Sensation and Perception – General Principles and Vision

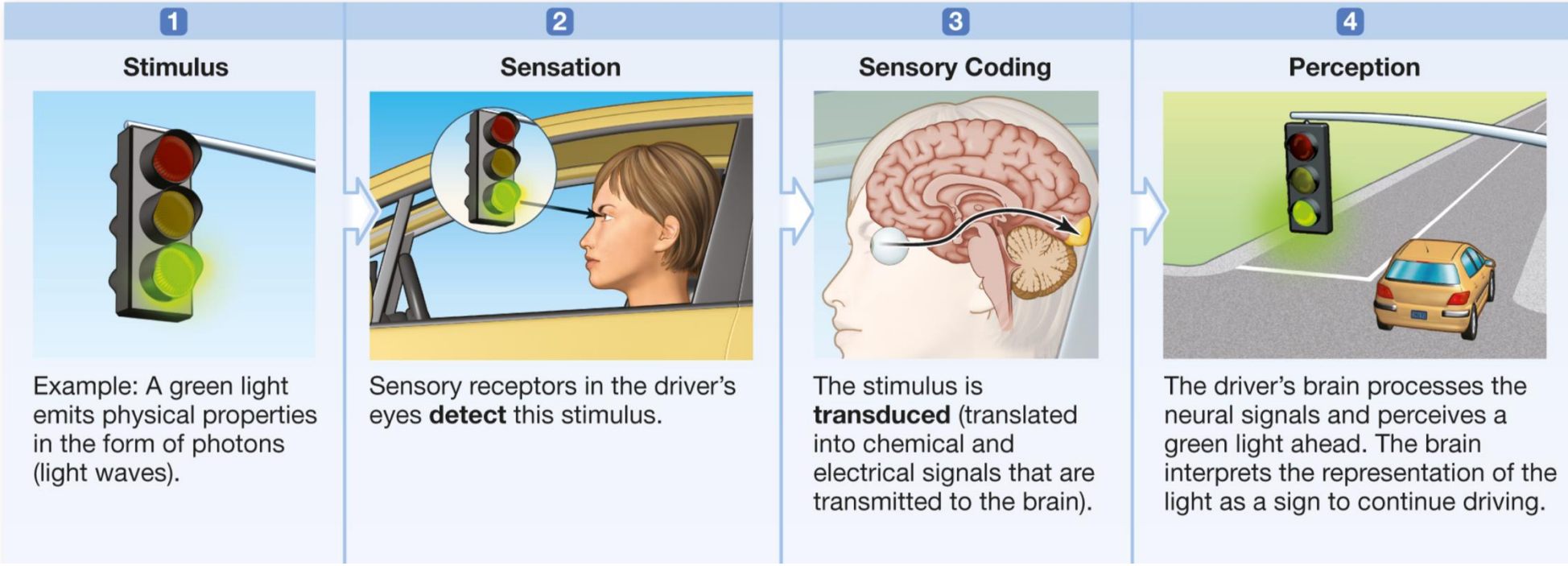
10/1/24

Basic Definitions

- **Sensation** – detection of physical stimuli and encoding that into information (**bottom-up**)
  - **Sensory transduction** – the specific process of transforming a stimulus into a nerve signal
- **Perception** – cognitive process of organizing, interpreting, making sense of the sensory input (**top-down**)
- **Sensory receptors** – different types of cells that have specific structures that respond to specific stimuli
  - Chemical (chemoreceptors), temperature (thermoreceptors), pressure (mechanoreceptors), light (photoreceptors), harm (nociceptors), fluid changes (osmoreceptors), internal organs (interoceptors), body position (proprioceptors)
- You have sensory receptors everywhere in your body. Only a small portion of them contribute to conscious sensation and perception.
  - Autonomic regulation, reflexes, and subconscious thought rely on sensory signals that are non-conscious

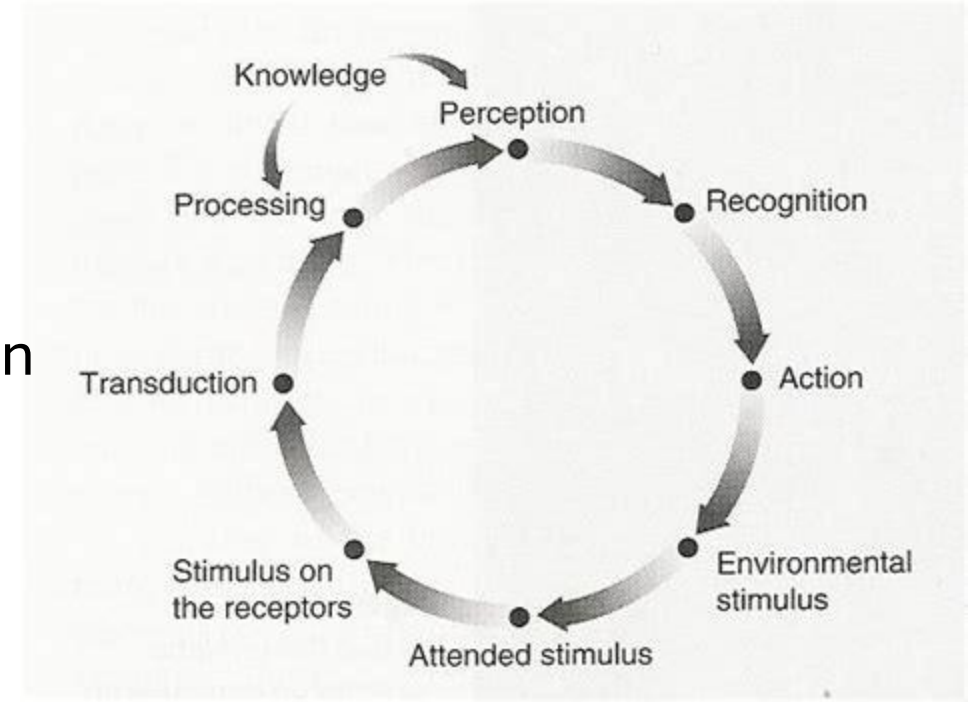
The basic model of perception

- Linear process going from stimulus to perception
- But wait, don't we need more of a systems approach?



