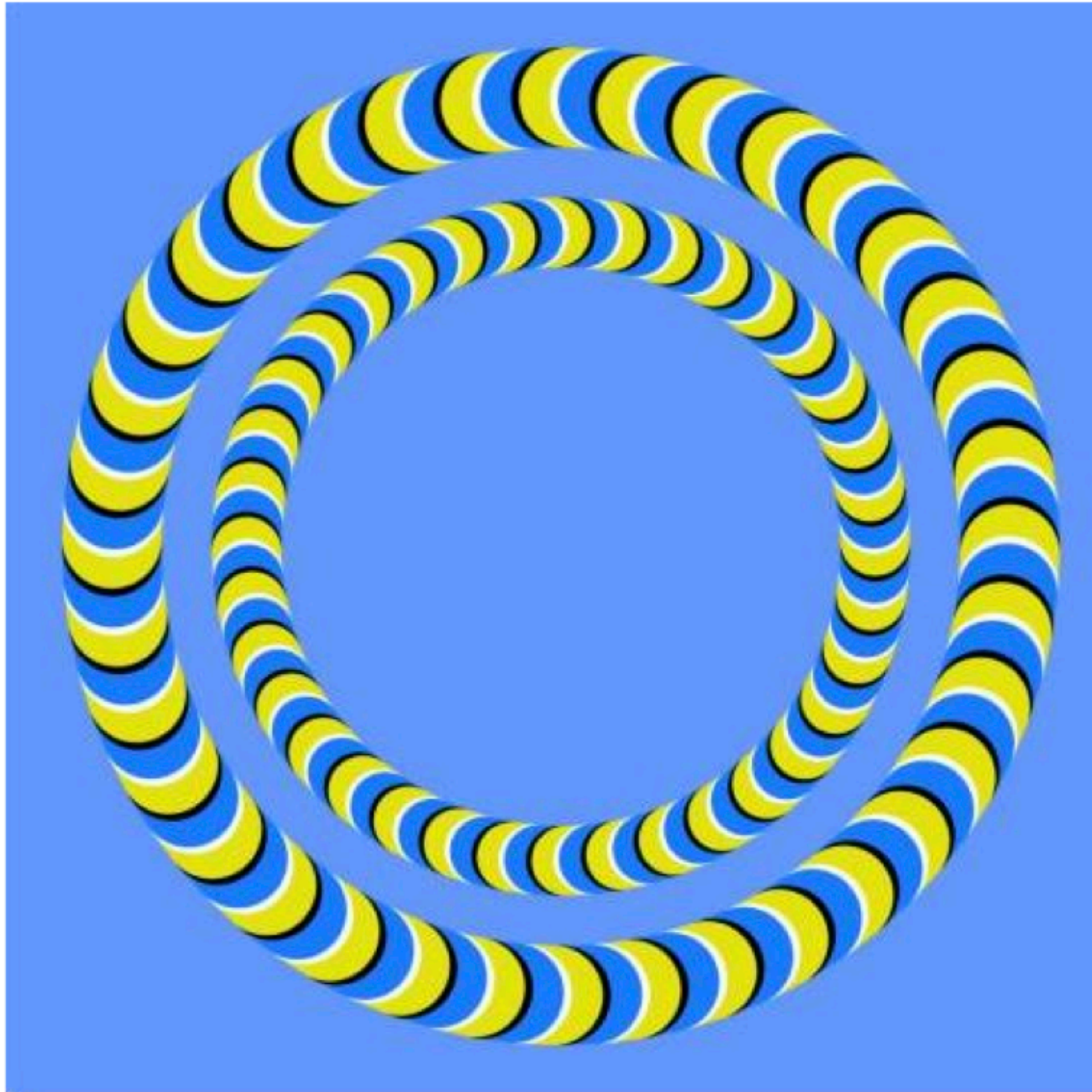
The Human Eye - Optical Illusion



The Human Eye - Optical Illusion

