fundamental difference between sensation and perception:

Sensation: physical activation of a sensory system detection / experience of an internal or external stimulus

(light striking receptors in the retina, sound vibrating receptors in cochlea, etc)

Perception - assigning a value or meaning to sensations; interpretation / understanding "conscious"

(requires higher order neural processing)

Sensory Systems

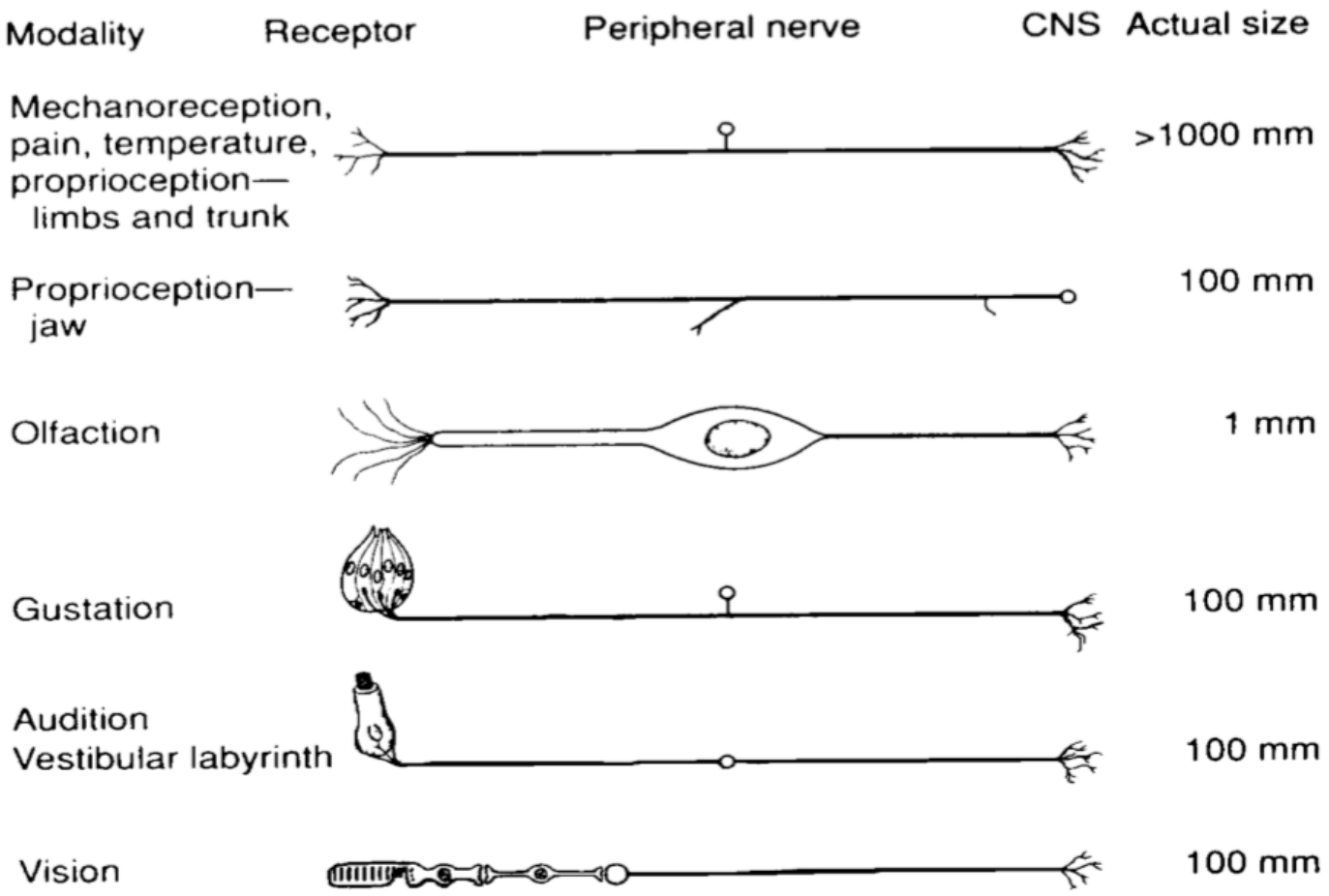
- *sensation*:
  - transduction > encoding > *perception*
    - somatic
    - vision
    - audition
    - taste
    - smell
    - balance (vestibular)

Sensory Systems

- diverse modalities governed by *similar processing principles*
  - *receptors* (neurons with specialized dendrites) *transduce* energy from the outside world into electrical / chemical signals
  - *afferent* pathways bring that info to various *integrator* circuits that parse out different types of information
    - qualitative information (“what” and “where”)
    - quantitative information (“intensity”)
    - information about “change”

Sensory Stimuli

- *receptors are specialized neurons for transducing information from the physical environment into a neural code (chemical and electrical signals)*
- *groups of myelinated* afferent *fibers are "nerves"*

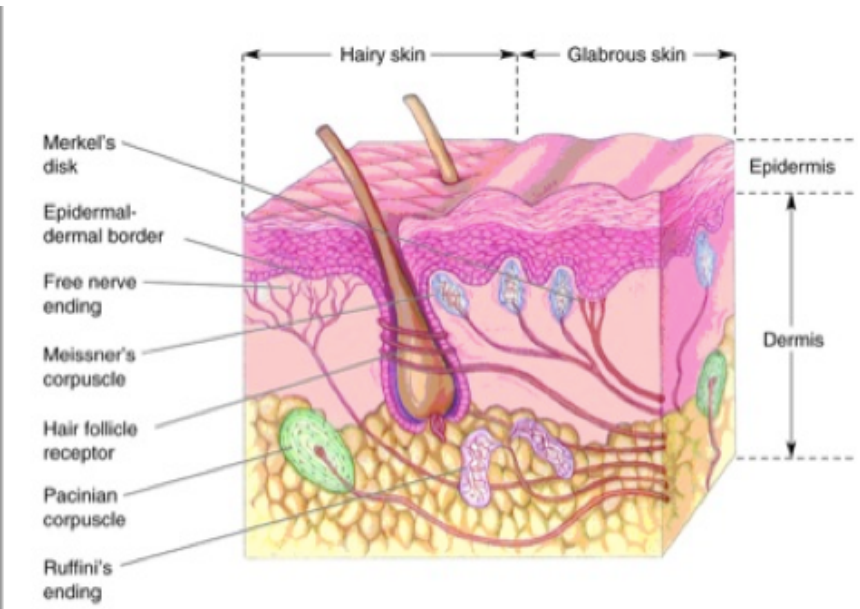


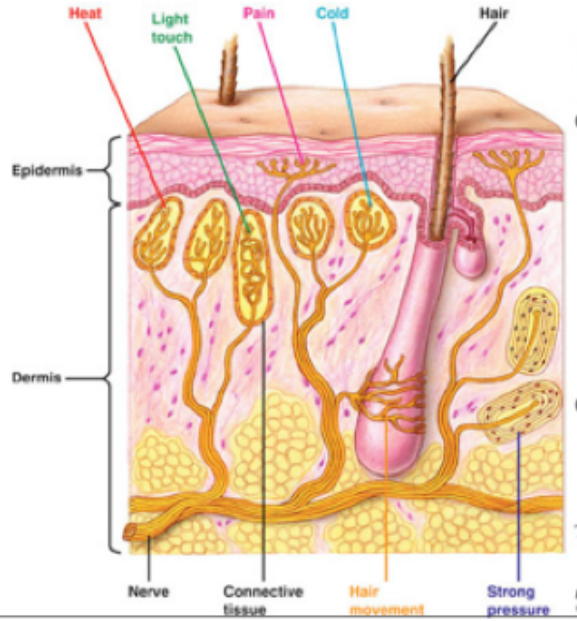
Sensory Stimuli

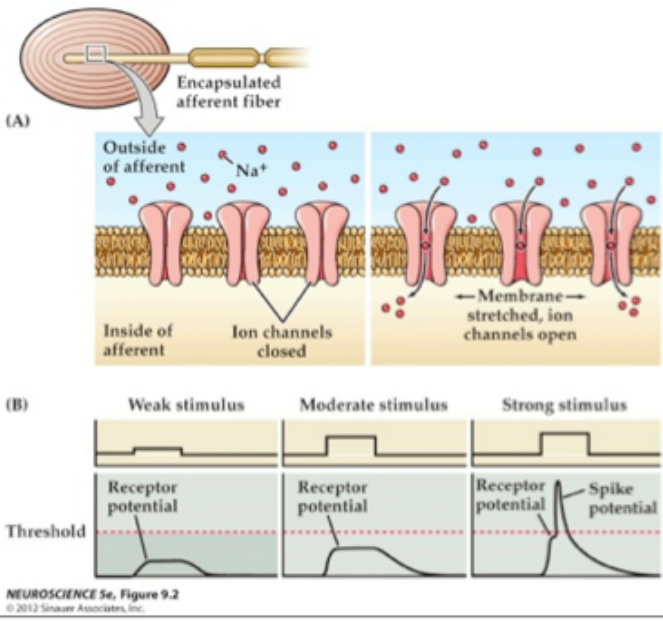
- Types of Sensory Stimuli – all receptors respond best to certain types of stimuli
  - *universal stimulus* – electricity
  - *adequate stimulus* - modality that activates a receptor at the lowest intensity
    - e.g., light for rods & cones
  - *inadequate stimulus* - can activate a receptor, but the threshold is much greater
    - e.g., mechanical pressure for rods & cones
  - *not* a stimulus – will not activate a receptor
    - e.g., light will not activate auditory receptors

Sensory Stimuli

- the *receptor* transduces the stimulus into "neural code"
  - *receptor potential:*
    - *graded* response analogous to an EPSP
      - directly proportional to the intensity of the stimulus
        - directly proportional to the rate of APs produced
          - and subsequent amount of transmitter released







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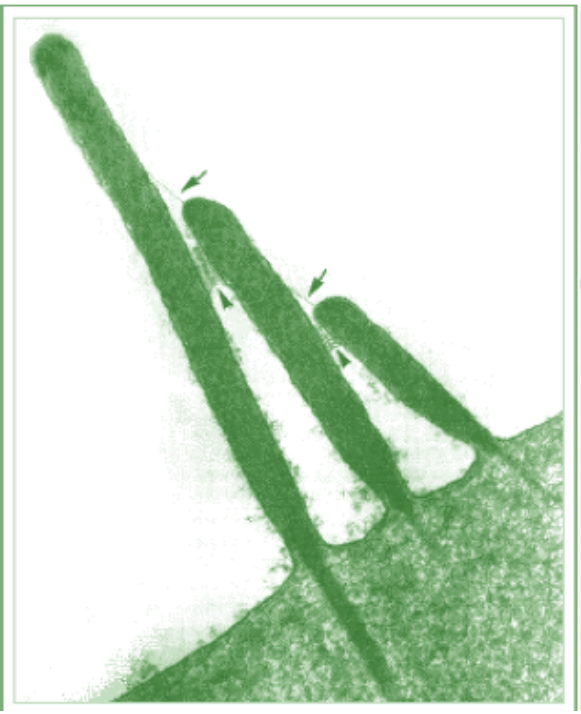

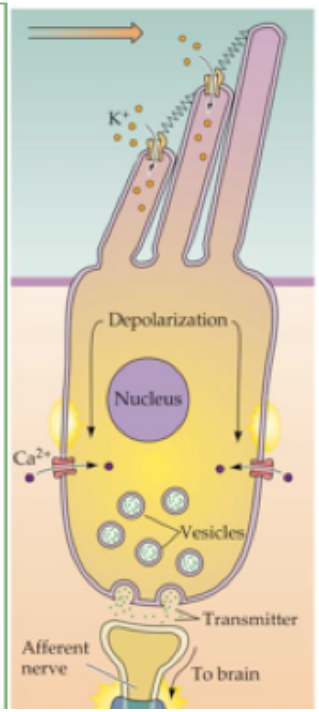

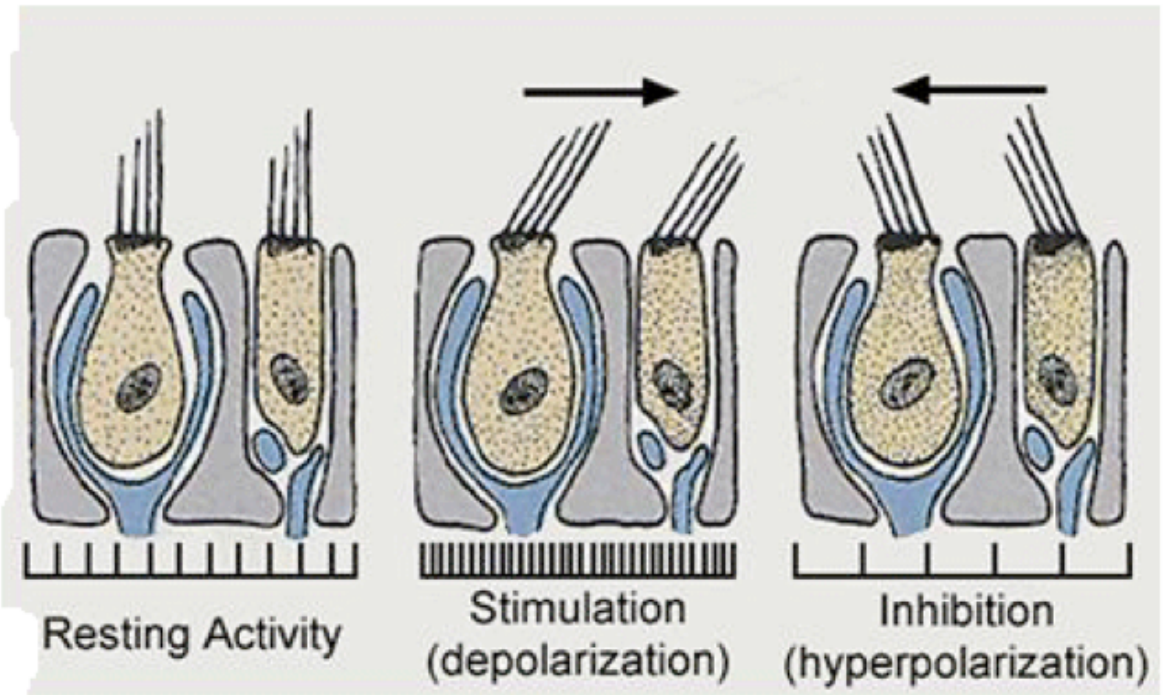

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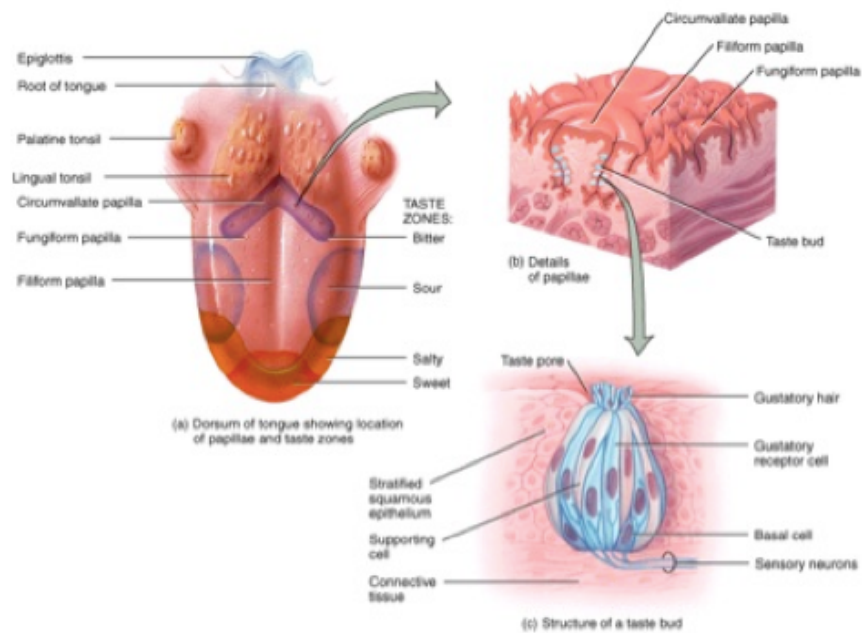