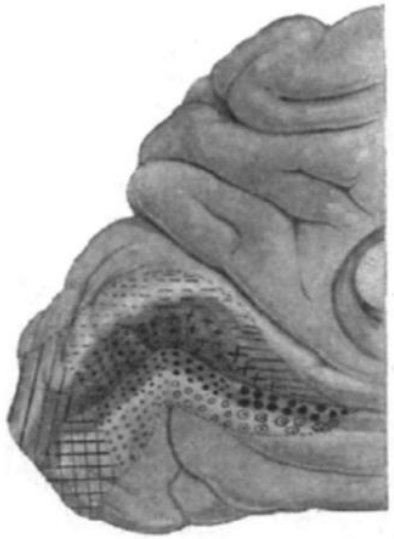
Top-down influence

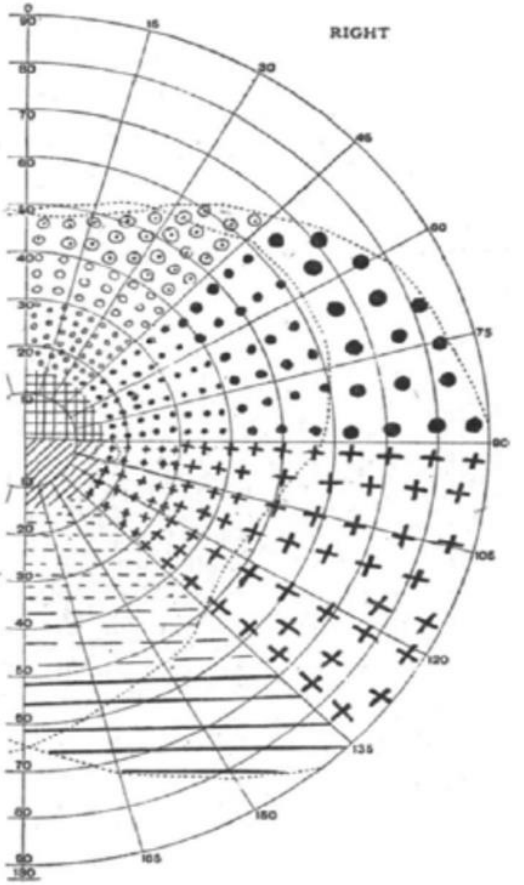
- The brain constantly generates predictions about what it expects incoming sensory information to be like.
  - The brain is trying to minimize prediction error
- This allows the brain to efficiently fill in gaps and resolve ambiguities so that it can make sense of the world.
- Memory, expectation, emotions, and attention can all influence sensation and perception
- Those top-down influences can turn up or turn down the sensory receptors themselves by modulating their excitability
- You may hear that sensation is passive, while perception is active. This is too simple of a distinction. It is a feedback system that is both active and passive.



Fields and Maps

- Each sensory neuron has a particular region of sensory space it is sensitive to – a region of the retina or skin, a range of auditory frequencies, a chemical feature like glutamate or aldehyde, a range of temperature changes
- The brain has a map for each sensory modality that maintains the spatial and functional relationships of the sensory receptors
  - Somatotopic (body), retinotopic (visual), tonotopic (auditory), olfactotopic (smell), gustotopic (taste)



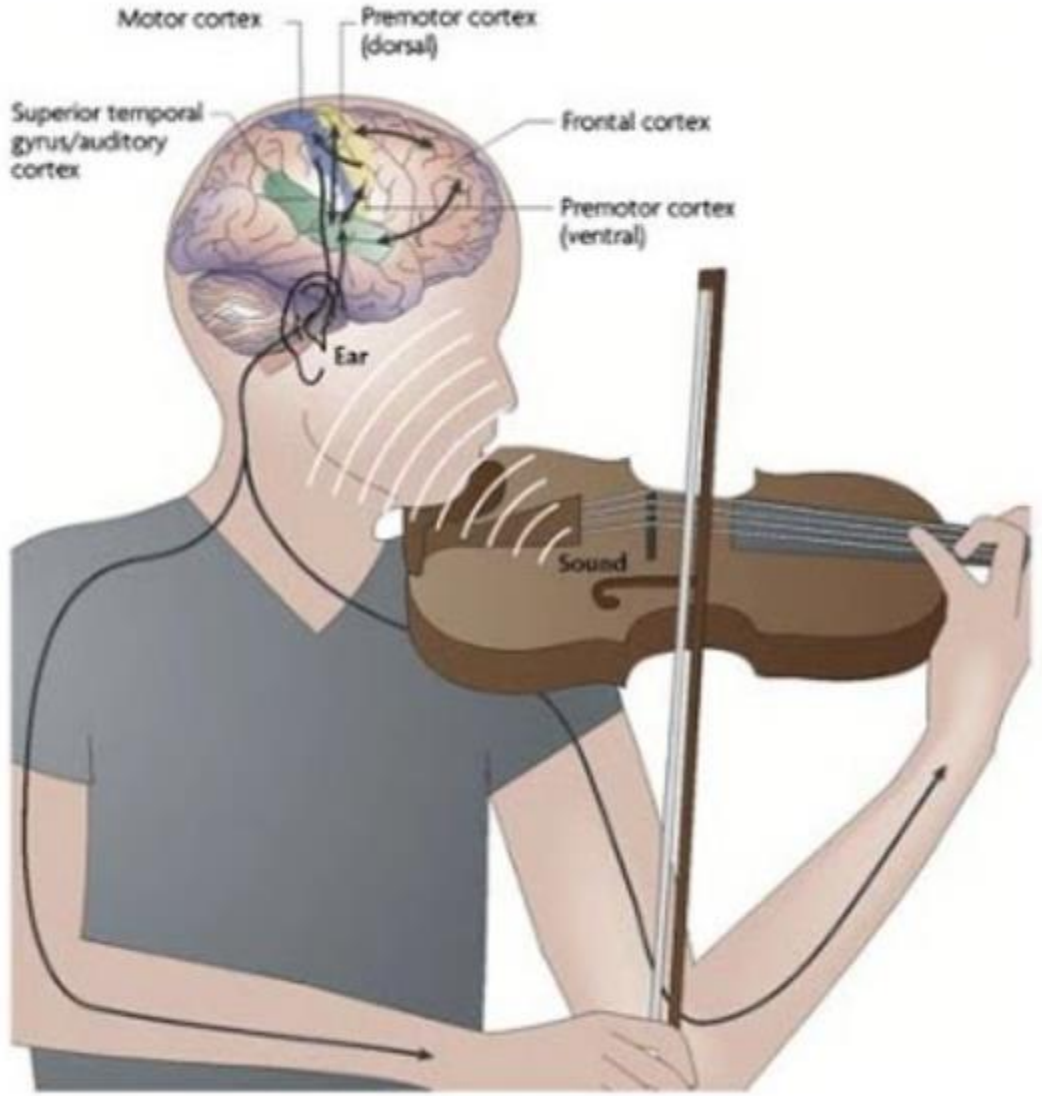


Learning and development

- Growth of sensory receptors themselves are mostly fixed by development
- **Critical period** – window during development when the brain is highly plastic to learning about stimuli
  - Important to give a child the correct stimuli during this period
  - Social perception begins in infancy
  - Between 6-12 months, child's auditory perception becomes tuned to the phonemes of its native language