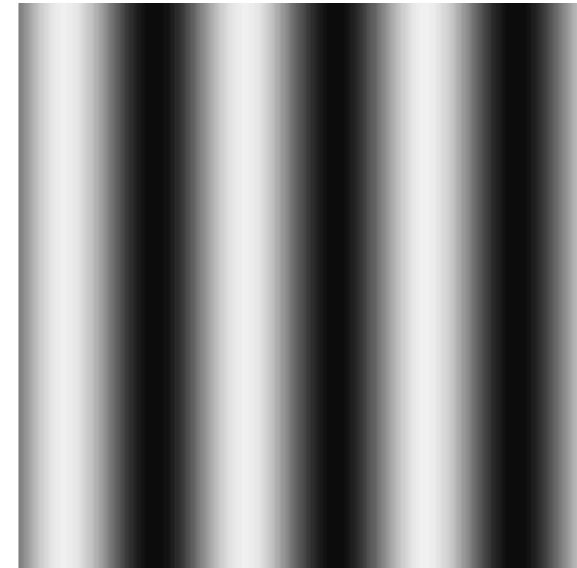
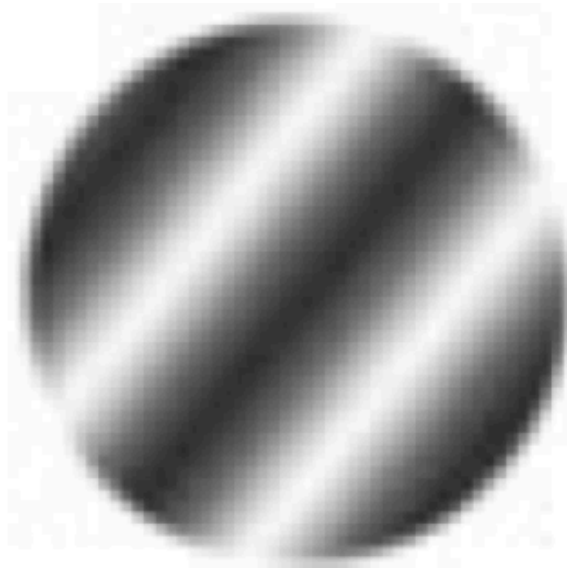
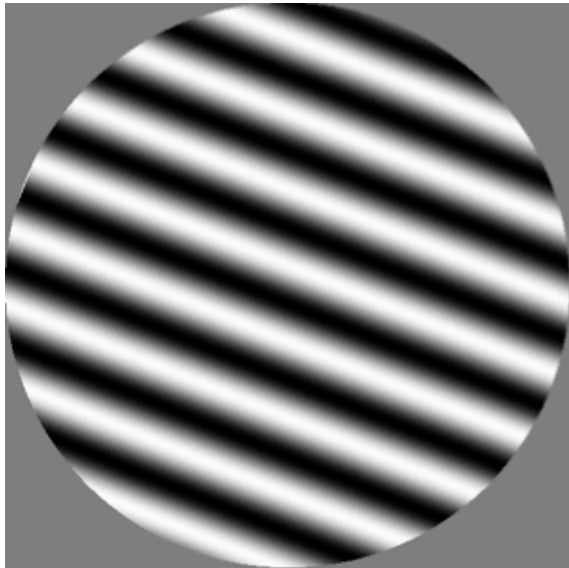