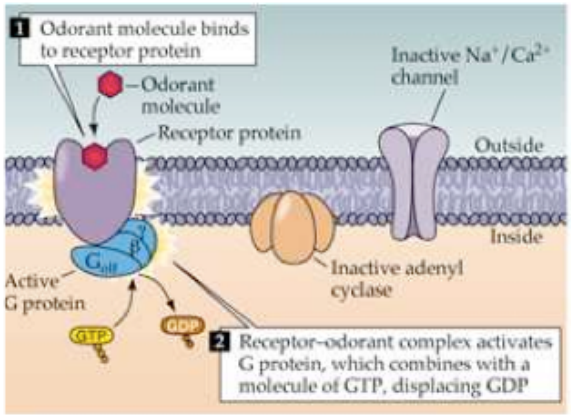

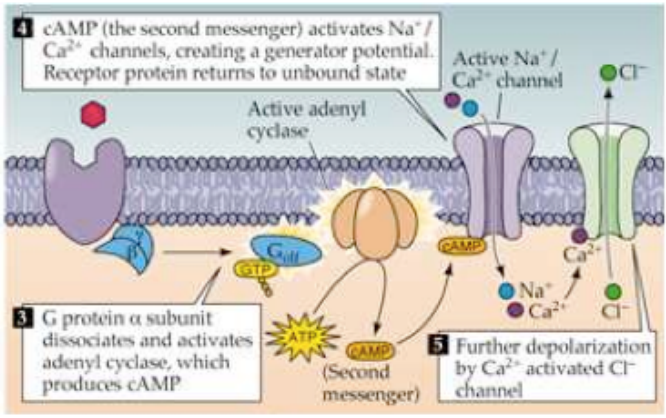

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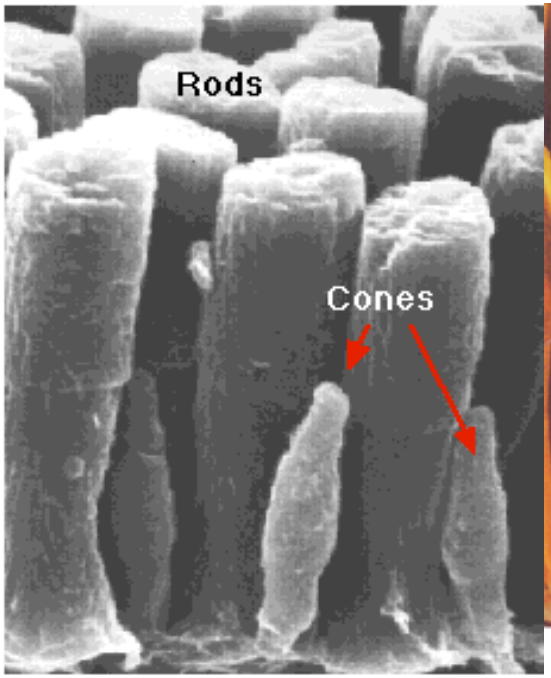
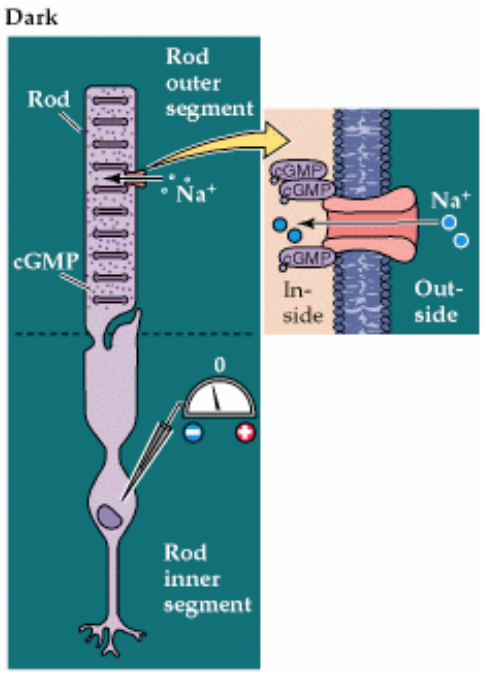
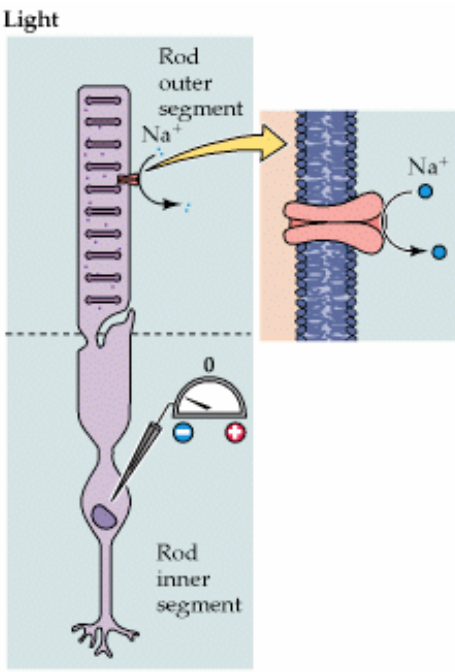


Fig1b. Scanning electron micrograph of the rods and cones of the primate retina. Image adapted from one by Ralph C. Eagle/Photo Researchers, Inc.





Information Processing

- What is the nature of "information" sent to the cortex?
  - Sensory Coding - all by way of "digital" / all-or-none APs

    - 1. *Qualitative* - "what and where is it?"
      - modality / submodality
      - *anatomical path (labeled line)* coding - chain of neurons that results in a topographically mapped sensation

    - 2. *Quantitative* - "how much / how intense?"
      - *frequency /rate* coding - how quickly APs are generated
      - *population* coding - # of receptors firing

    - 3. Is there a "change?"
      - Adaptation coding by response to *constant* stimulation
        - *slowly* vs *rapidly* adapting

Information Processing

Qualitative / location- “what and where is it?”

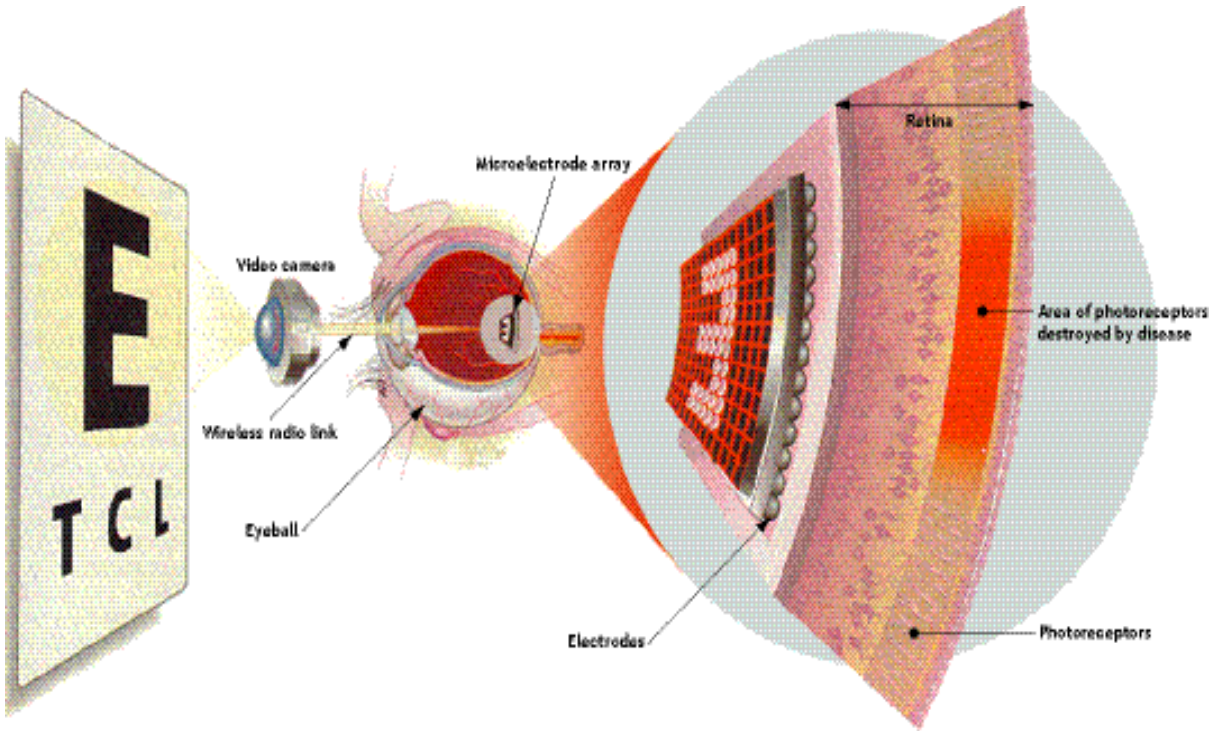
- Anatomical pathways / labeled line coding
  - receptive sheet for a whole sensory system
  - receptive field for individual sensory neurons
  - thalamic sensory relay station
  - topographic maps - adjacent neurons project to adjacent neurons

Sensory Systems - Modality

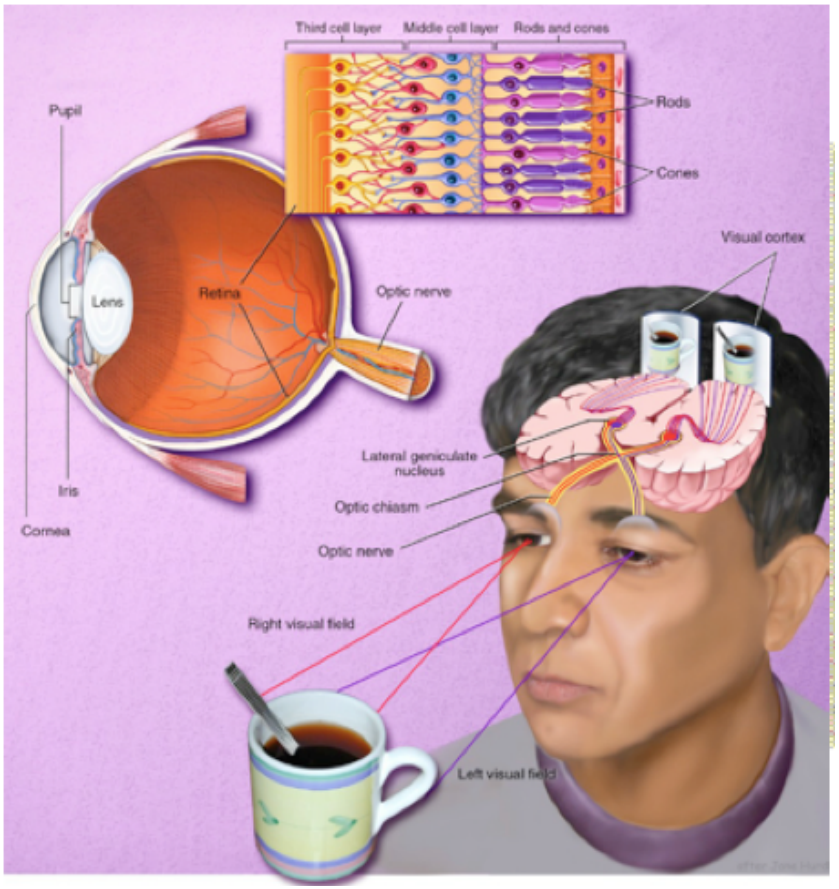
- Submodality
  - receptors (1st order / sensory neurons) - characteristics
  - afferents pathways
    - 2nd order
      - cell bodies
      - exiting fiber pathways
    - 3rd order
      - cell bodies
      - exiting fiber pathways
  - integrators:
    - thalamus
    - primary, secondary, and association cortices
      - Because of baseline firing rates, responses of individual neurons are probabilistic (and relatively unimportant)

Information Processing

- *receptors* ("1st order" cells) innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *retina* is the visual receptive sheet
      - "movie screen" with images projected from lens
        - lined with *photoreceptors* (rods / cones)
        - these *transduce* image into electrical > chemical signals to subsequent neurons (2nd order +)

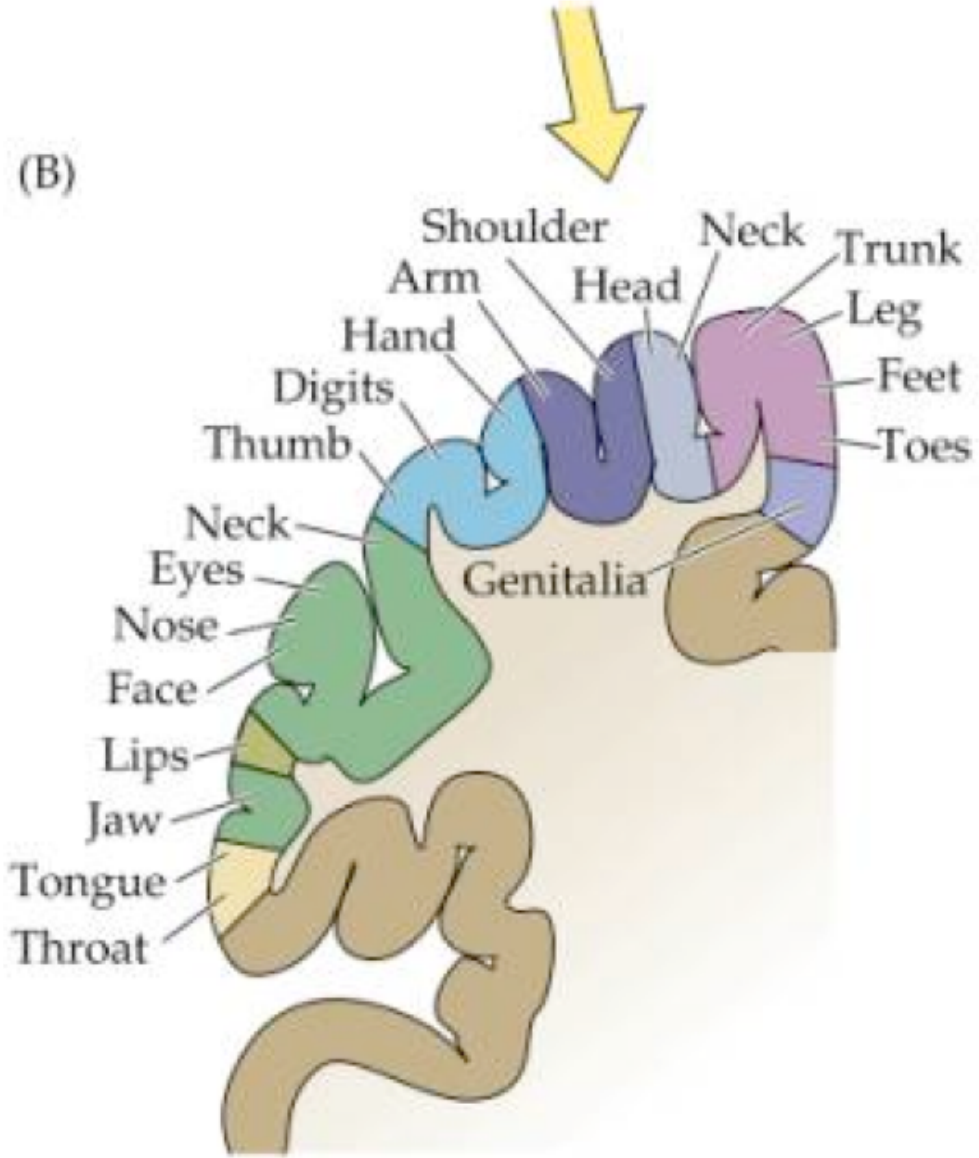


LLNL is working on an implantable microelectrode array for DOE's Artificial Retina Project. This flexible array, which will conform to the eye's retina, serves as an interface between an electronic imaging system and the eye. [Illustration courtesy of the University of Southern California, UC Santa Cruz, and North Carolina State University.]