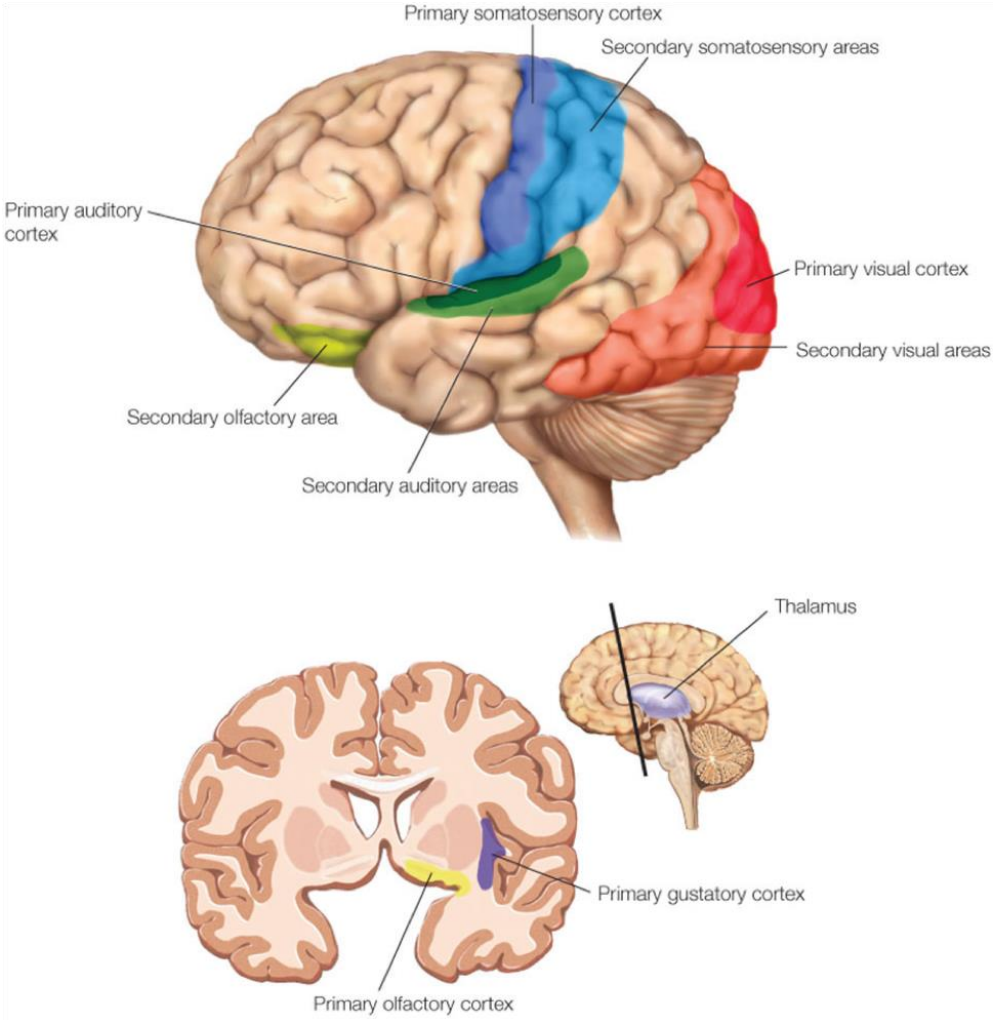
Adaptability

- Brain's sensory systems are highly adaptable and can reorganize in response to changes – neuroplasticity in action
  - Blind people use their visual cortex to process auditory information
- **Perceptual learning** – repeated sensory experiences refine neural circuitry's ability to discriminate
  - Exposure to musical harmony trains the auditory system on those scales
  - If you give a child the right musical exposure (before age 6), they can develop perfect pitch
  - Tonal languages like Mandarin sensitize people to pitch