The Human Eye - Optical Illusion



The Human Eye - Contrast Sensitivity Function

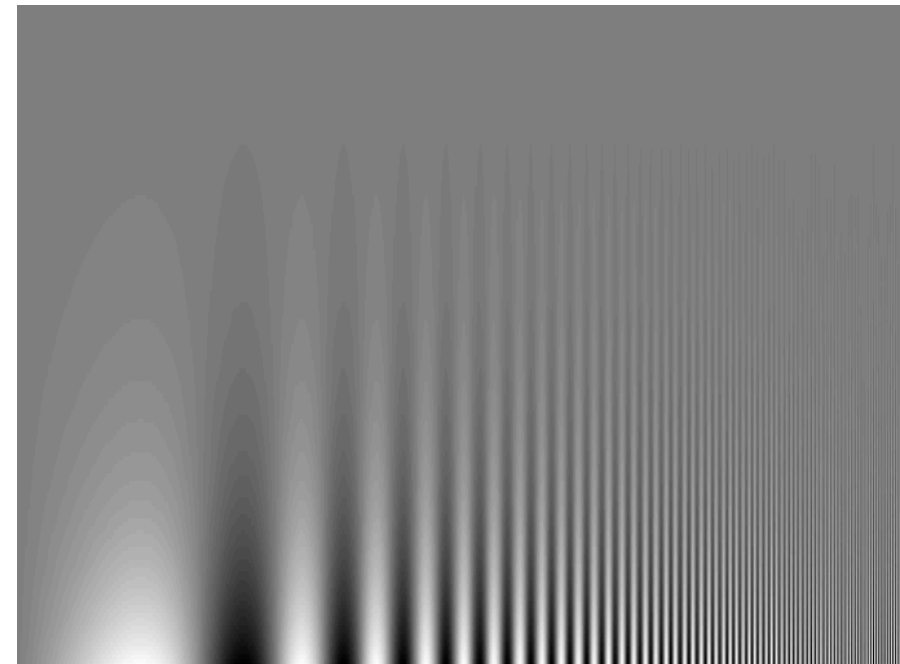
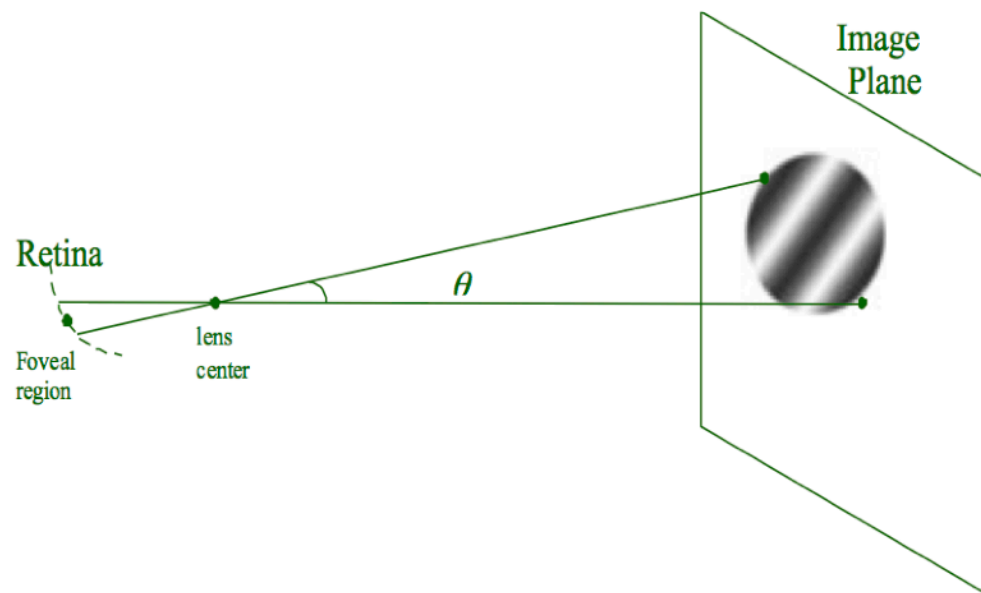
Campbell and Robson Experiment



- Contrast defined as: $C = \frac{L_{max} - L_{min}}{L_{max} + L_{min}}$
 - L_{max}, L_{min} are the maximum and minimum luminance over a patch
- Sine wave grating: $G = C \times \sin(Ux + Vy) + 1; 0 < C < 1$
- Spatial frequencies: (U, V) along (x, y) respectively
- Orientation = $\tan^{-1} \frac{V}{U}$, radial frequency = $\sqrt{U^2 + V^2}$