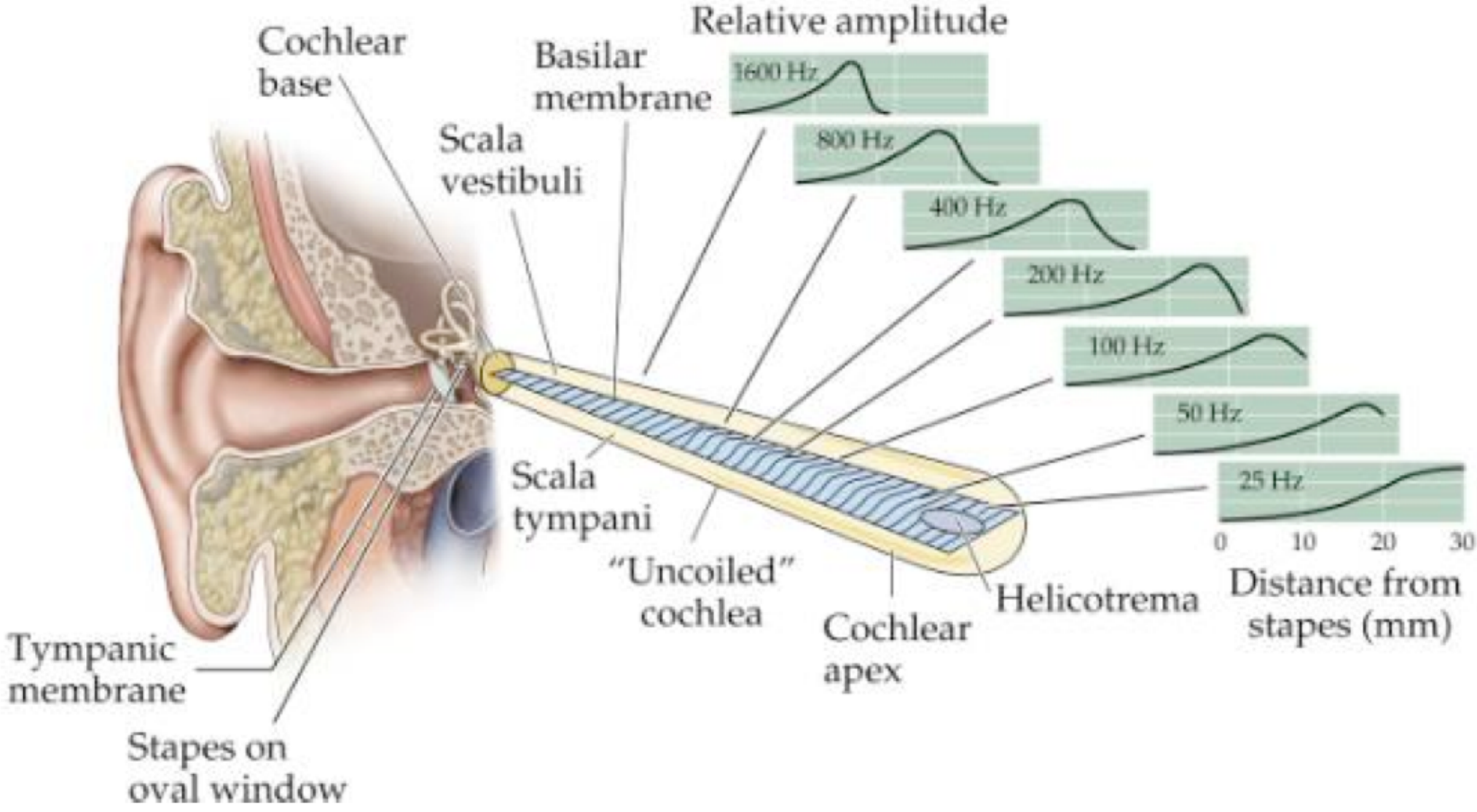
Information Processing

- *receptors* innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *total surface area* is the somatic receptive sheet



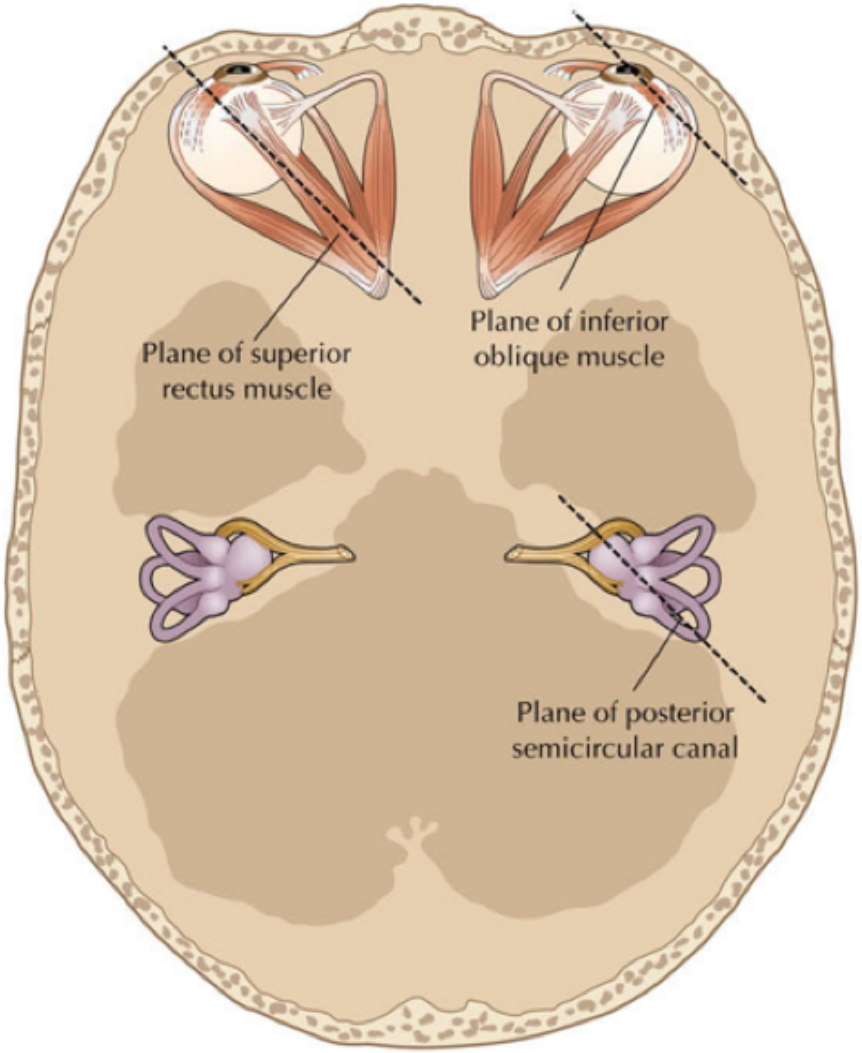
Information Processing

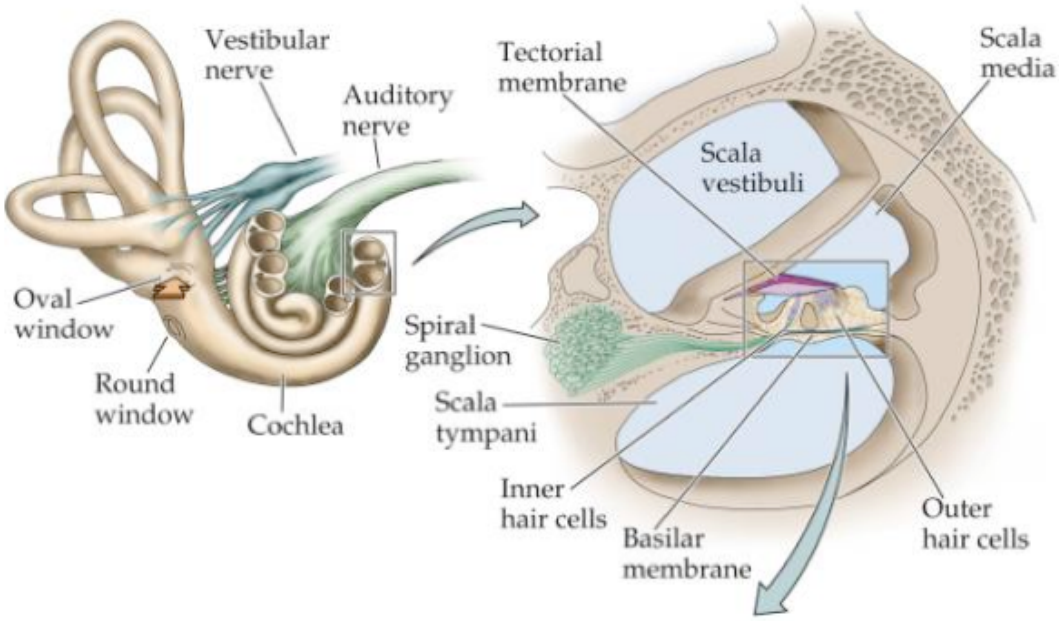
- *receptors* innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *cochlea* is the auditory receptive sheet

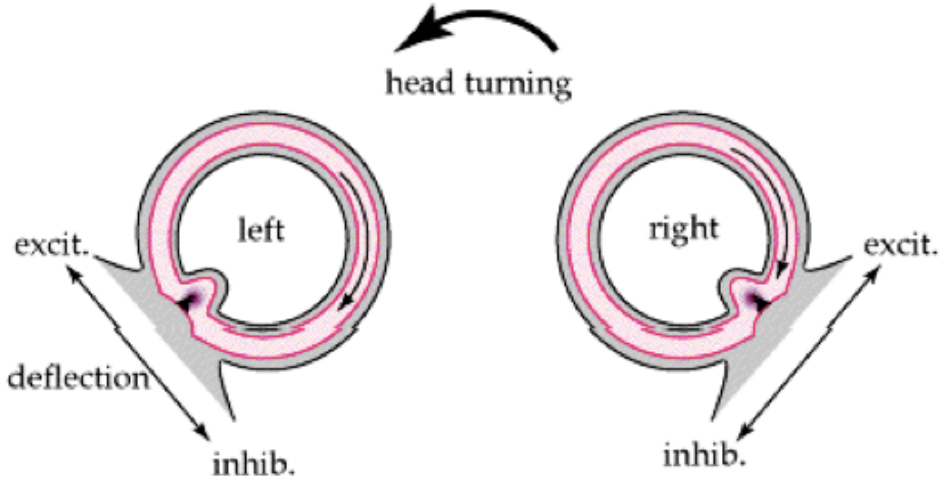


Information Processing

- *receptors* innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *semicircular canals* are the vestibular receptive sheet

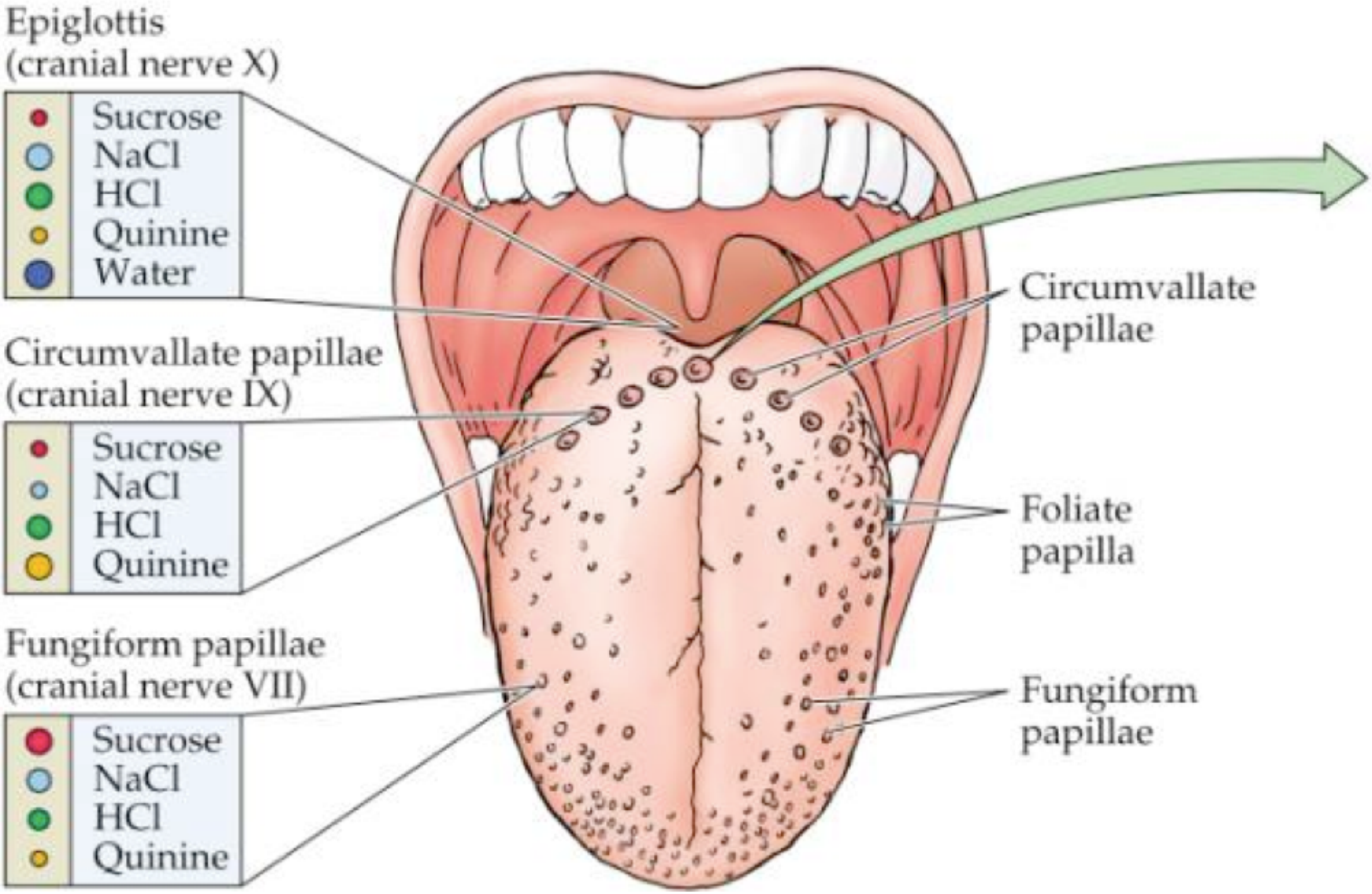






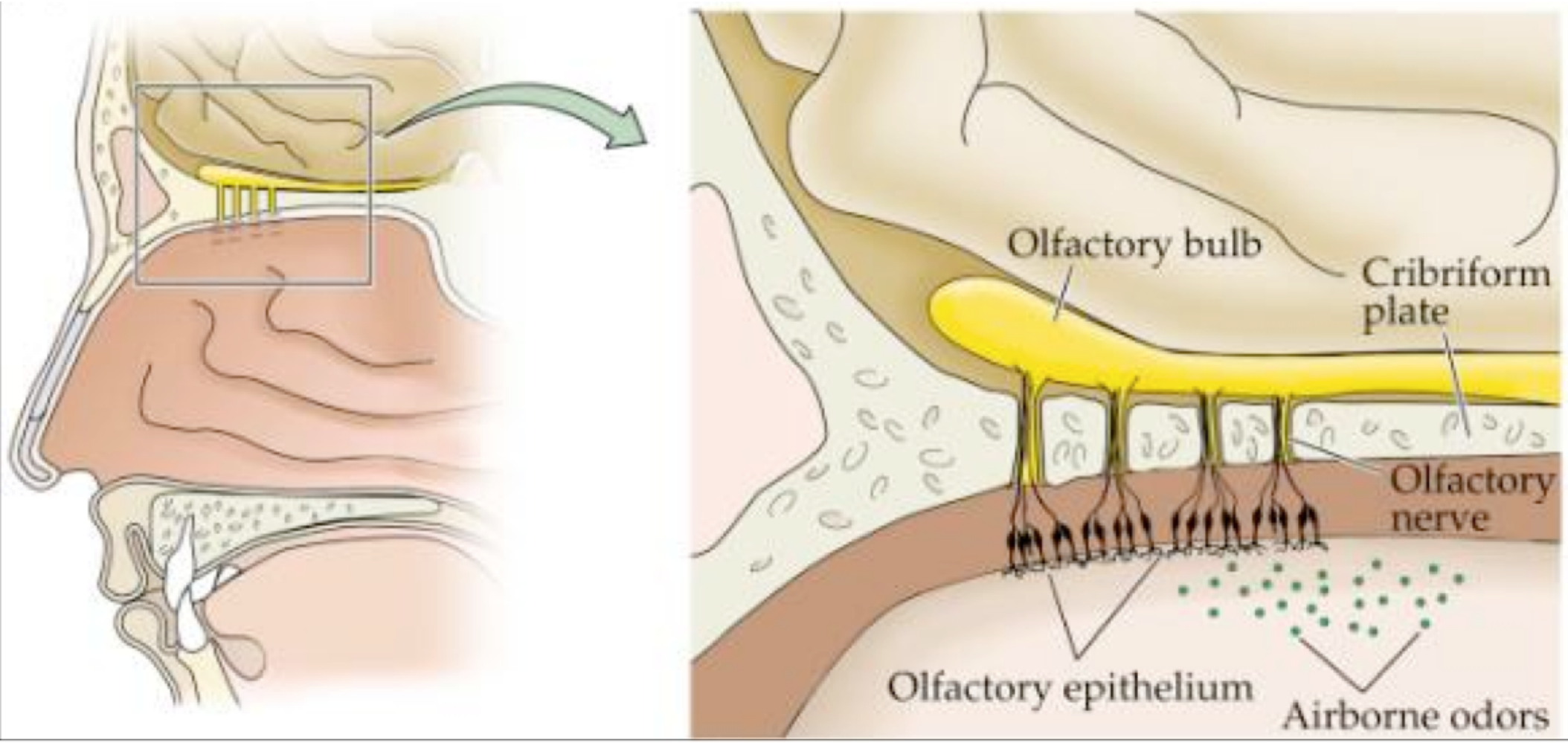
Information Processing

- *receptors* innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *tongue (etc)* is the gustatory receptive sheet