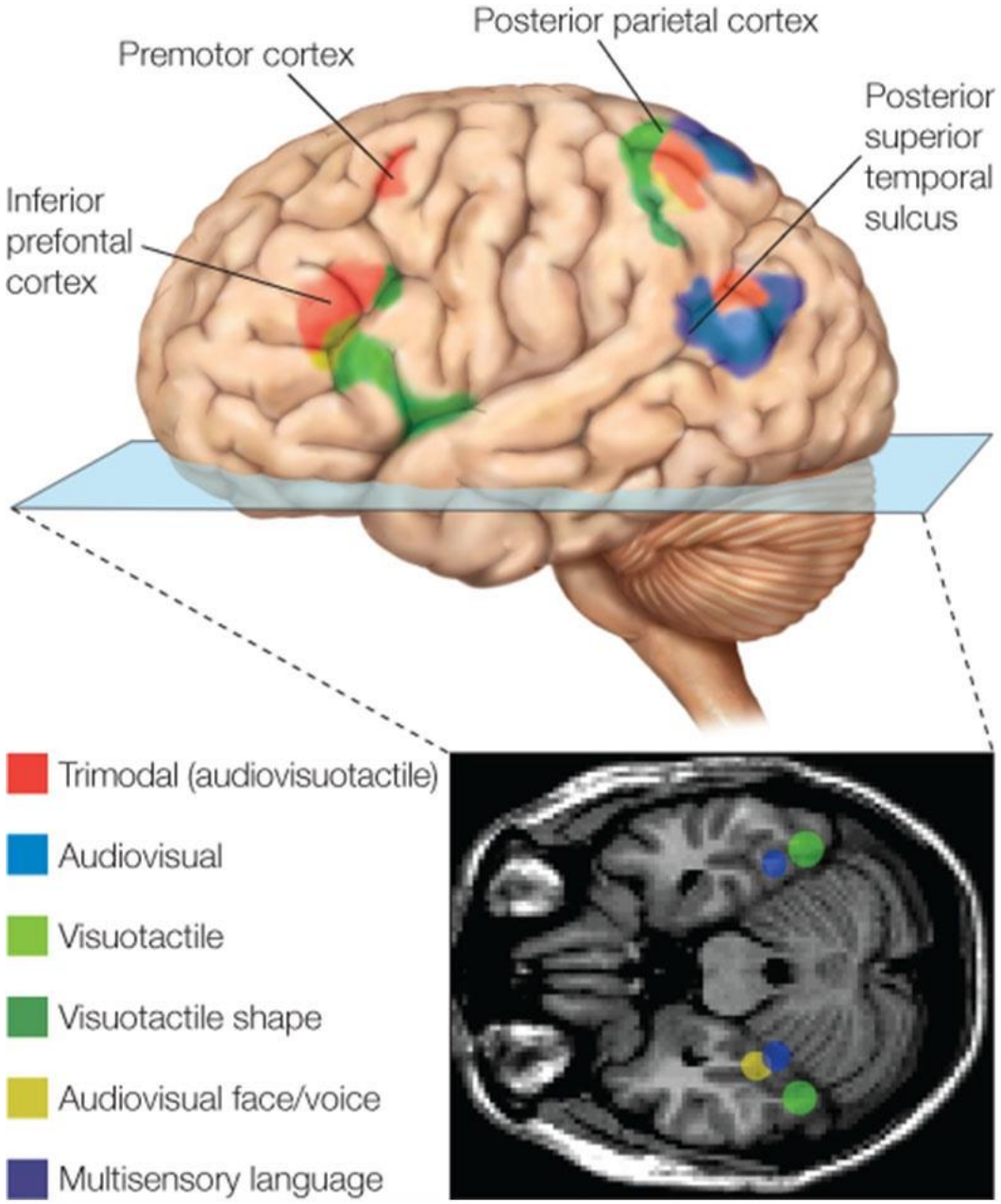
In the brain

- Each major sensory modality has a specialized cortex for processing
- **Thalamus** – except for olfactory, all sensory processes filter through thalamus on their way to their sensory cortex
- **Multimodal integration** occurs primarily in attention and default mode networks



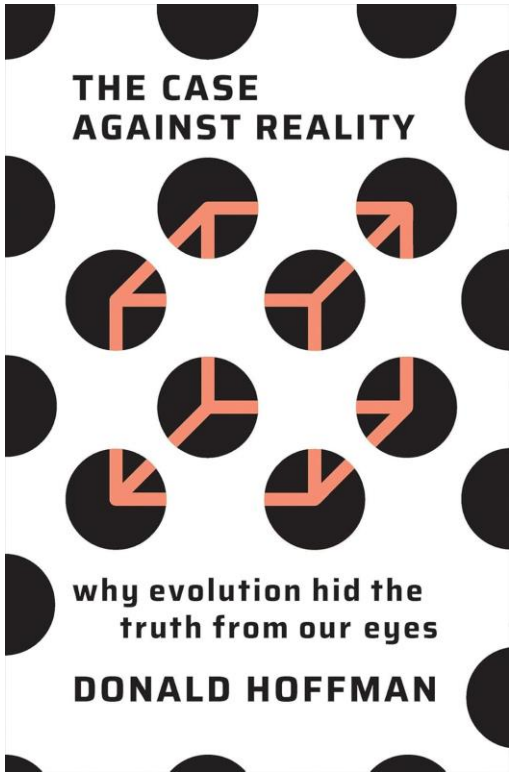
Integration

- **Multimodal perception** – the ability to combine all these different inputs into an integrated perception of the world
- Sensory modalities all influence each other
  - Input from one modality will affect the expectation effects on the other, and vice versa
  - Watching someone's face helps you interpret their speech
  - Distance appears as farther when you are carrying a heavy bag
    - The potential for physical effort influences a perceptual judgment!
  - Your perception of your body's position influences your perception of your emotional state
- **Mirror neurons** – specialized brain cells that fire when an individual both perceives an action and performs the action
  - Helps us simulate others' movements, enhancing learning, social cognition, empathy