The Human Eye - Contrast Sensitivity Function

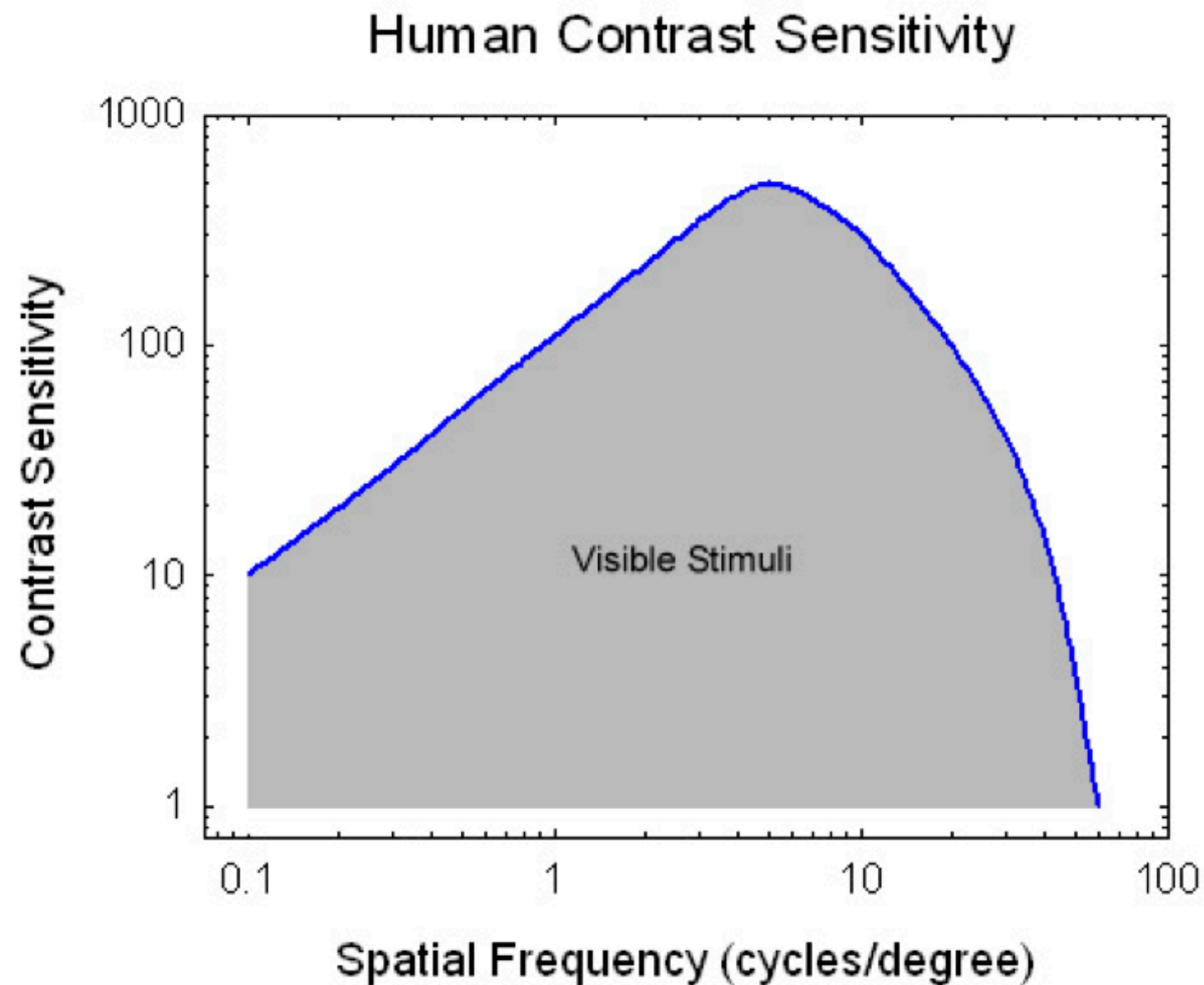
Campbell and Robson Experiment



- Visualize loss of visibility as a function of frequency and contrast
- Human contrast sensitivity function has bandpass nature
- Important consequences in image sampling and compression