Information Processing

- *receptors* innervate very discreet regions of the body
  - specific part of the body which a sensory system innervates = *receptive sheet*
    - the *olfactory epithelium* is the olfactory receptive sheet



Qualitative / location- “what and where is it?”

so…… **Sensory systems** (visual, auditory, vestibular, olfactory, gustatory, somatosensory) have **receptive sheets** - this is the specific part of the body that is *innervated* by a sensory system’s **receptors**:

- the retina for the visual system
- the cochlea for the auditory system
- semicircular canals for the vestibular system
- nasal epithelium for the olfactory system
- tongue etc for the gustatory system
- body surface for the somatosensory system

Individual neurons (1st order sensory and subsequent afferent pathway neurons) have **receptive fields** - that portion of the environment or "sensory space" in which stimulation elicits a response (changes its firing rate from baseline)…

this will depend on the sensory neuron's specific physical location within the receptive sheet (or the anatomic "labeled-line" for each of the subsequent neurons in the afferent pathway)

Information Processing

• each receptor neuron has a precise receptive field, depending on its physical location within the receptive sheet (or the anatomic "labeled-line" for each of the subsequent neurons in the afferent pathway)

  • density of receptors in receptive sheet correlates with sensitivity

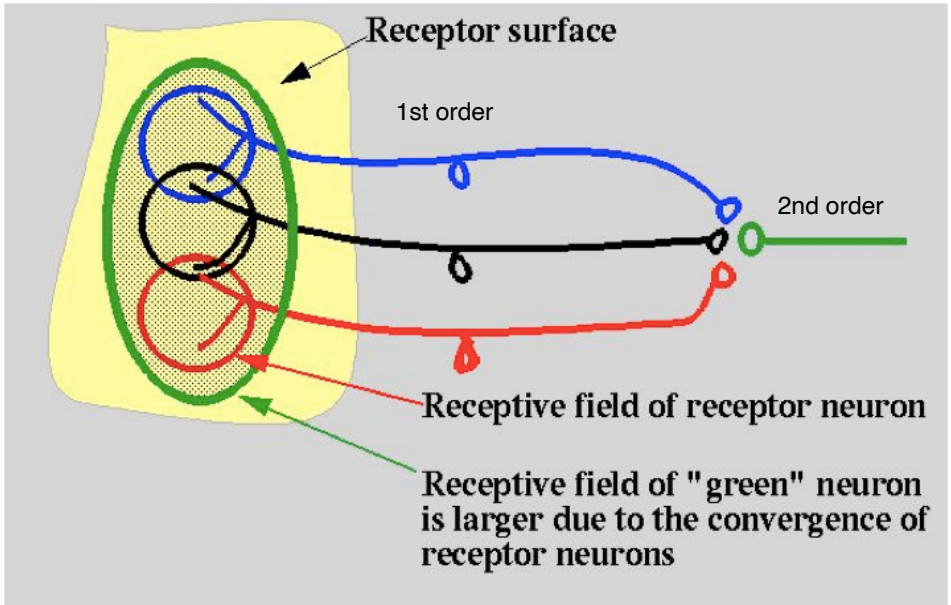
    • e.g., fovea, fingertips = more sensitive

    • more “pixels” = higher resolution

• each *subsequent* neuron (2nd order, 3rd order, etc) also has a (larger) receptive field

  • convergence / divergence at each subsequent synapse creates larger / more complex receptive fields

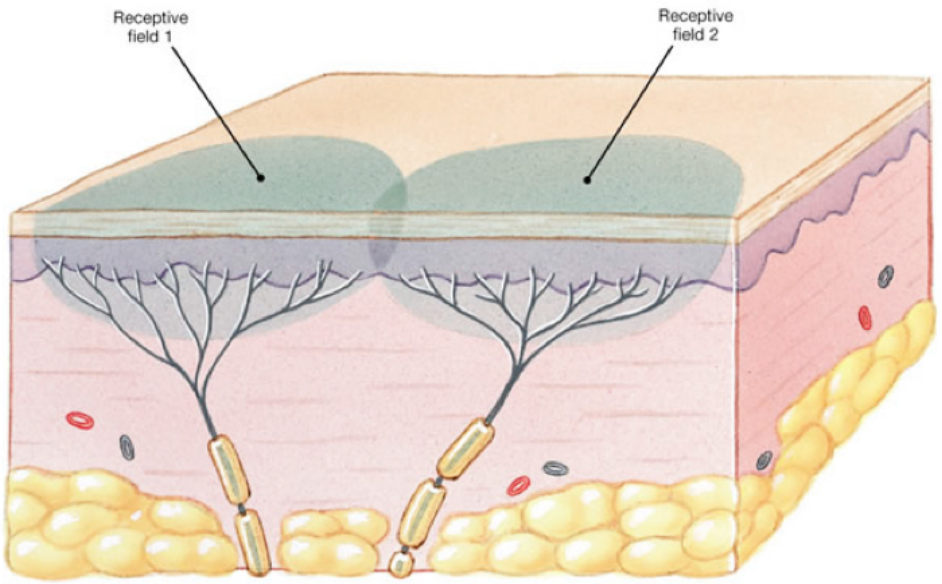
    • increased coding and abstraction of “information”

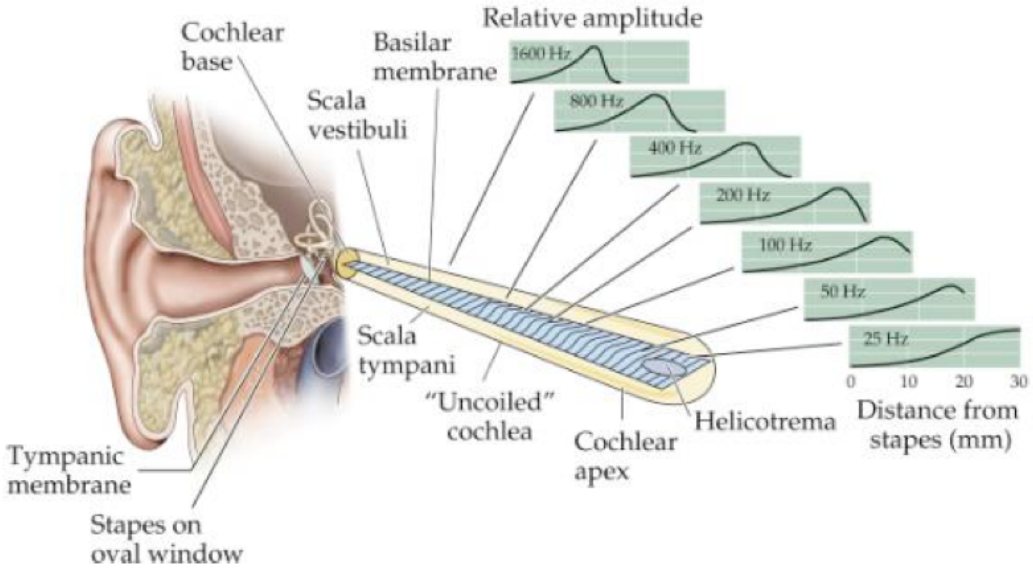


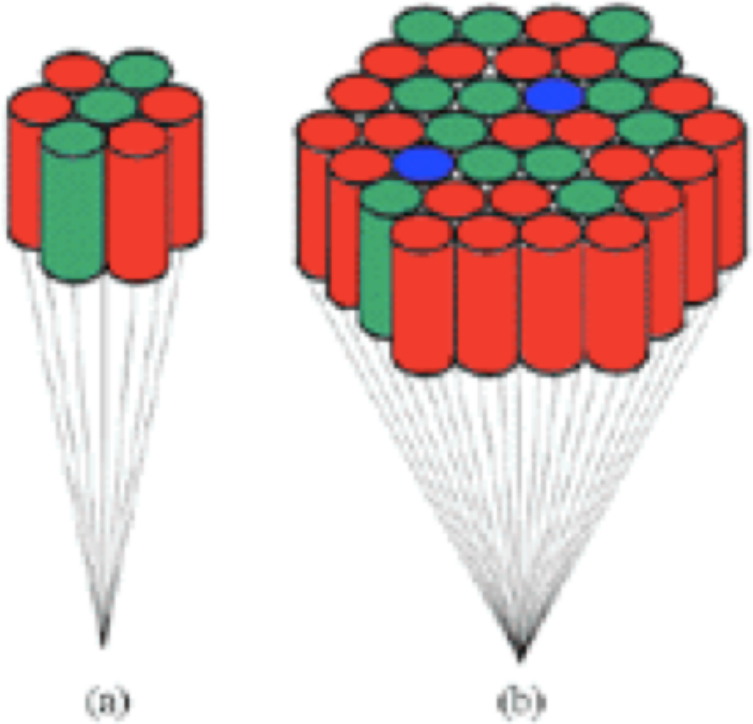
1st order - small / “discrete”

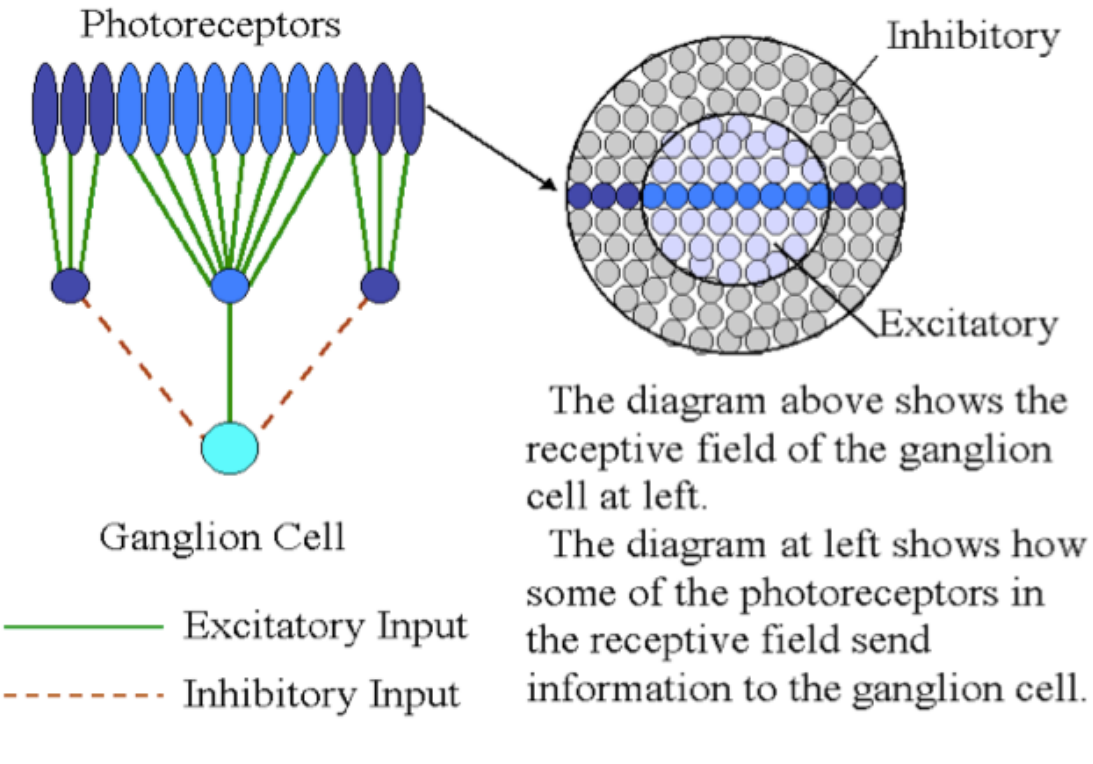
2nd order - larger / overlapping

Information Processing







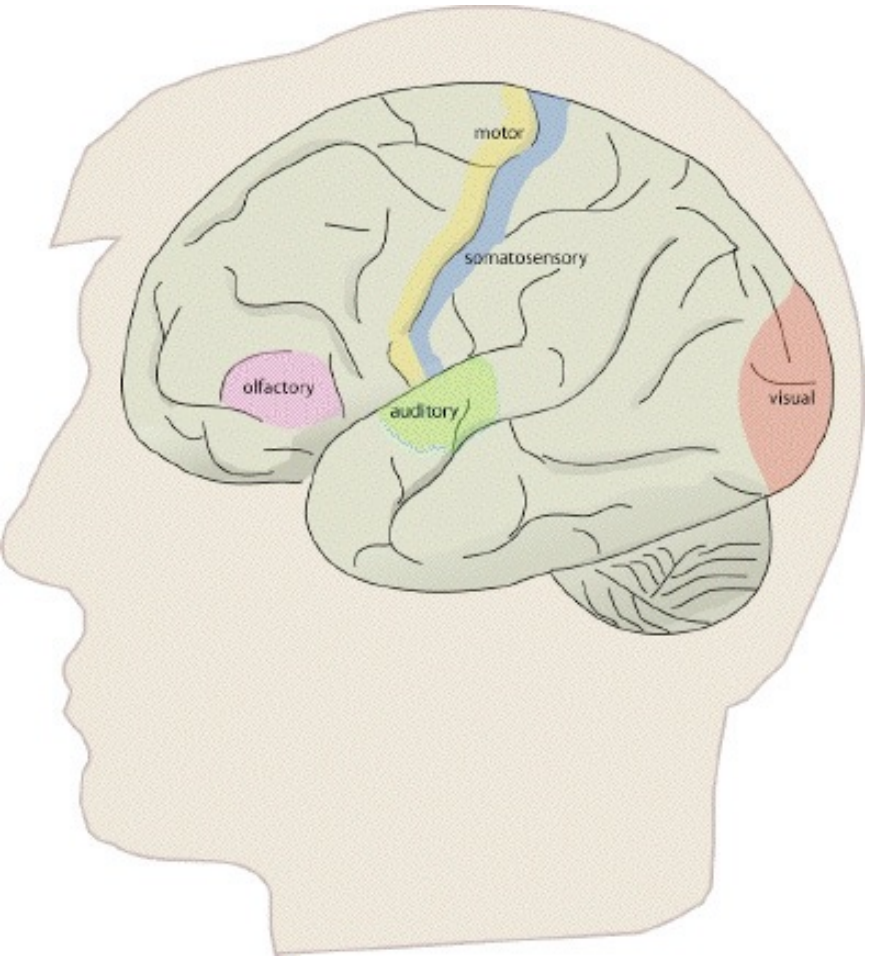


The diagram above shows the receptive field of the ganglion cell at left.