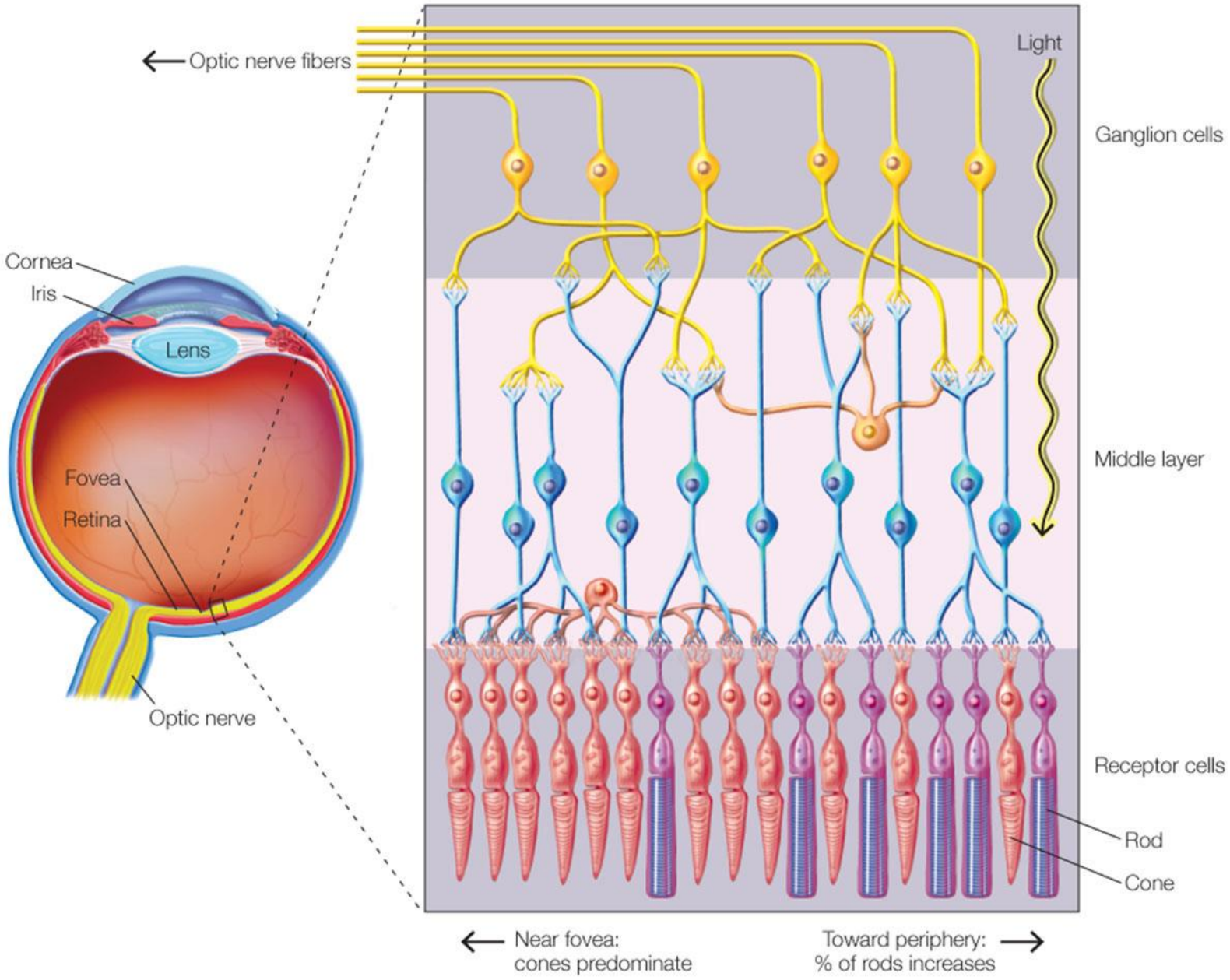
The Case Against Reality

- Our perception evolved to maximize fitness, not to reflect the truth of reality
- **Interface theory** – sensory experiences are presented like a user interface (like an “icon” on a computer screen) to minimize complexity and maximize efficient decision making
  - The simplest level, chemotaxis: single cells navigating chemical gradients do not appear to “know” what nutrients “are,” they just follow cues
  - Experiences like color act as symbolic indicators (ripe fruit, or dangerous poison)
- Critique: There must be a correlation between perception and reality (truth?) for effective navigation of the world.
  - We are in constant compromise to balance tension between accuracy and efficiency



Vision

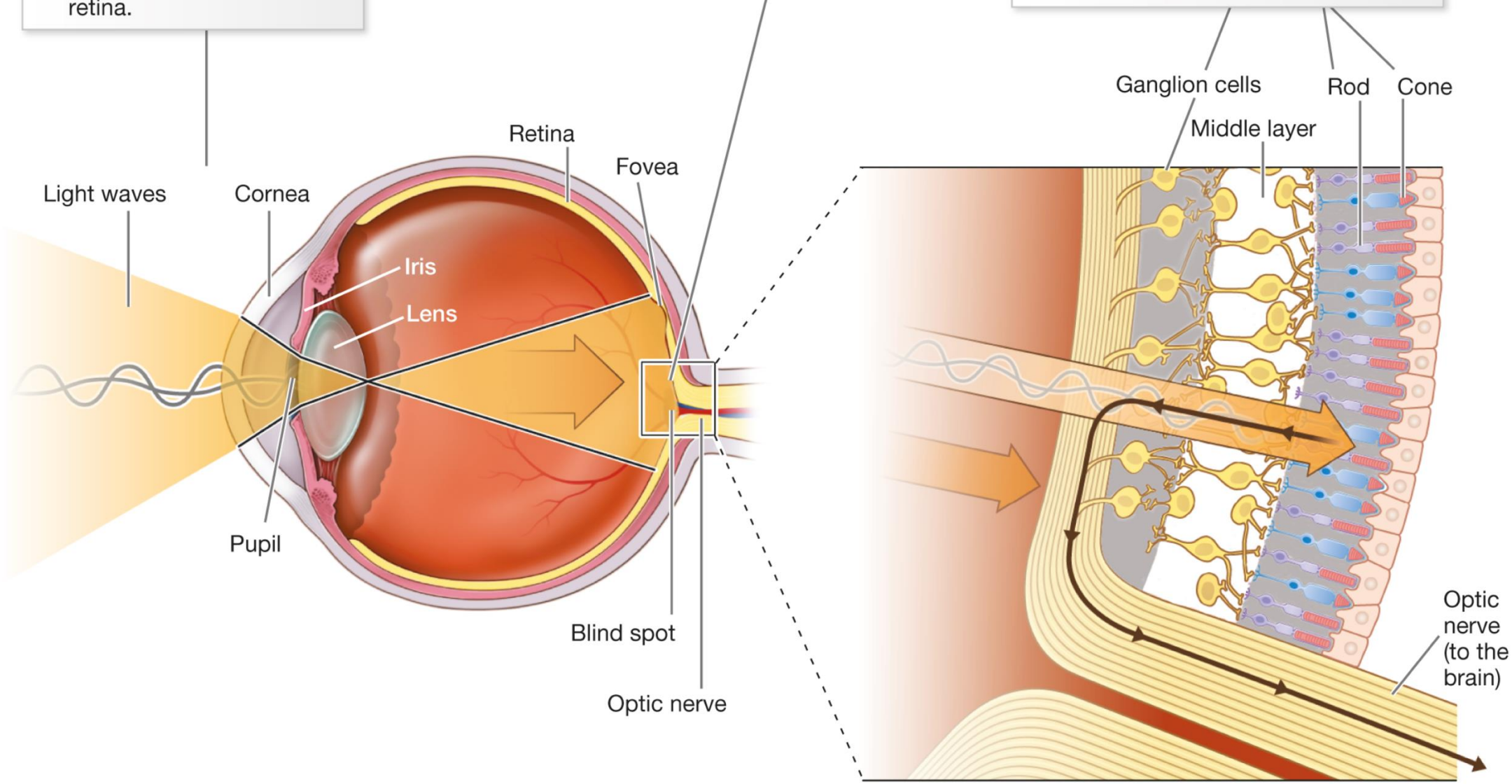
- **Rods** – photoreceptors sensitive to brightness
- **Cones** – photoreceptors sensitive to color
- Pigments in the photoreceptors structurally change in response to light, causing the photoreceptor to induce action potentials in ganglion cells



1 Physical stimulus:
Light waves reflected from the image pass through the cornea and enter the eye through the pupil. The lens focuses the light on the retina.