The Human Eye - Contrast Sensitivity Function

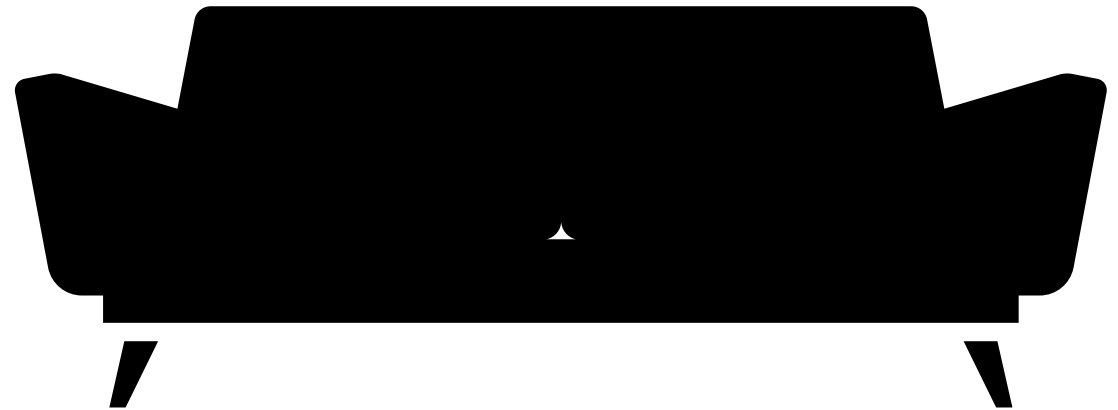
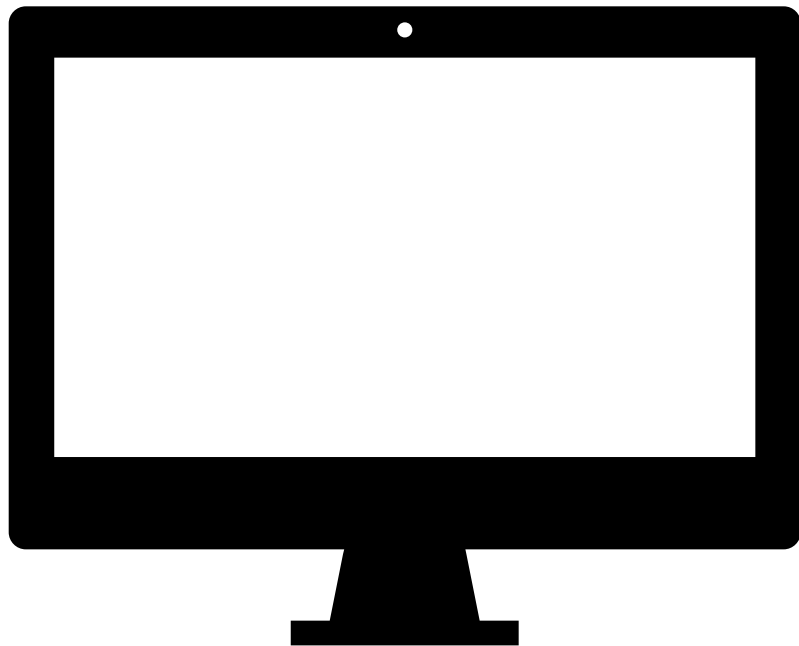
Campbell and Robson Experiment



The Human Eye - Contrast Sensitivity Function

Living Room Design

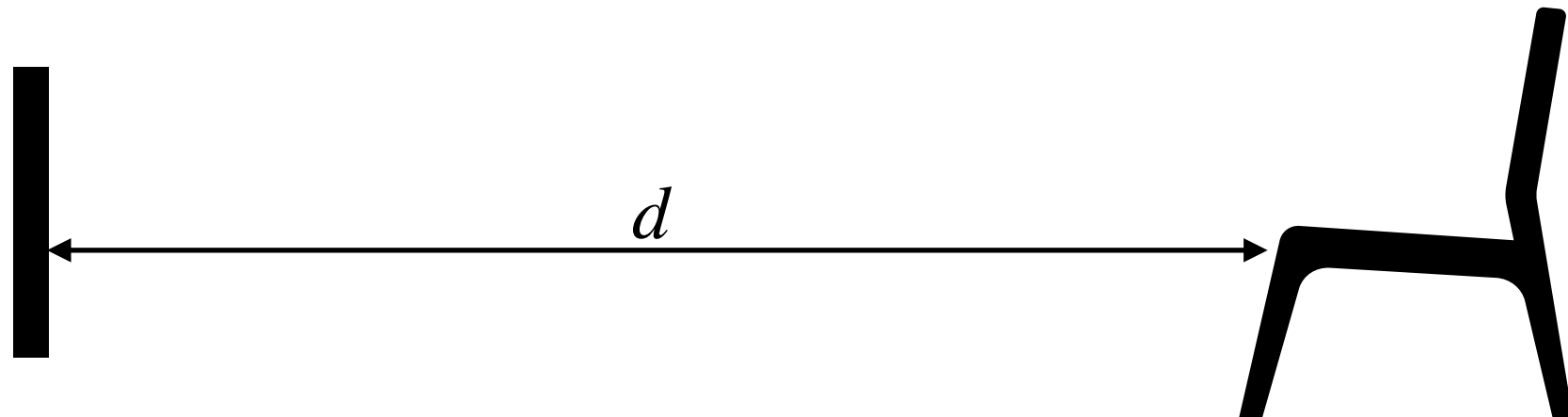
- How far should the couch be from the TV?