The diagram at left shows how some of the photoreceptors in the receptive field send information to the ganglion cell.

Information Processing

• receptors generally send info about the external world to the opposite hemisphere *thalamus*, which is a sensory relay station to several areas of *primary sensory cortex*



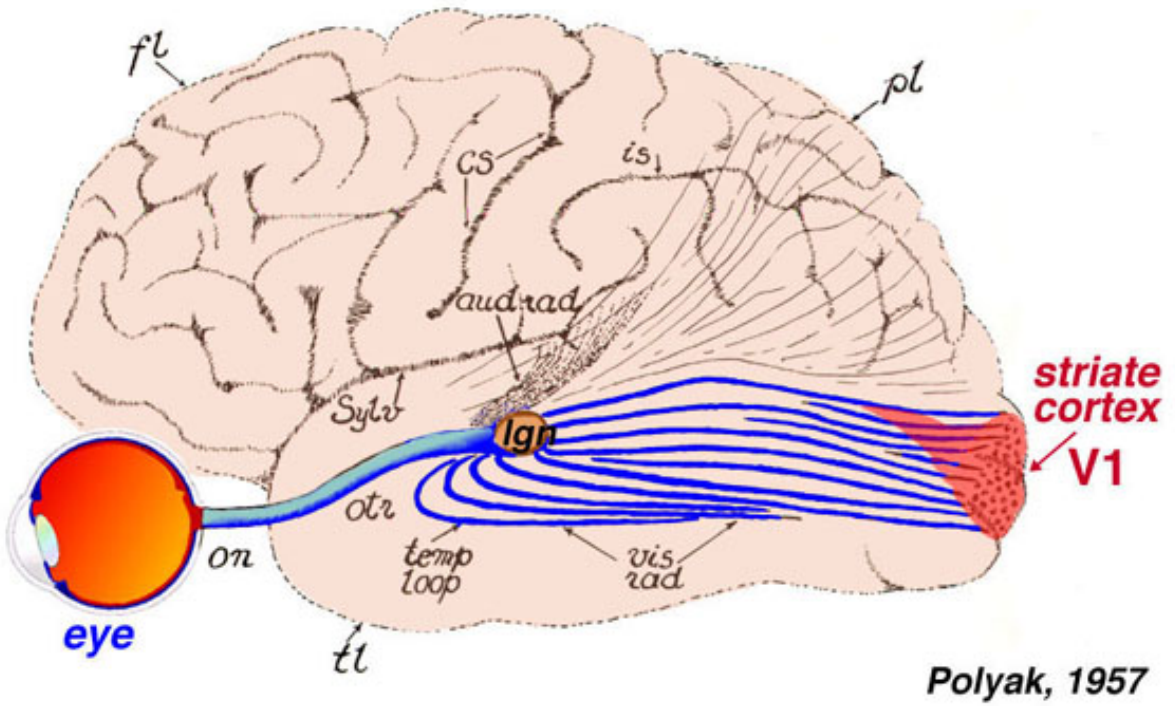
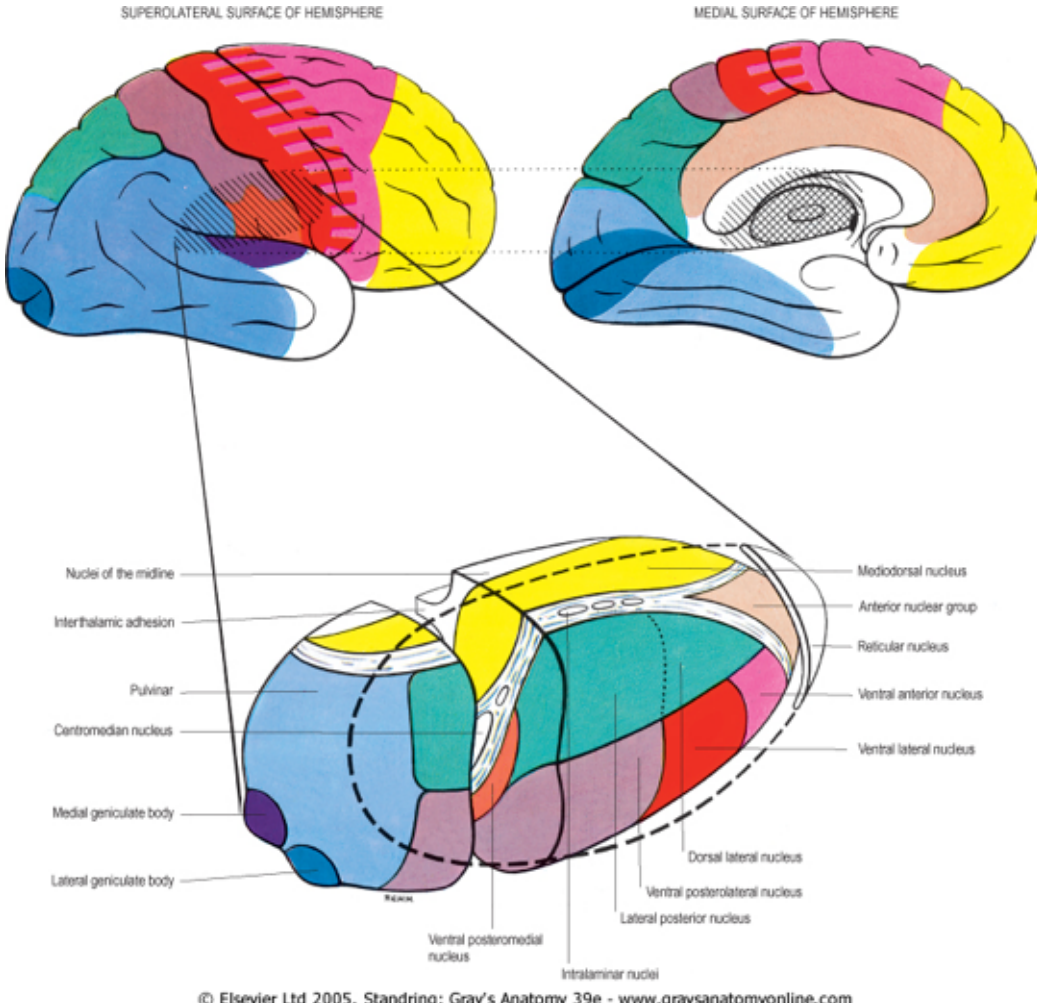
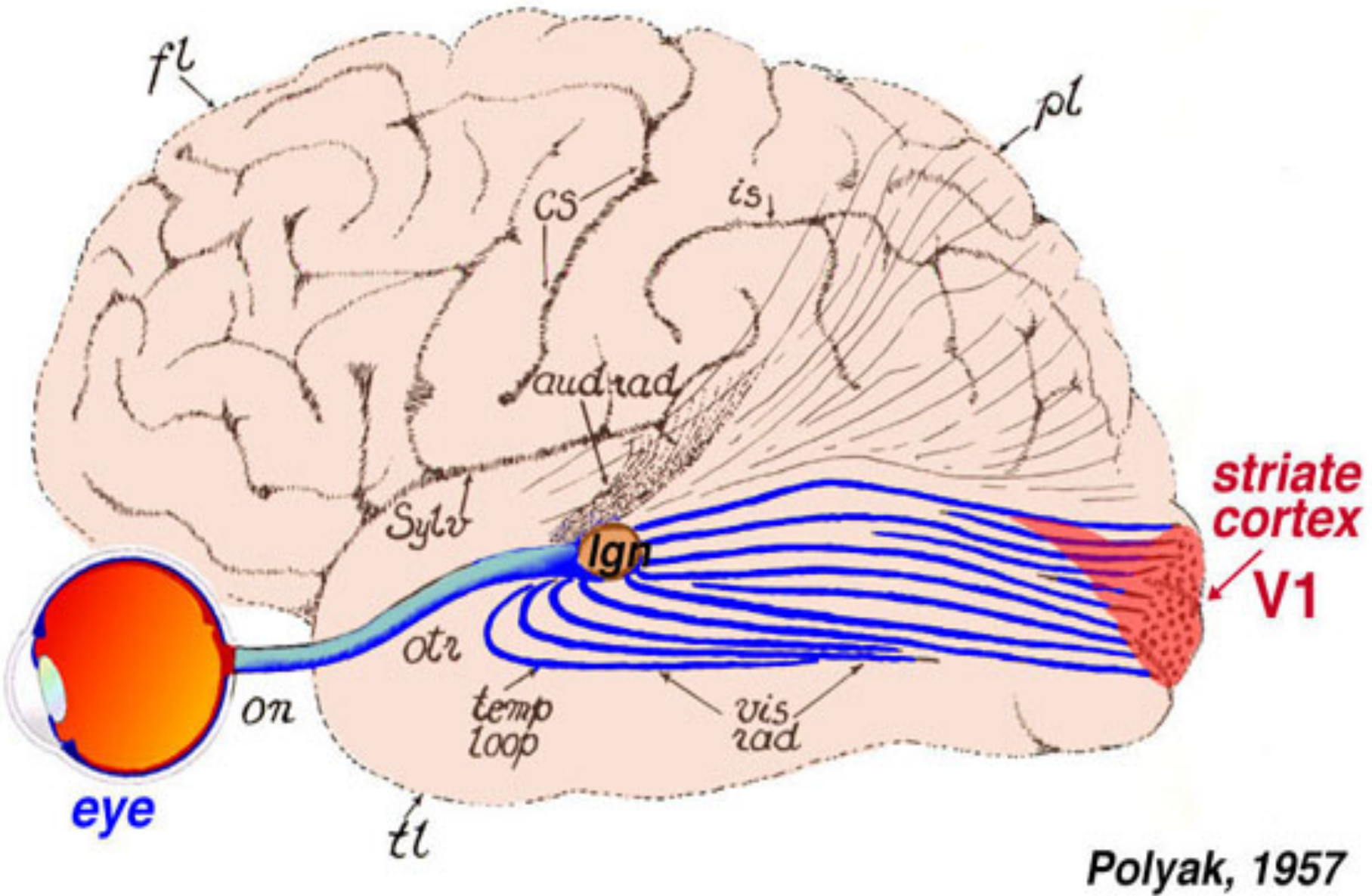


Figure 8. Visual input to the brain goes from eye to LGN and then to primary visual cortex, or area V1, which is located in the posterior of the occipital lobe. Adapted from Polyak (1957).

• Afferent pathways generally send info about the external world to the opposite hemisphere *thalamus*, which is a sensory relay station to several areas of *primary sensory cortex*





“QUALITATIVE INFO” (WHAT / WHERE)

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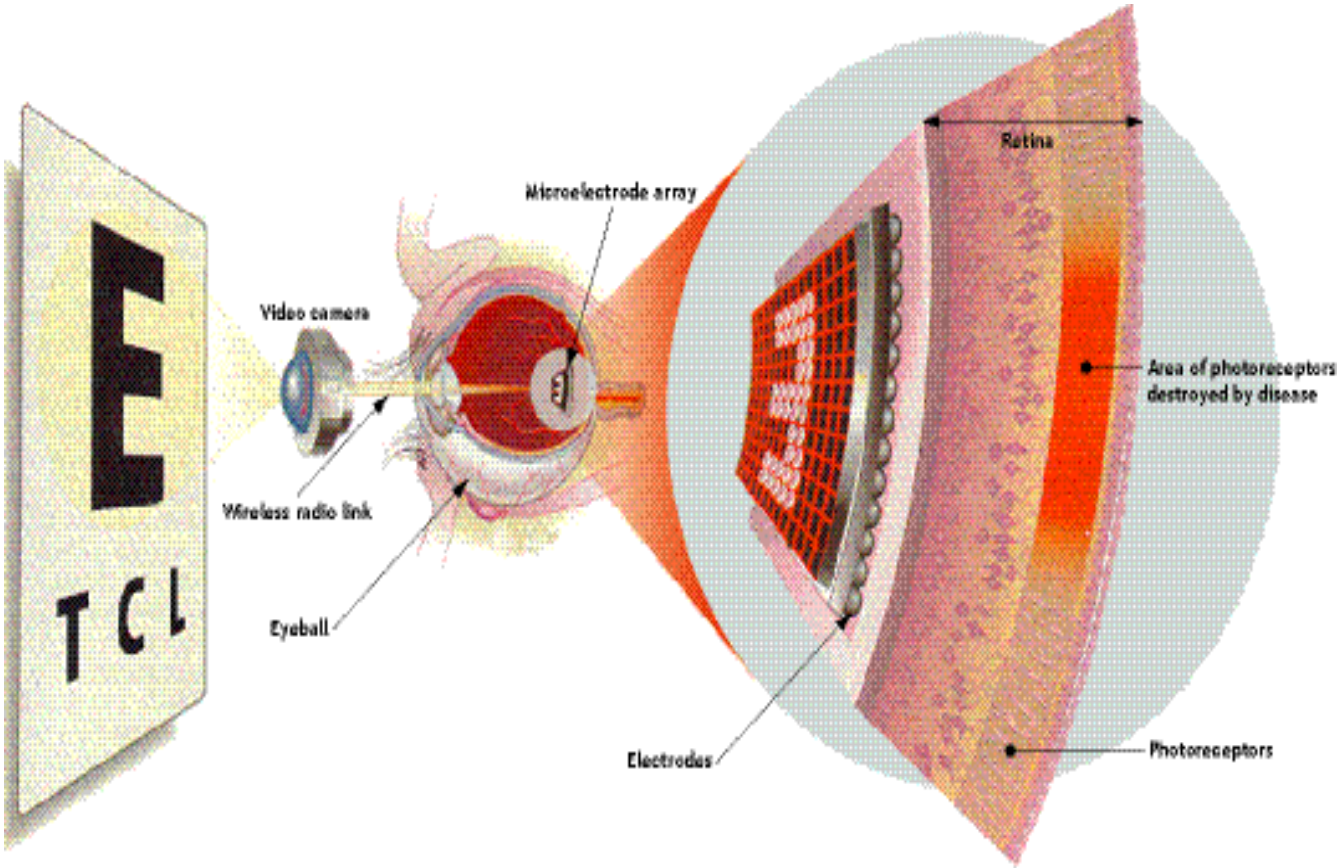