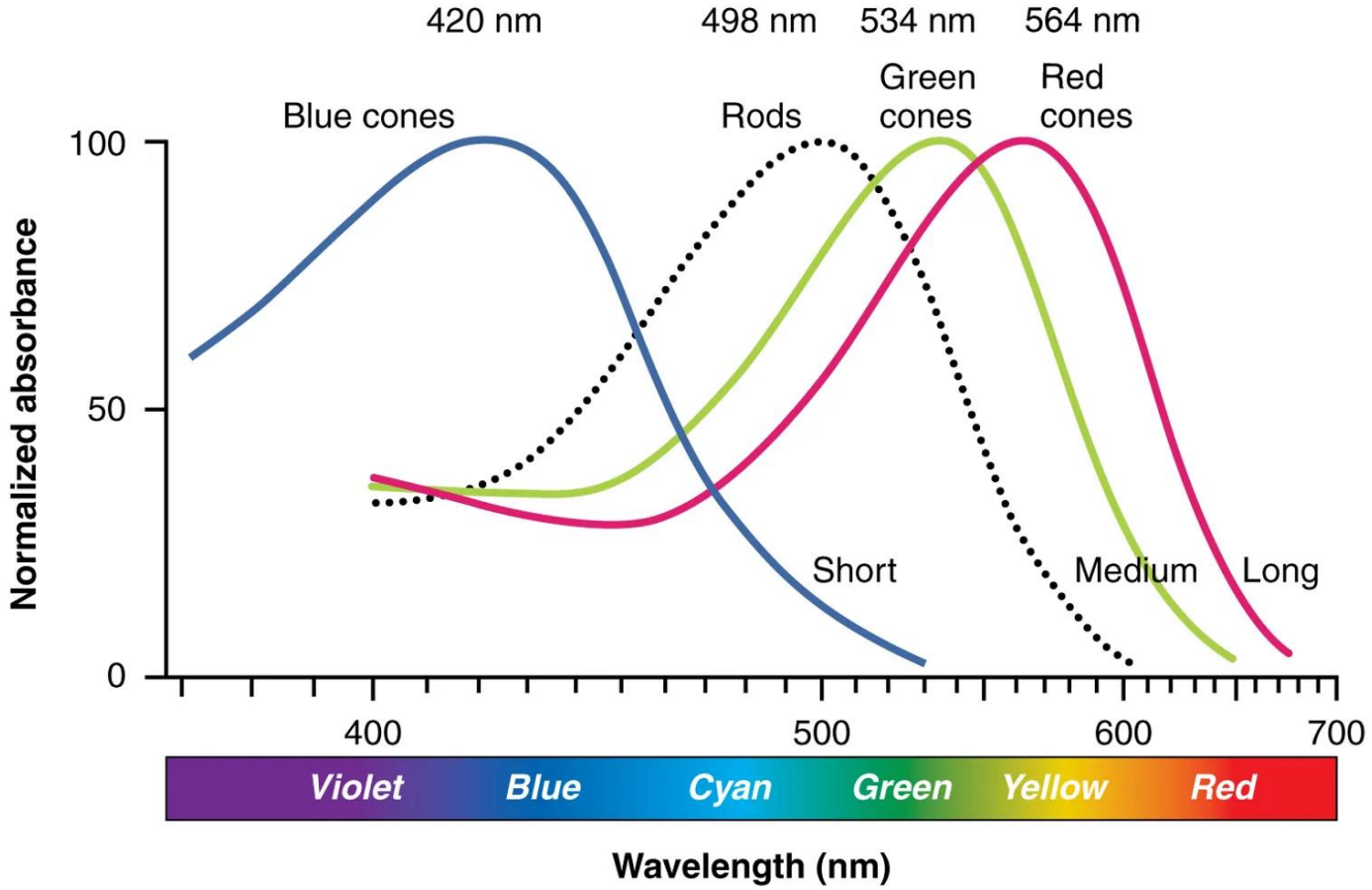
2 Sensation:
Sensory receptors in the retina, called rods and cones, detect the light waves.

3 Transduction:
Rods and cones convert light waves into signals. Those signals are processed by ganglion cells, which generate action potentials that are sent to the brain by the optic nerve.