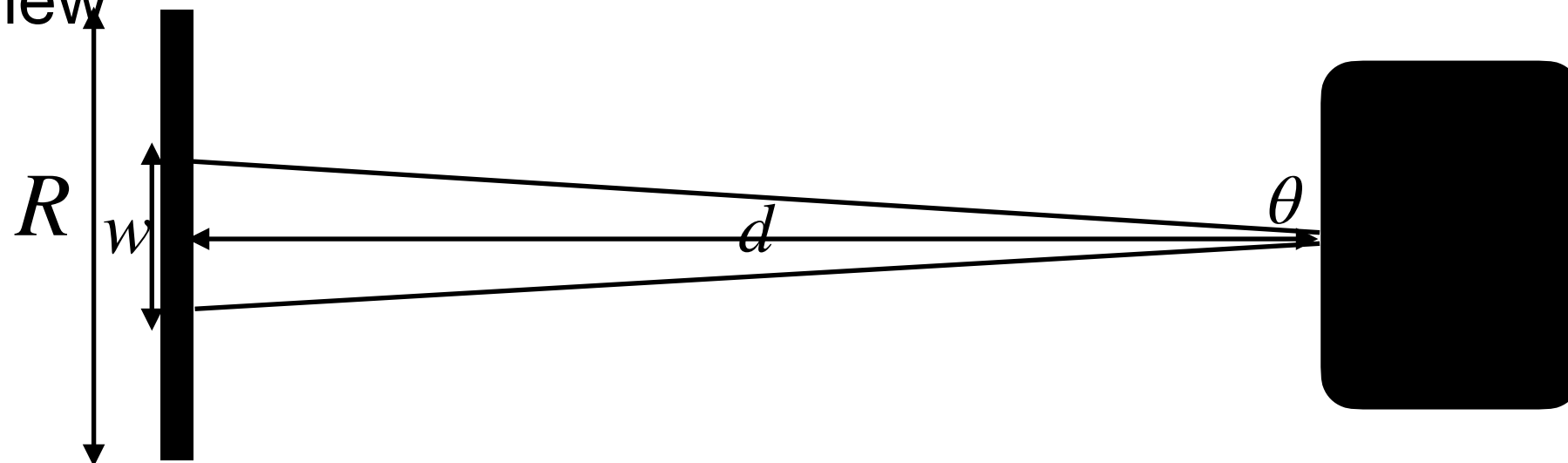
The Human Eye - Contrast Sensitivity Function