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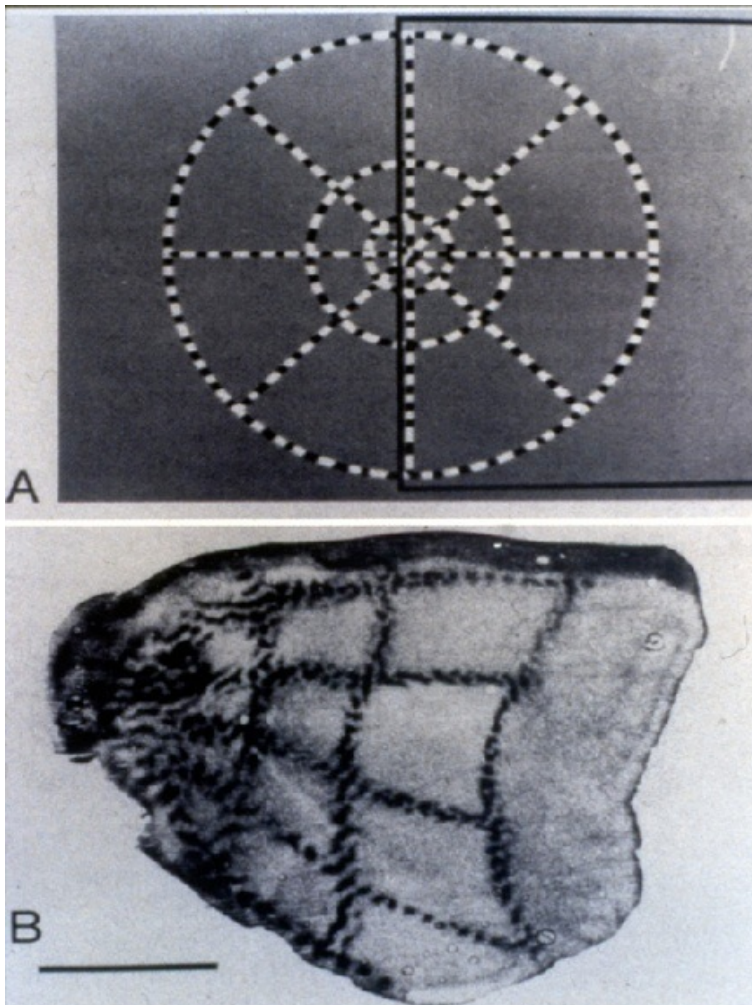
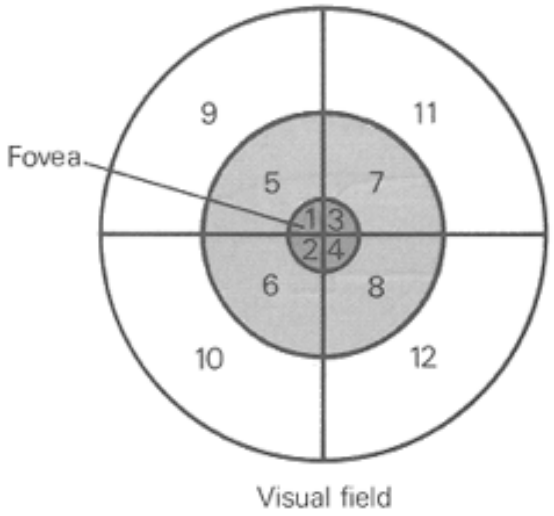
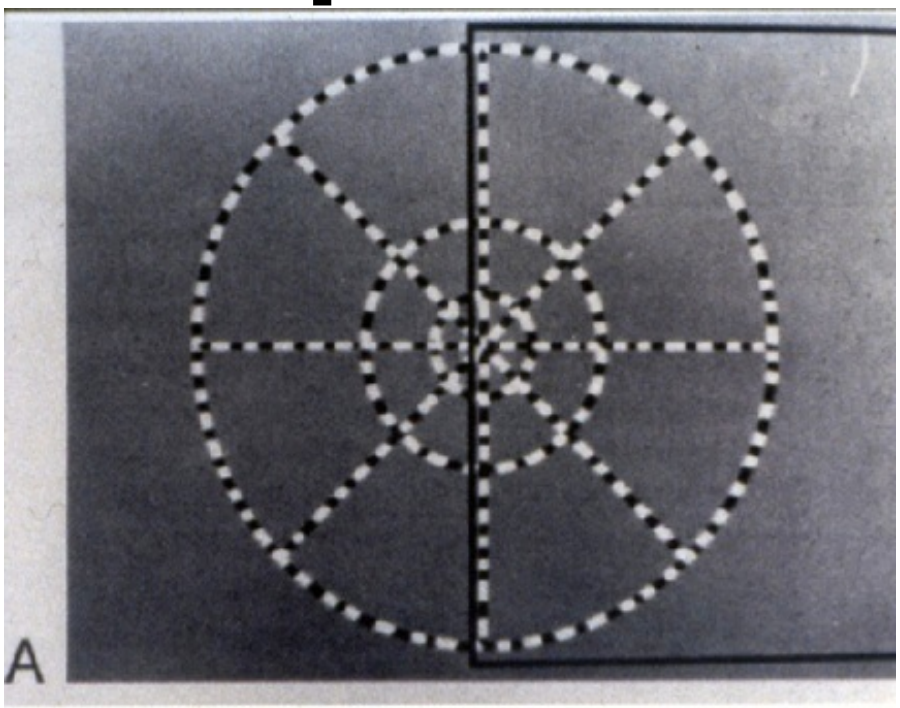
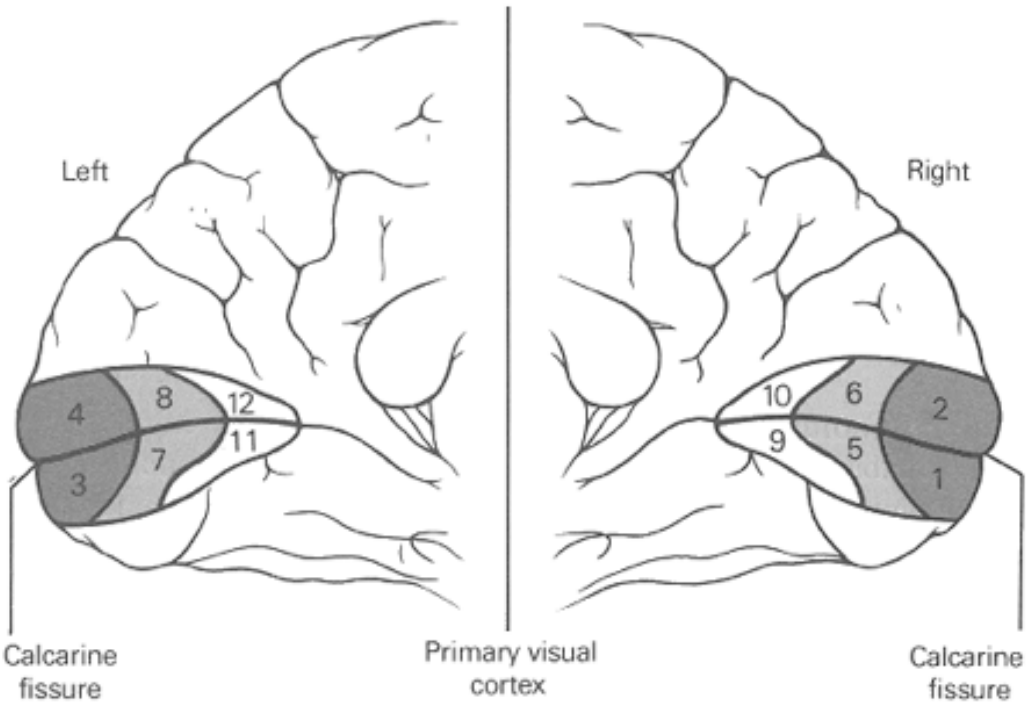
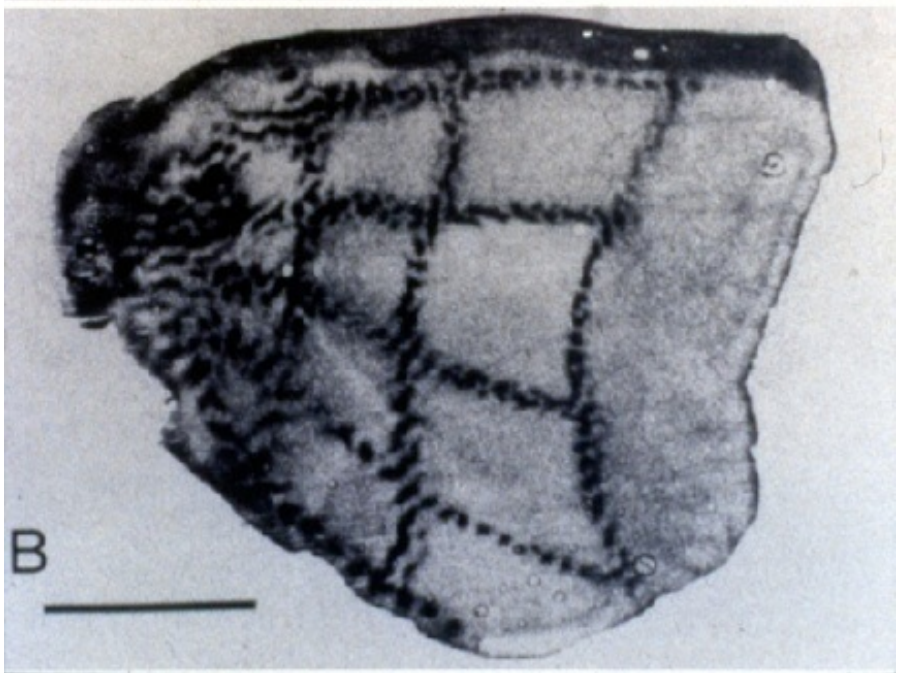


Topographic Maps









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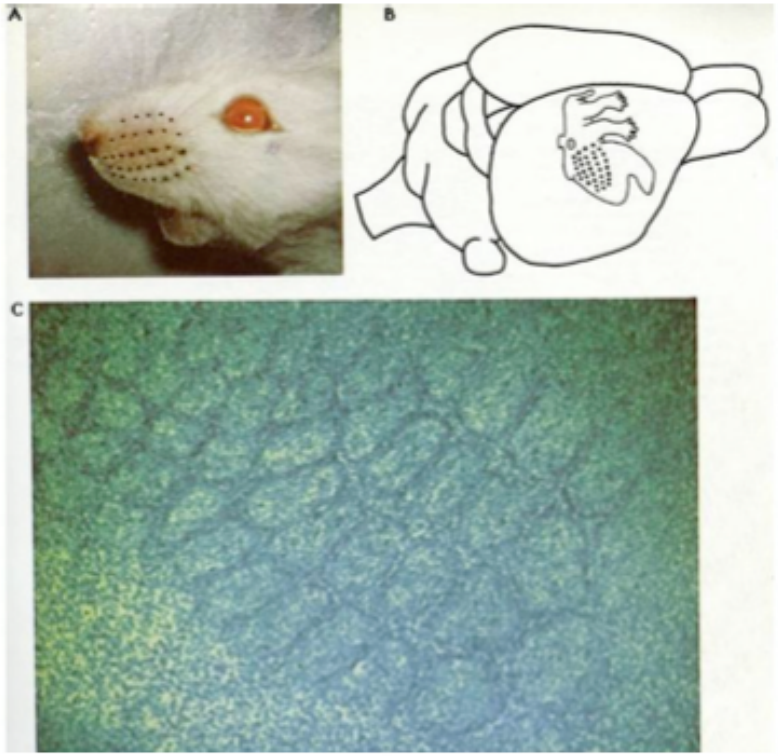

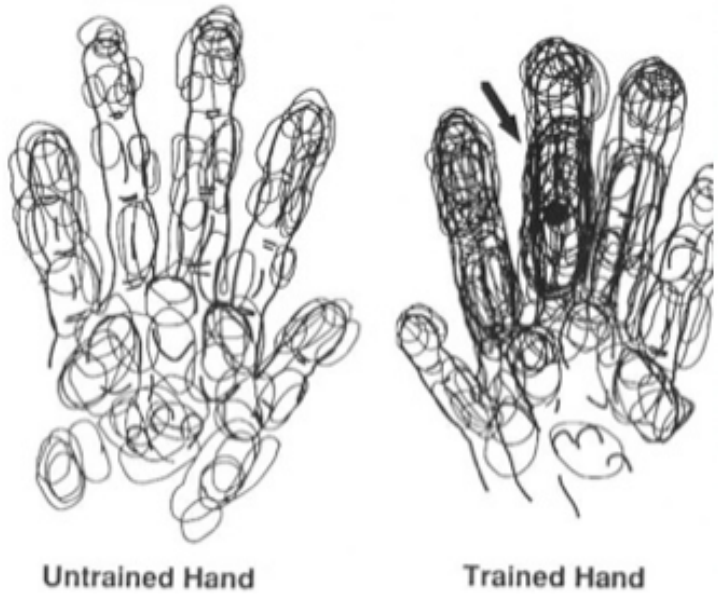

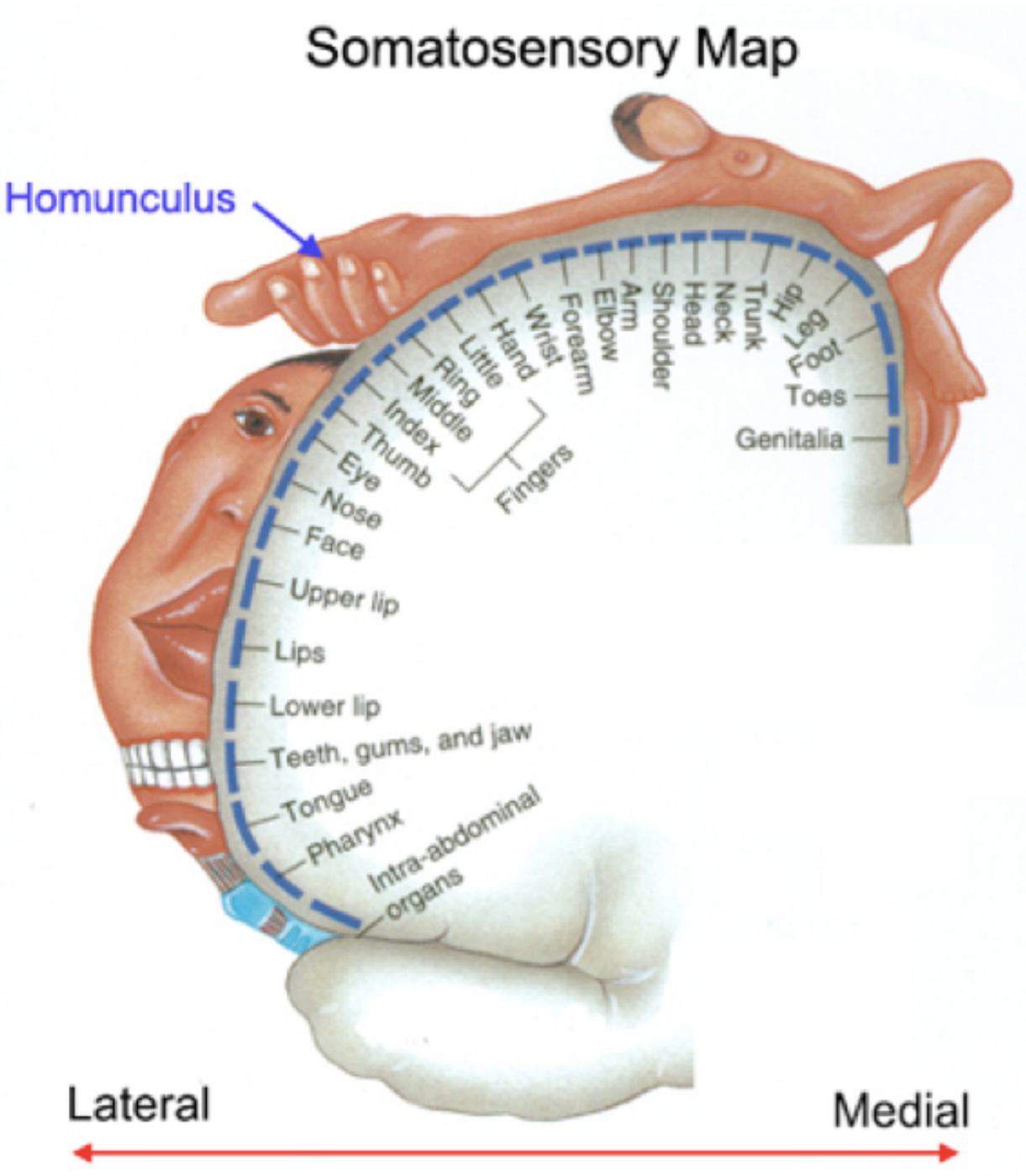

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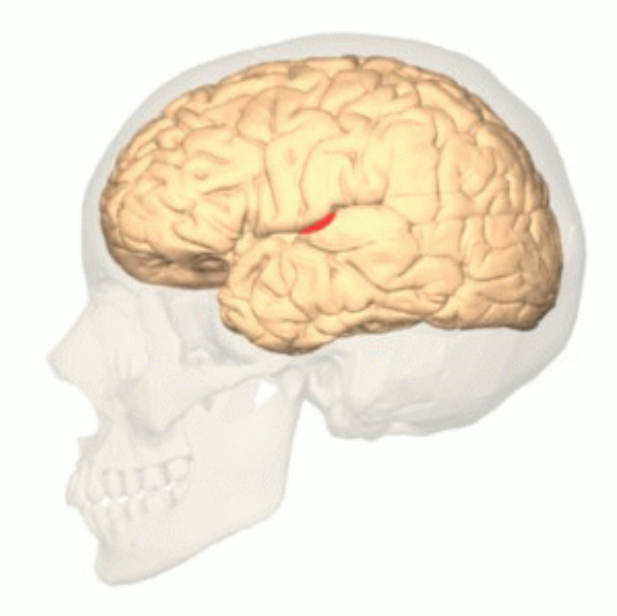