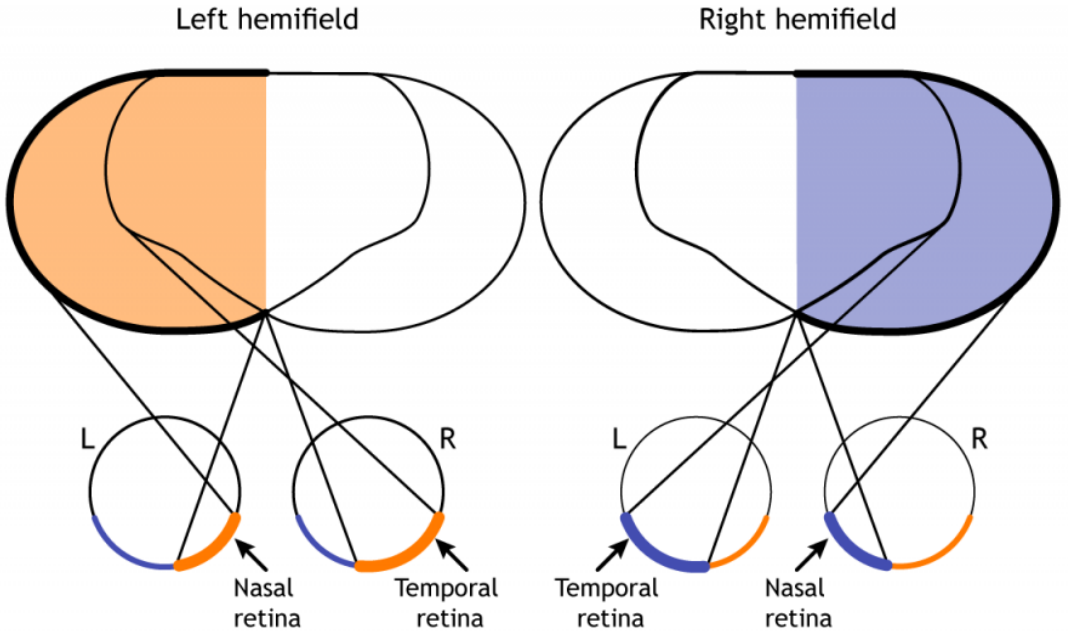
Color Perception

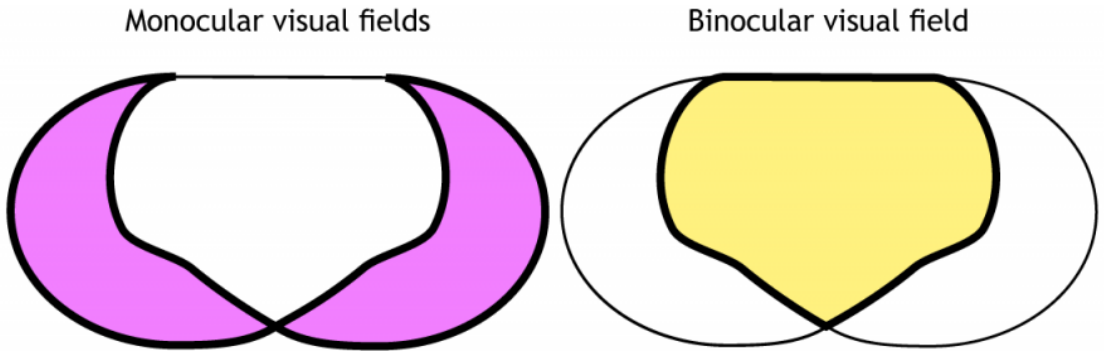
- Three different cones are sensitive to different wavelengths of light
  - You experience “one octave” of light
  - ~380-750 nm
- Your brain uses these three signals to create a continuous impression of color
  - Purple is an artificial color, made to blend into red



Binocular Vision

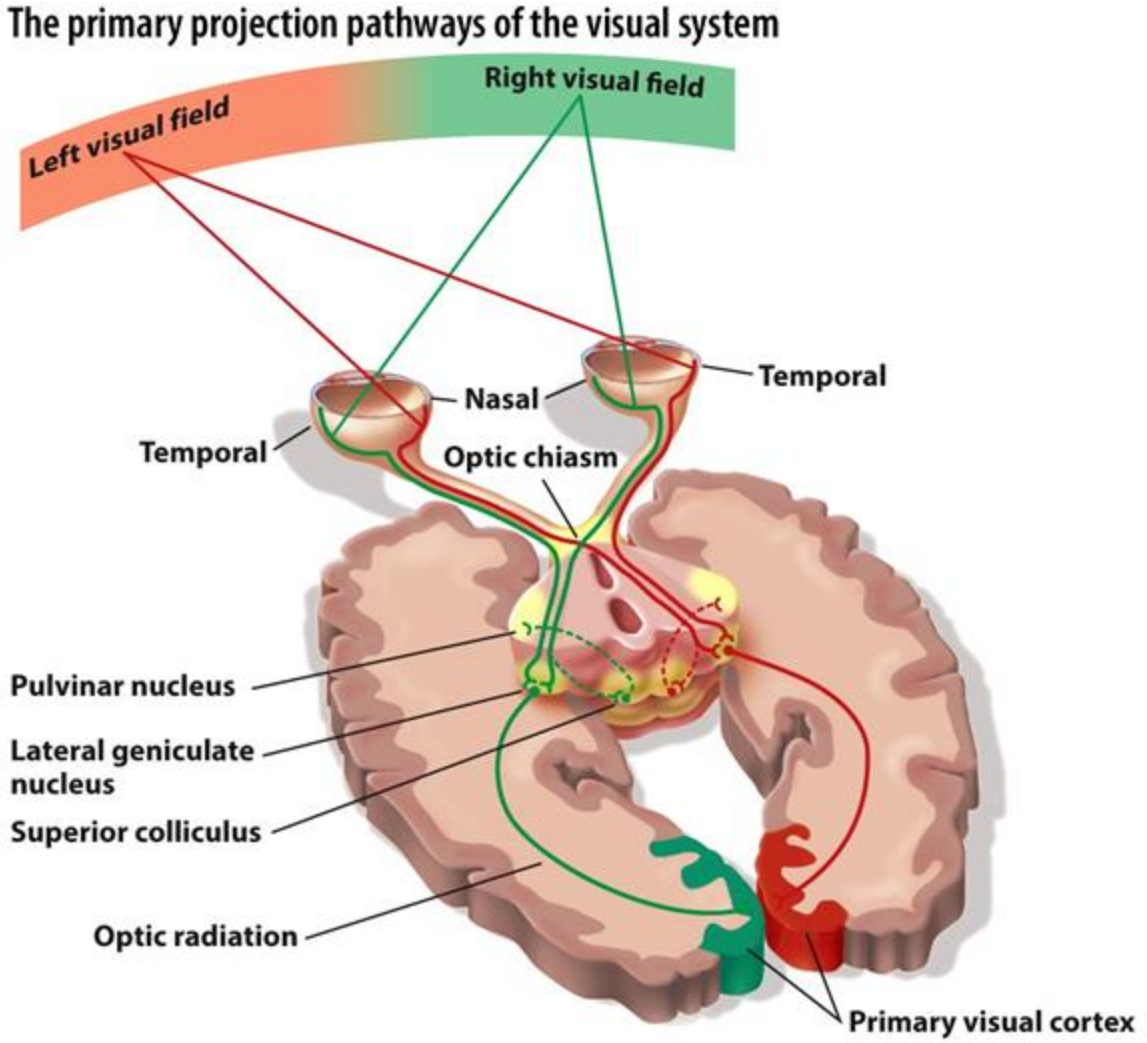
- Two eyes allows you to generate depth perception – a sense of distance
- Predator animals will have more binocular visual fields to judge the distance to their prey
- Prey animals will have more monocular visual fields to monitor more of their environment