Living Room Design

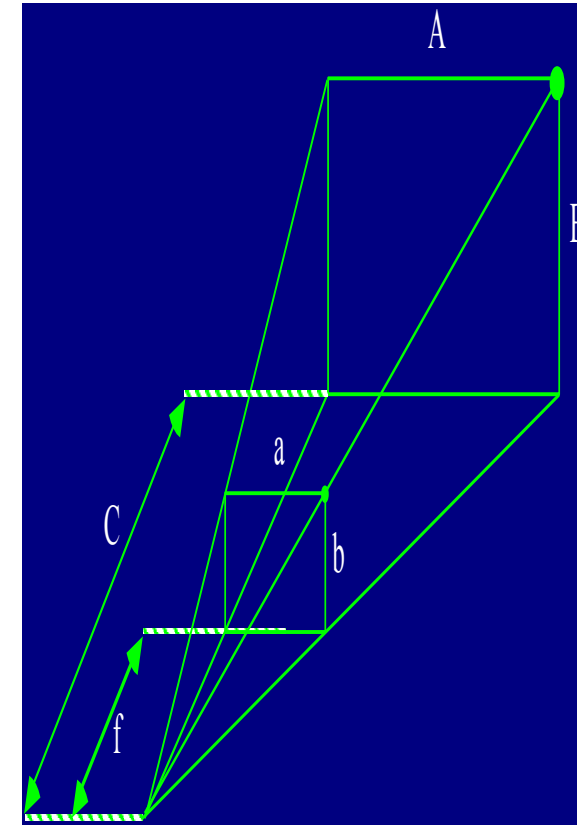
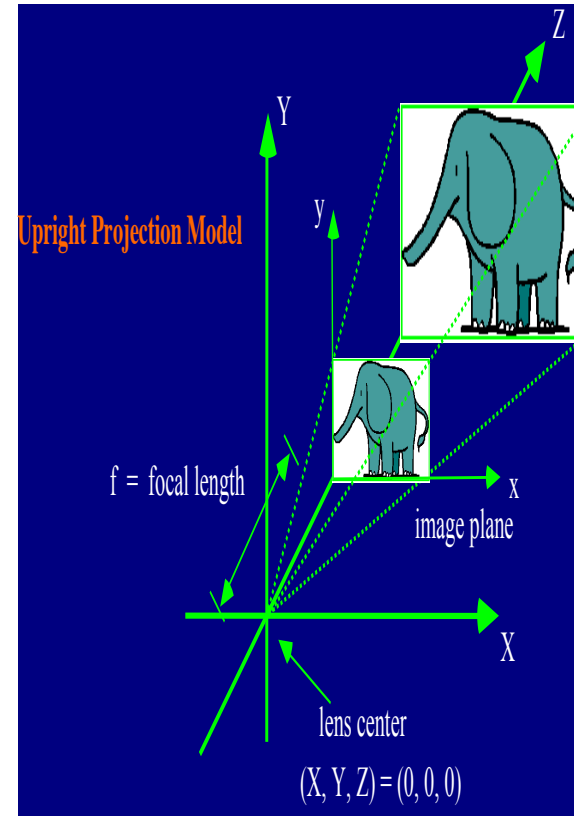
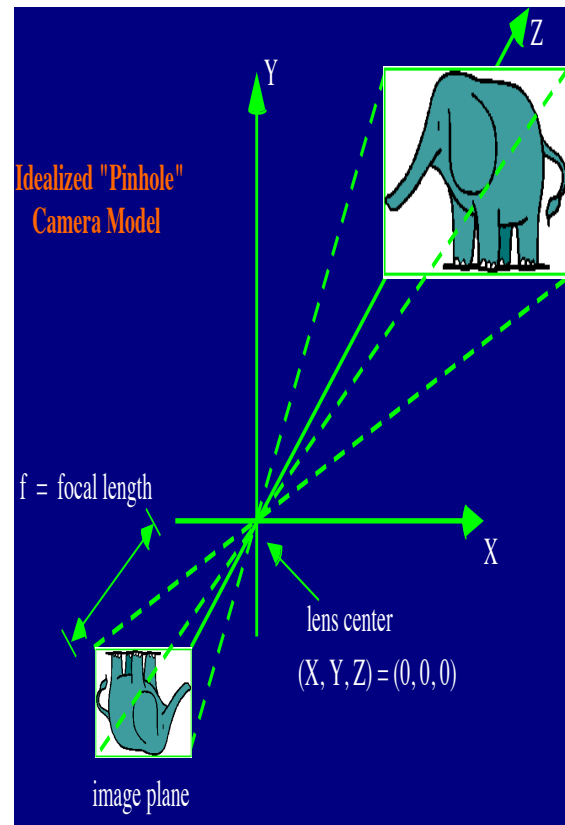
- Side View