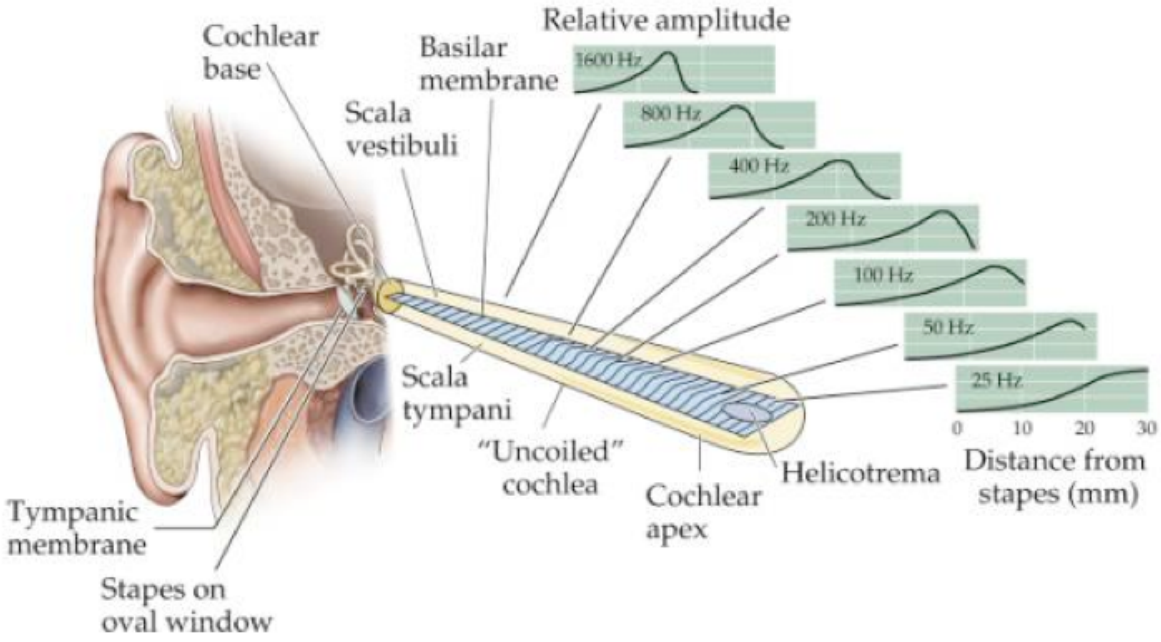

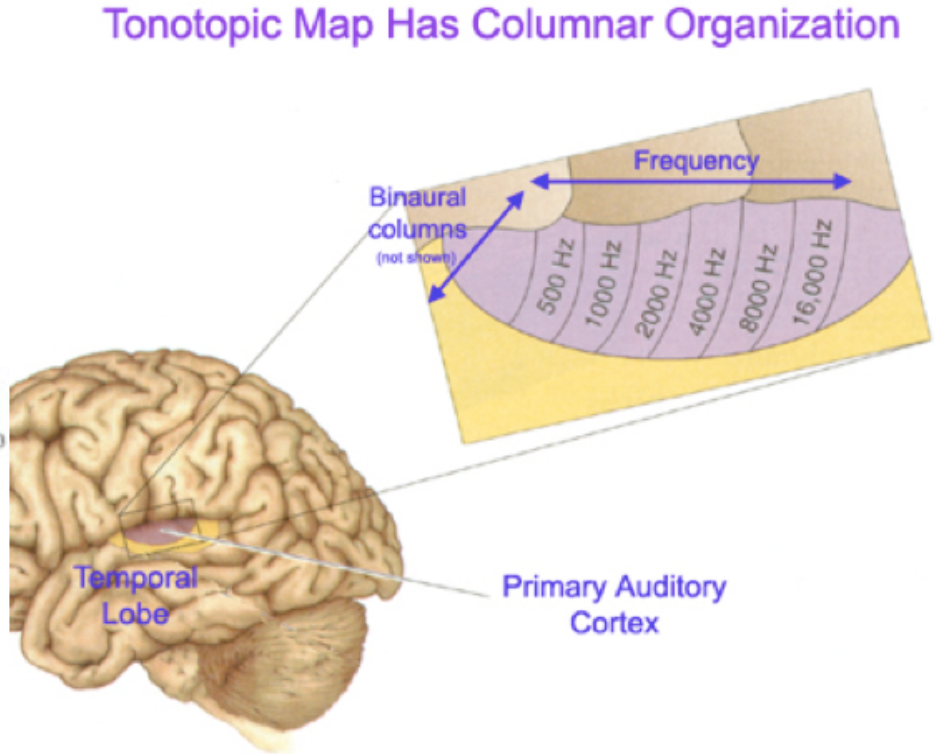

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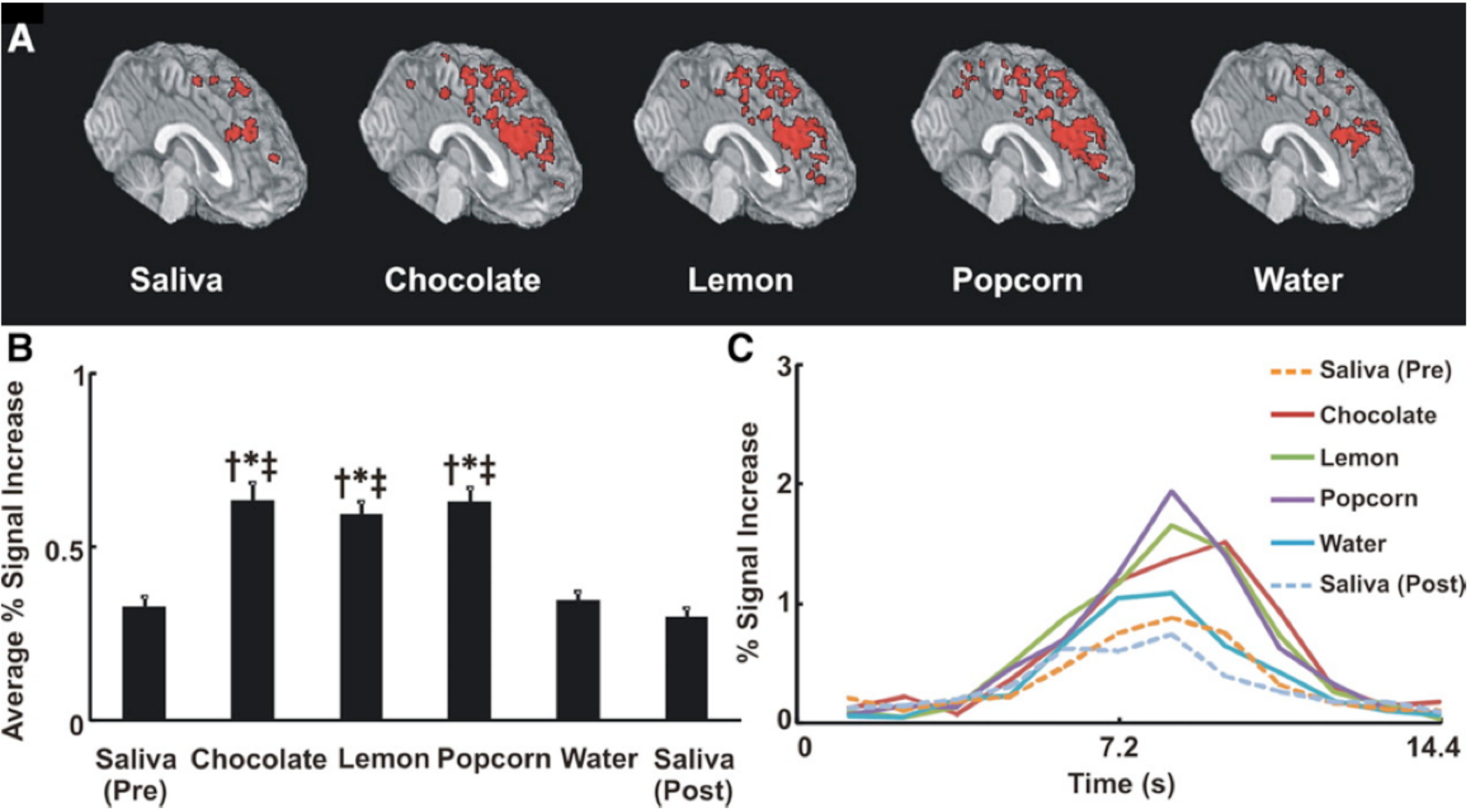
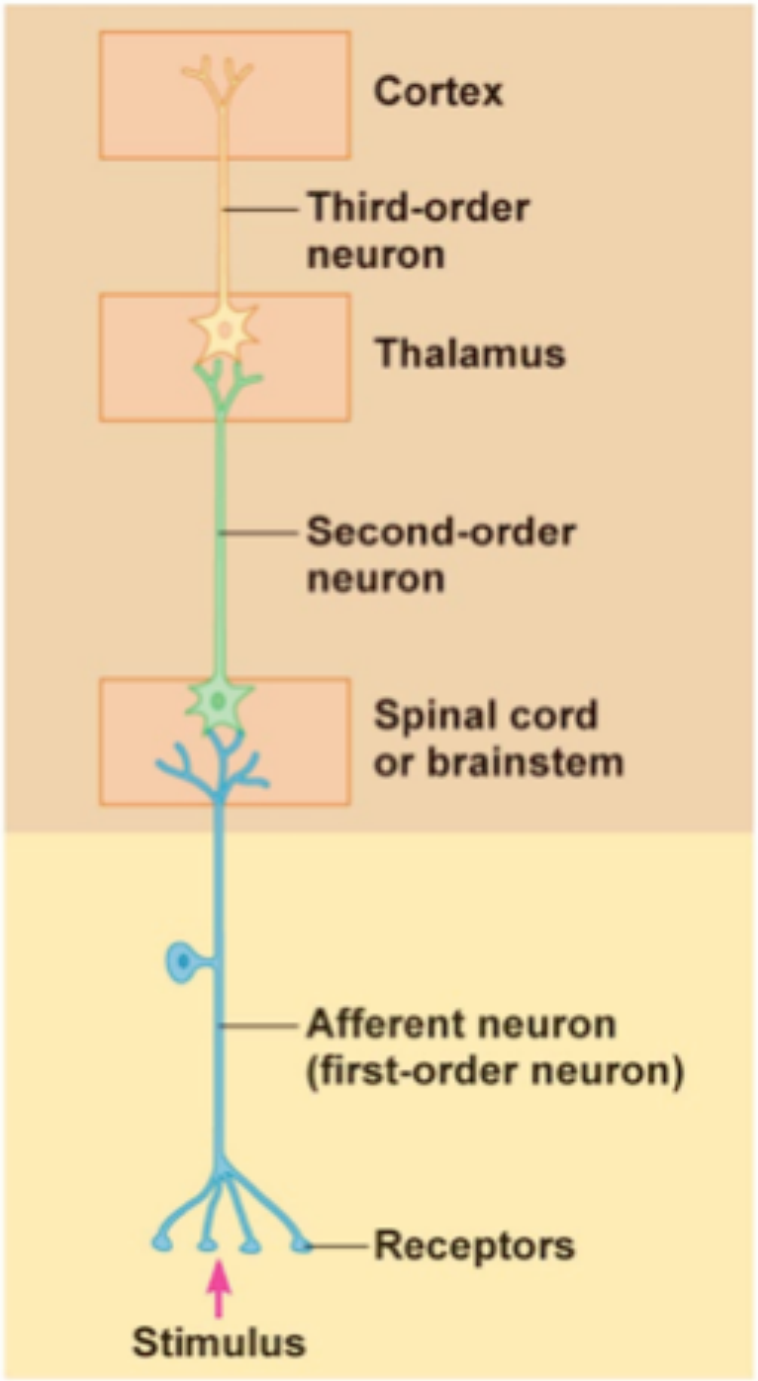


GENERIC TEMPLATE FOR SENSORY SYSTEMS



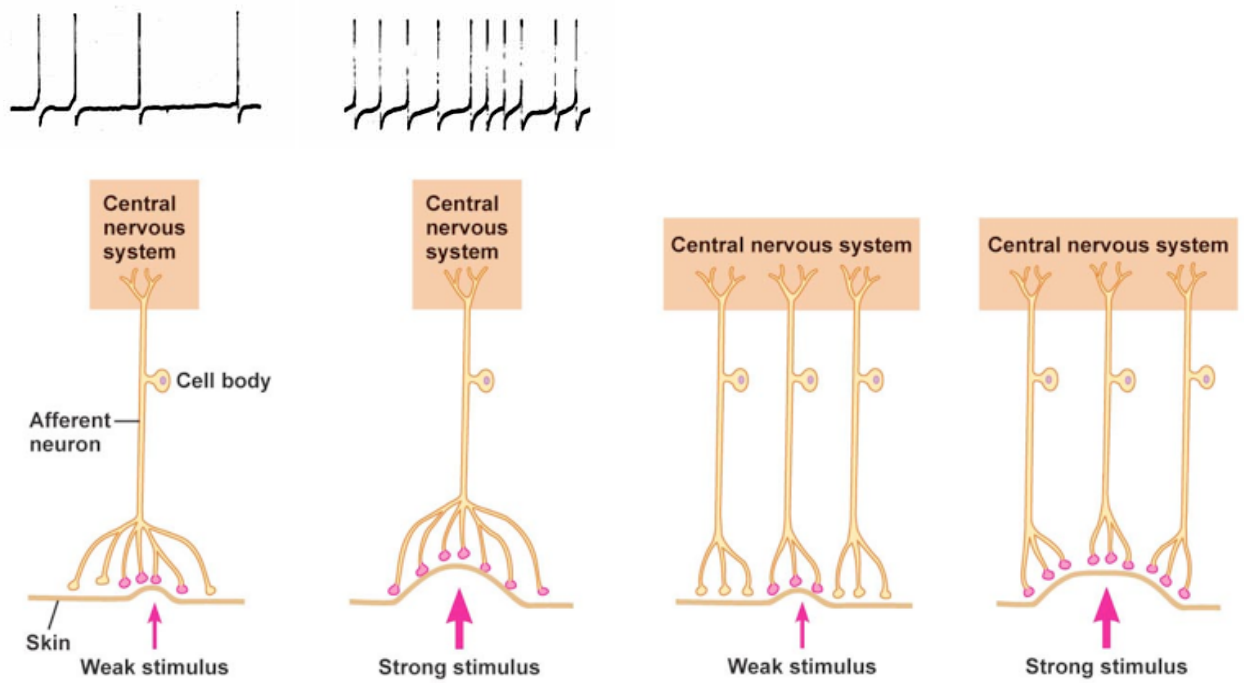
Larger / overlapping

Small / discrete

Information Processing

Quantitative - “how much / how intense?”

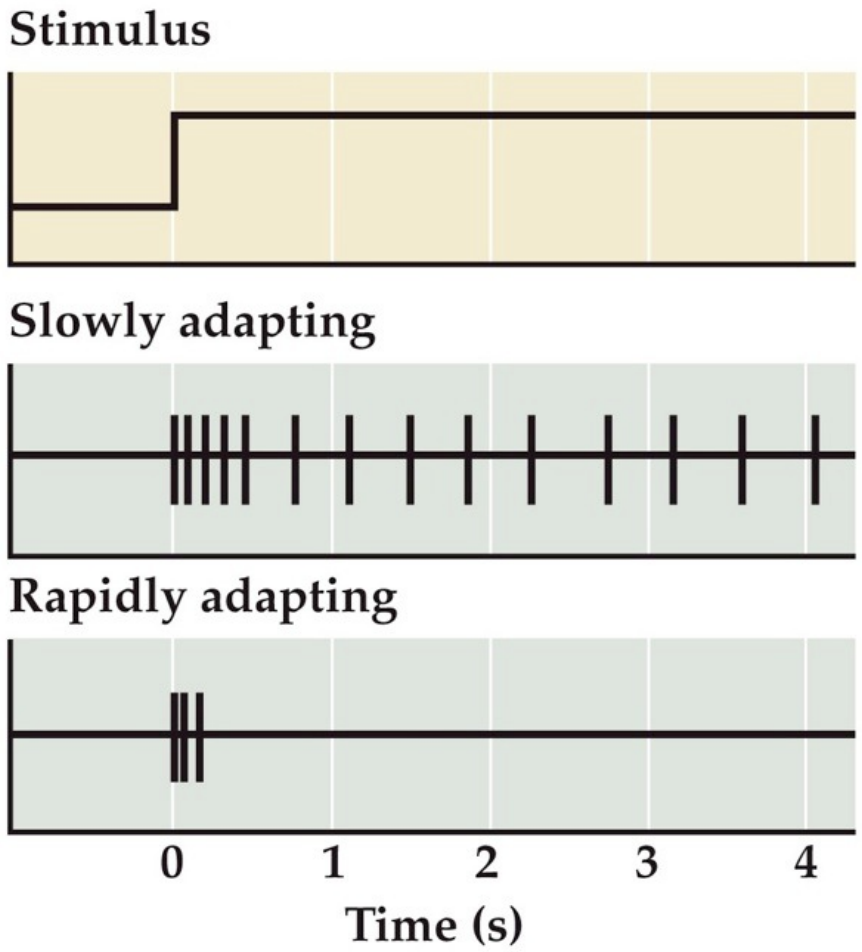
- Frequency / rate coding
- Population coding



Information Processing

Is there a “change?”

