● Sensing and Perceiving
  ○ Physical stimulus → sensory receptors → transduction → receptor potentials → sensory processing → perceiving

○ Physical stimulus
  ■ Photons and the electromagnetic spectrum.
    ● Light is a ‘radiation’
      ○ A sine wave
        ■ Frequency
        ■ Altitude
        ■ Length

  ○ Light is characterized by 3 parameters:
    ○ Hue (wavelength)
      ■ Related to the ‘frequency’ of the sine wave
    ○ Saturation (purity)
      ■ Purity of the sine wave
    ○ Brightness (intensity)
      ■ Amplitude of sine wave

○ The Eye
• Not all eyes are the same
  • Species to species variations
  • Visual field
    o Part of space that you see if your head doesn’t move
  • Monocular
    o Seen by one eye
  • Binocular
    o Seen by both eyes

• The Human Eye
  • Conjunctiva
    o Merges with inside of the eyelids
  • Cornea
    o Outer layer of iris
  • Iris
    o Responsible for eye color
  • Pupil
    o Opening in iris
  • Lens (Accommodation)
    o Helps you focus
    o Retracts or contracts to take in less or more light
  • Sclera
    o Oculomotor
    o Trochlear
    o Abducens
    o Control eye movements
    o Responsible for saccadic eye movements
      • 4 times a second
    o Can be controlled during ‘pursuit’ movements
  • Layers of retina
    o At least 5 types of cells, organized in 3 layers
    o 1st layer: photoreceptor layer
      • Rods and cones
        • Rods
          o 120 millions
          o Periphery
          o Not color sensitive
          o Poor spatial acuity
          o Good in dark
          o Good for motion
        • Cones
          o 6 million
          o Fovea
          o Color sensitive
          o High spatial acuity
          o Poor in dark
          o Poor for motion
      • Have lamellae (on the very tip of these cells) → cell body → dendrite → bipolar cells
- Innermost layer in eye
- Lamellae has photopigment
  - Photopigment + light → opsin (rhodopsin) + retinal (from Vitamin A) → release neurotransmitter on bipolar neurons
- 2nd layer: bipolar cell layer
  - Full of bipolar cells
  - Horizontal cells connects to 1st layer
  - Amacrine cell connects to 3rd layer
- 3rd layer: Ganglion Cell Layer
  - Receptive fields
  - ON/OFF or OFF/ON receptive fields
    - ON center, OFF surround cells are active when they are presented with bright light in the center, or dark spot on surround
  - Sensitive to contrast
  - Color perception
    - Trichromatic photoreceptors
      - 3 types of cones
        - Red
        - Blue
        - Green
      - Much less blue cones
  - Genetic disorders
    - Protanopia
      - Red cones filled with green opsin
      - Male prevalence - 7%
    - Deuteranopia
      - Green cones filled with red opsin
      - X chromosome
      - Male prevalence - 7%
    - Tritanopia
      - No blue cones
  - Color sensitive
    - 3 types of photoreceptors but only 2 types of color sensitive ganglion cells
      - red/green and yellow/blue
  - Opponent processing
    - Red ←→ green
    - Yellow ←→ blue
    - Yellow sensitivity is due to simultaneous red and green cones inputs
      - ON/OFF receptive fields are color specific
    - All have intact visual acuity
• Visual acuity
  • Central (fovea) vs peripheral vision
    • Ganglion cell gets information from 1 photoreceptor in the central (fovea)
      • More accurate
    • Ganglion cell gets info from more than 1 photoreceptor, never know which one from the peripheral
      • Less accurate
    • Cells have receptive fields that cover a small part of the visual field
    • Ganglion cells in the fovea are more accurate than ganglion cells in the periphery

• Vitreous humor
• Optic nerve
• Blood vessels
• Fovea
  o Straight behind the lens in back of eye
  o Objects are inverted
• Blind spot
  o Where everything exits the eye
  o Hole in retina
  o Cannot perceive
• Visual pathway
  • Each eye receives information from the right and left visual fields
• Lateralization
  o Left visual field → right hemisphere
  o Right visual field → left hemisphere
• Mapping
  o Two nearby cells in the visual cortex have two nearby receptive fields