- Top view

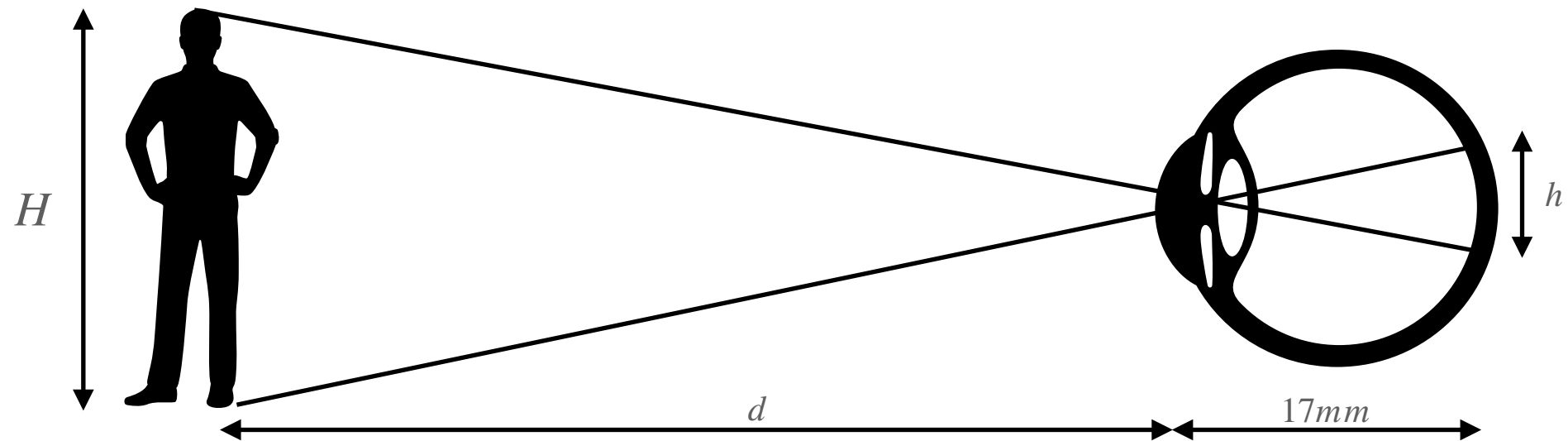


The Human Eye - Image Formation



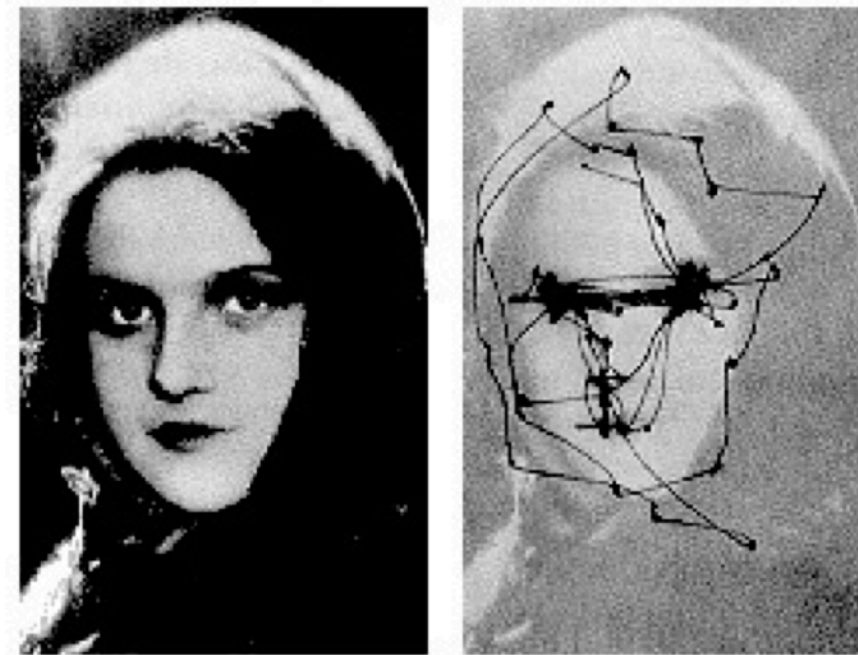
- Image reversed and upside down
- Convenient to fix it to not reversed and right side up
- Similar triangle to solve length problems
- Focal length f fixed to ≈ 17 mm

The Human Eye - Image Formation



- Distance between lens and retina fixed: $\approx 17\text{ mm}$
- Lens shape varies according to distance to object
- Use similar triangles to find object height on retina

The Human Eye - Eye Movement



- Constant eye motion to keep fovea at place of interest
- Types of motion: saccadic, pursuit, vestibular, microsaccadic, vergence
- Several applications including compression