- slowly vs. rapidly adapting



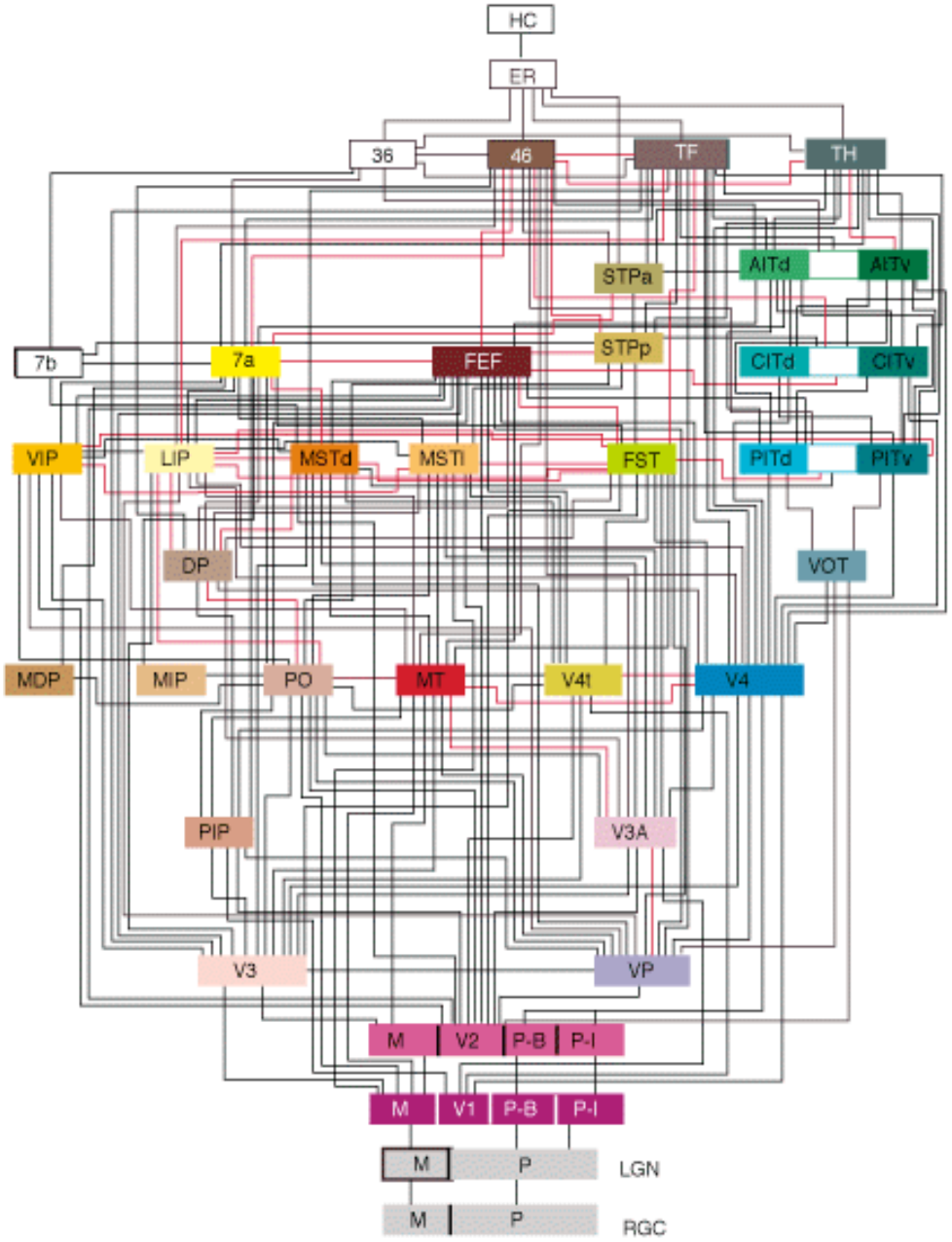
NEUROSCIENCE 5e, Figure 9.4

Cortical Information Processing

- By the time info gets to cortex, even more elaborate processing is already taking place
  - distinct regions of cortex respond (change firing rate) to stimuli on small, specific regions of the receptive sheet
    - cortical (higher order) neurons have overlapping *receptive fields*
      - built up from smaller receptive fields of "earlier" (lower order) neurons
    - adjacent neurons represent adjacent parts of the field
      - receptive fields are organized in a *topographic map* of the receptive sheet

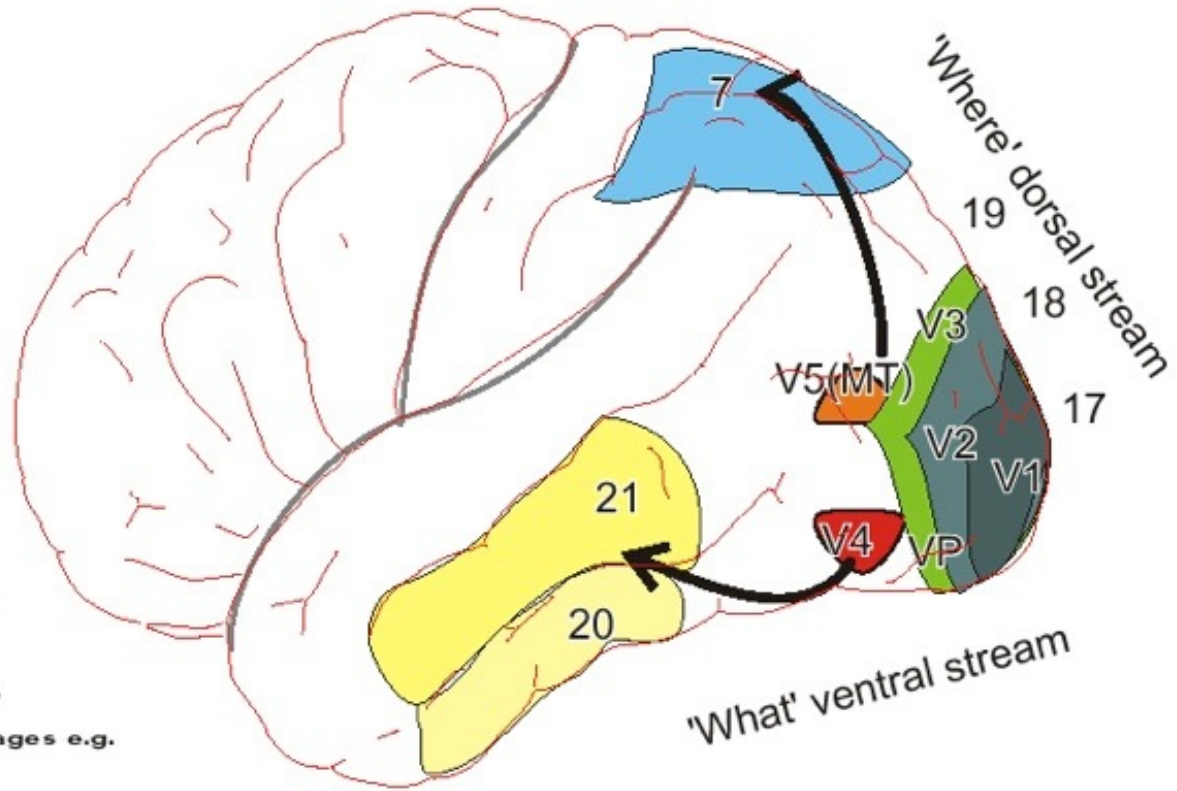
Cortical Information Processing

- *serial* and *parallel* connections
  - there is as much backward flow as forward flow
    - facilitate or inhibit sensory “traffic”



Cortical Information Processing

• within each sensory area, there exists a hierarchy of larger circuits representing increasingly more complex processing of incoming sensory information

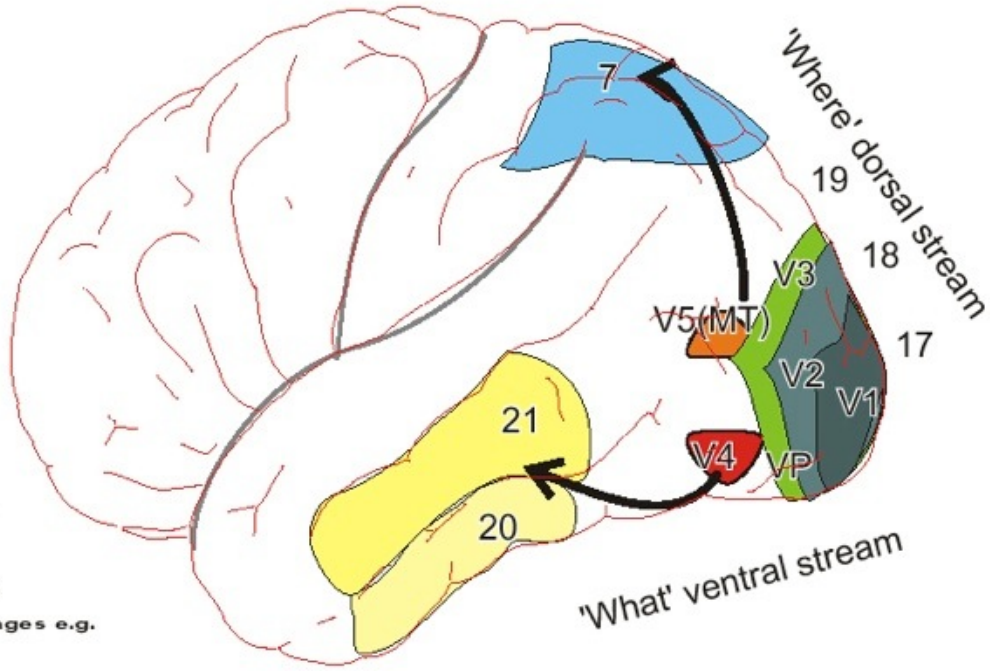


Processing begins in V1 which extracts simple features that are common to all images e.g. lines

It ends in areas that extract very complex features particular to a few related objects e.g. faces.

Cortical Information Processing

- early, lower, "upstream" areas identify basic stimulus properties
  - Visual system:
    - orientation
    - spatial frequency
    - speed
    - color
    - location

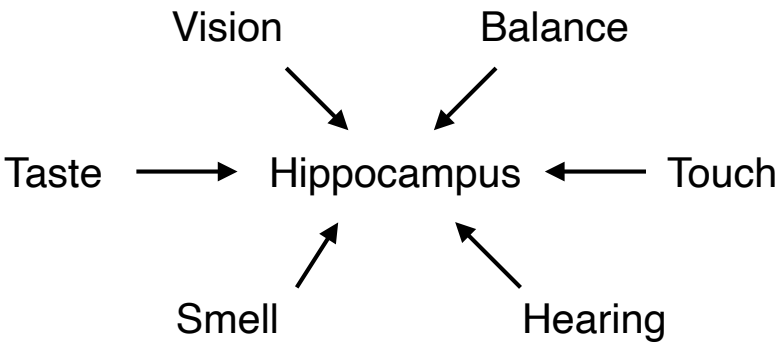


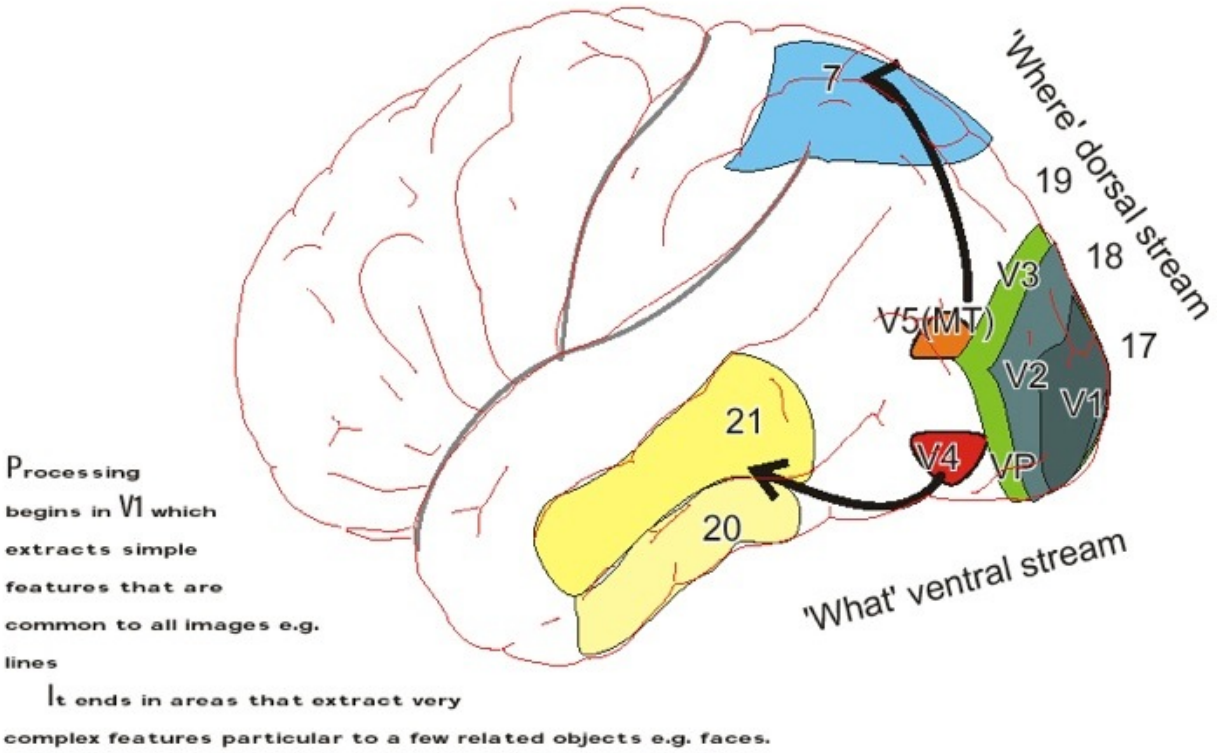
Processing begins in V1 which extracts simple features that are common to all images e.g. lines

It ends in areas that extract very complex features particular to a few related objects e.g. faces.

Cortical Information Processing

- later, higher, "down-stream" levels of processing
  - "maps" get fuzzier higher in the cortical hierarchy
  - response properties of these cells more complex (takes more specific info to activate them)
    - arise from combinations of inputs from lower levels
      - what (ventral) streams - "categorization" (faces, hands, etc.)
      - where (dorsal / parietal) - localizing in 3D space





Big Picture

- Language of the brain is "rhythm"
  - constantly changing dynamic chemical bath
    - produces constantly changing dynamic electrical patterns
      - from no activity to full on firing (in different areas)
- different and overlapping networks naturally tend to "pulse" at different frequencies
  - seconds (high freq) to hours (low freq)
- this ball of cells detects things in the environment that cause transient changes in the pulsation frequencies
- each possible "spatio-temporal" pattern of activity is associated with a specific perceptual state