• Eyes → LGN → V1 (visual perception)
• Eyes → LGN → Hypothalamus
  o Circadian rhythms
• Eyes → LGN → Tectum - superior colliculus
  o Eye movements accommodation
    ▪ Lateral Geniculate Nucleus (LGN)
      • 6 layers of neurons in 3 groups
        o Parvocellular (3,4,5,6)
          ▪ Red & green cones
          ▪ High resolution
          ▪ Slow
        o Magnocellular (1,2)
          ▪ Low spatial resolution
          ▪ Fast
        o Koniocellular groups (in between)
          ▪ Blue cones
          ▪ Low resolution
- **V1**
  - Primary Visual Cortex (V1)
    - “Striate Cortex”
    - Has 6 layers as well
    - At least 3 types of cells
      - Simple
      - Complex
      - Hypercomplex
    - Orientation selectivity
    - Spatial frequency and disparity
    - V1 module: blobs and interblobs
  - Striate Cortex
    - Visual cortex has 6 parallel layers of neurons running along the brain surface
    - Most of the visual information enters through layer 4, is processed across all layers and leaves from layers 1-2
  - Response of V1 cells
    - Orientation selectivity: simple cells
    - Sensitive to the orientation of bars of lights
    - If environment is very rich, your neurons become sensitive. If not, your neurons adapt to only be sensitive to those colors.
    - Edge detectors
      - Elongated receptive field
      - Inhibitory surround
      - In center: simple cell is excited
      - Off center: simple cell is inhibited
    - Motion detector
      - Elongated receptive field
      - No inhibitory surround
      - Complex cell is excited by all 3 stimuli and by motion in a particular direction
    - Line-end detectors
      - Elongated receptive field
      - Inhibitory flank
      - No stimulus if bar is outside of the receptive field
      - Strong response if the bar is inside the receptive field
      - Once it crosses there is a weak/no response
  - Visual Angle, Spatial Frequency
    - Most cells in V1 are also sensitive to ‘spatial frequency’
    - High spatial frequency – more details
• Low spatial frequency – low details
  • Used for the perception of textures
  • Retinal disparity: Perception of Depth
    • ‘Far’ cells and ‘near’ cells are maximally active when stimuli are on on-corresponding parts of the retina (retinal disparity)
    • We use many other cues to perceive depth (shape, angles)
  • Putting it all together
    • Blobs
      • Low spatial frequencies
      • Color
      • Binocular
    • Interblobs
      • Orientation
      • High spatial frequency
      • Motion
      • Disparity (depth)
      • Binocular
  • Beyond V1
    • Extra-striate cortex
      • The visual system is complicated!
    • The 2 visual pathways
      • 2 streams of information leave V1 (into V2)
        • Dorsal pathway
          • Where?
          • Location of objects in space
          • Posterior parietal lobe
          • LOCATION INFORMATION
        • Ventral pathway
          • What?
          • Identity of object
          • Inferior temporal cortex
          • SHAPE INFORMATION
          • The further the information goes along the ventral pathway (temporal lobes), the more selective the cells for specific objects or visual features
        • Ventral: Perception of color
          • CO blobs → V4...V8
          • V4: color constancy
          • Perception of color depends on ‘context’
          • Cerebral achromatopsia (damage to V8)
            • Loss of color vision with no loss of acuity
            • Some patients can recognize colors, but not shapes
        • Ventral: Perception of faces
          • Face cells
          • Cells selective to faces, emotional expressions, identity
          • In humans, face cells are located in the ‘fusiform face area’
        • Ventral Stream
          • Respond to complex 3D objects, colors, and forms
- Large receptive fields
- Faces and bodies are special
  - Face
    - Fusiform Face Area
  - Bodies
    - Extrastriate Body Area
  - Objects
    - Lateral Occipital Complex
  - Scenes
    - Parahippocampal place area
- Damage to ventral stream: Visual agnosia
  - Deficit in perception of object
    - Good recognition
  - Deficit in associating a shape with a name
    - Good perception
  - Usually together with a language deficit
  - Prosopagnosia
    - Deficit in the perception of faces (fusiform face area)
- Dorsal Stream: Motion Information
  - Magnocellular $\rightarrow$ Area MT (V5) + MST
  - Compute optic flow
    - Optic flow: When something is moving, you see it move in a particular direction
    - Center of expansion
    - One goal is to separate objects from each other and from the background
  - Inferring form from motion
  - Akinetopsia
    - Selective deficit in motion perception, not form
  - Blindsight
    - Seeing motion only
    - Collicular