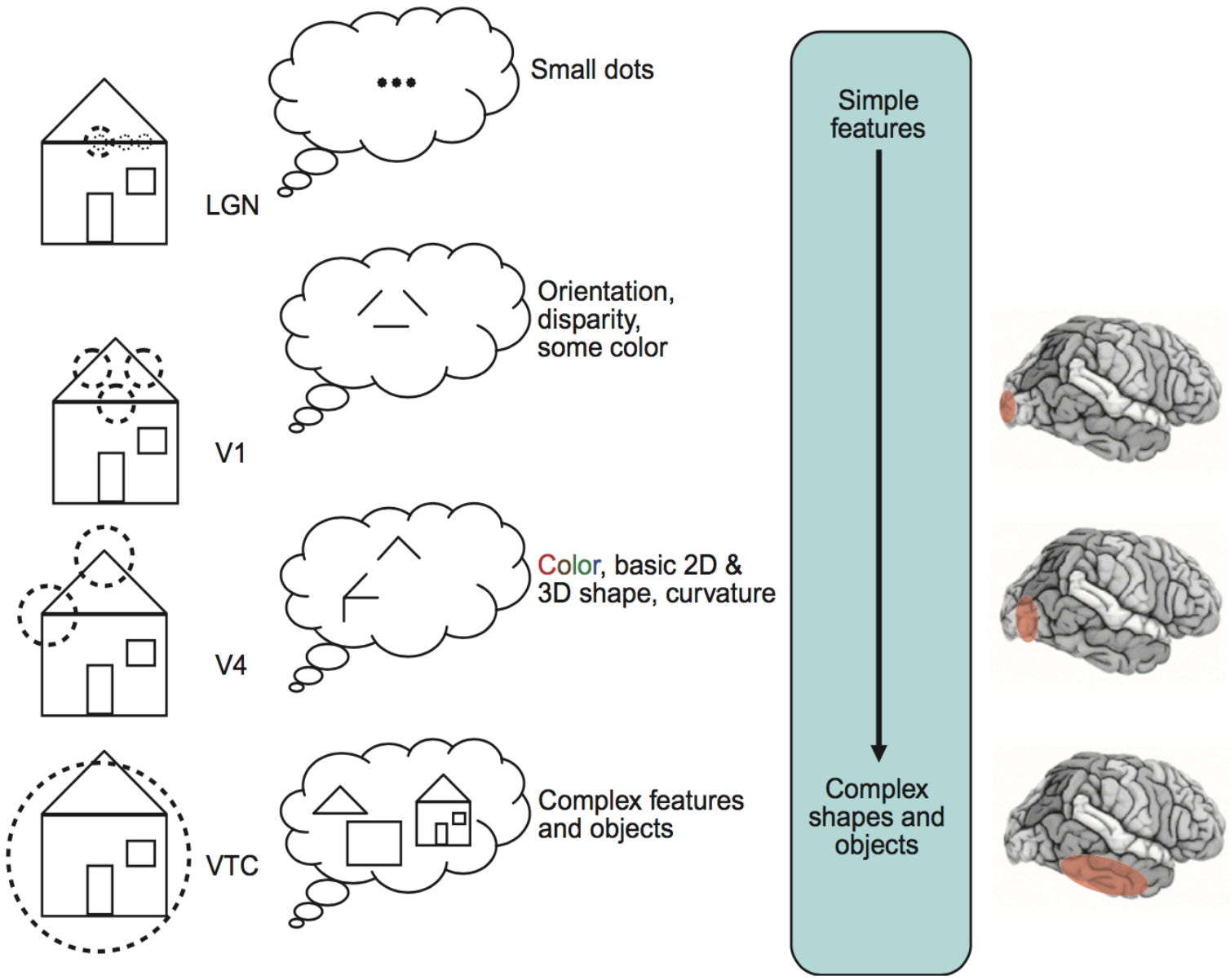
Projection to the Brain

- Signals pass through thalamus for initial processing
- Filtering based on attention, relevance
- Contrast enhancement and edge detection
- Synchronization and integration with other sensory inputs



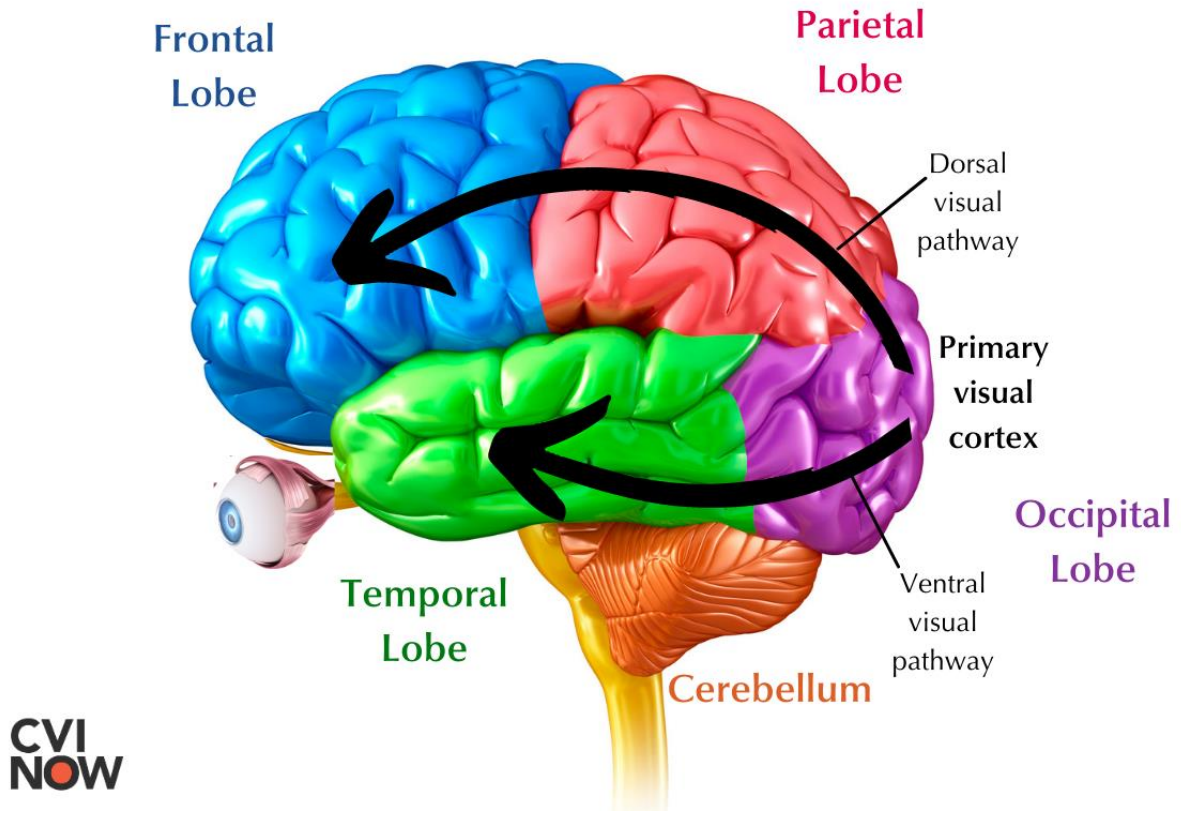
Visual Cortex

- Increasingly refined processing to extract visual features
- Edge and orientation detection
- Texture and contrast
- Color information
- Movement, direction, and speed



Two Streams

- **Dorsal stream**: "where" and "how" pathway
  - Spatially locate and interact with objects
  - Objects as **affordances**: a given object affords the opportunity for a specific action
- **Ventral stream**: "what" pathway
  - Identify an object



Dorsal → premotor cortex (motor planning), supplementary motor area (motor coordination), dorsolateral prefrontal cortex (executive control, action planning)
Ventral → ventrolateral prefrontal cortex (meaning, value, decision-making)