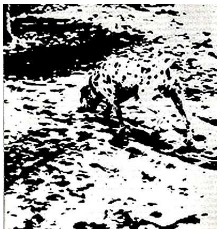
CISC 3250 Systems Neuroscience

Perception
(Vision)



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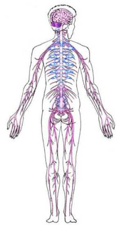
Pathways to perception in 3 (or fewer) synaptic steps

0 Input through sensory organ/tissue
1 Synapse onto neurons in spinal cord/brain stem
2 Synapse onto neurons in thalamus
3 Synapse onto cortical neurons in "primary ____ cortex"
4⁺ Further cortical processing

Bundled track of nerves to brain: spinal cord/cranial nerve



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Touch/"Tactile"

Skin → (Spinal cord) Dorsal horn → (spinal cord) Thalamus: Ventral postero-lateral (VPL) nucleus → Cortex: Post-central sulcus (SI)

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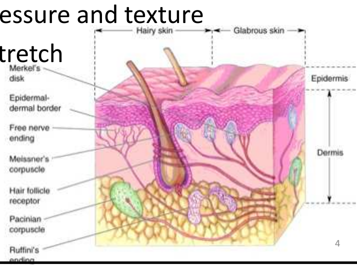
Touch: Inputs

Mechanoreceptors in skin

- Pacinian corpuscles – vibrations
- Meissner's corpuscles – light touch
- Merkel's discs – pressure and texture
- Ruffini endings – stretch



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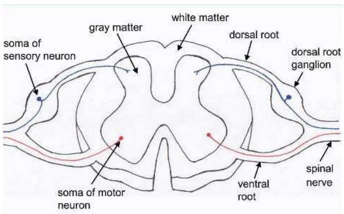
Communications in the spinal cord

- Sensory activity in back – ***dorsal***
- Motor command in front – ***ventral***



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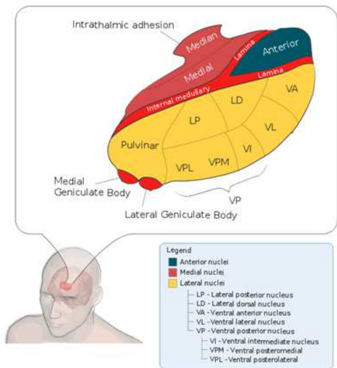
Thalamus – the "relay" station



Region names largely based on location

VPL for somatosensation

http://en.wikipedia.org/wiki/File:Thalamus-schematic.svg

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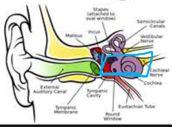
Hearing/“Auditory”



Cochlea

Cochlear nerve →

Cochlear nucleus (-> Superior olive) -> Inferior colliculus

Brain stem →

Thalamus

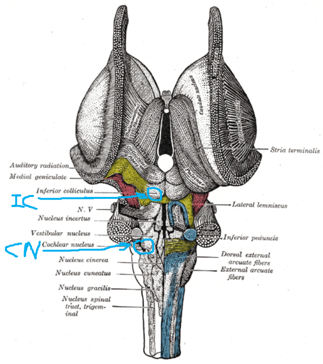
Medial geniculate nucleus (MGN)

→

Cortex

Primary auditory cortex (AI)

Regions of the brainstem



Dorsal view (back-of-the-head)

2-3 synapses in auditory brainstem path

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Seeing/“Visual”

Retina

Optic nerve →

Thalamus

Lateral geniculate nucleus (LGN)

→

Cortex

Primary visual cortex (VI)

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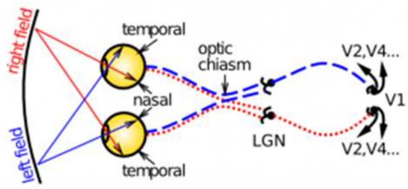
Lateralization

Flipping of right and left in vision

- Left hemisphere – right visual field
- Right hemisphere – left visual field



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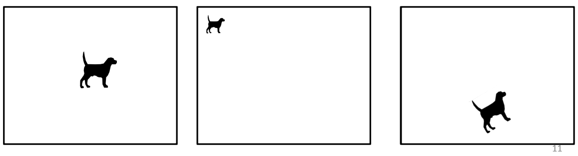
Sensitivity to perceptual variations

- V1: Surround-suppression for shifted edges

- PFC: Same object detected at diverse locations and scales



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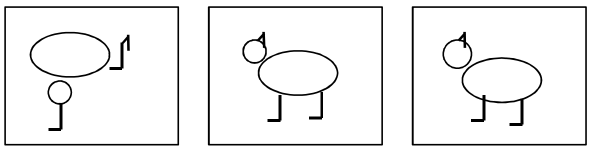
Selectivity to perceptual variations



- More complex percepts invariant to greater spatial transformations

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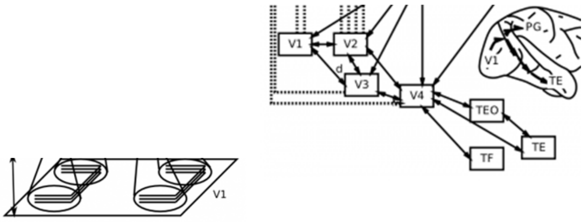
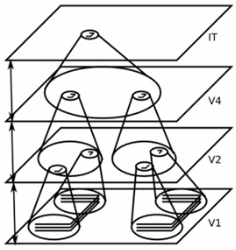
HMAX – model of hierarchical vision



- Higher cortical levels cover larger visual spans
- Object recognition invariant to changes in location and orientation

HMAX – model of hierarchical vision



1. Gabor "filters" (edge detectors) 
2. Perform "Max pooling" (semi-invariance over space)
3. Weighted combination of space-invariant edges
4. Further max pooling

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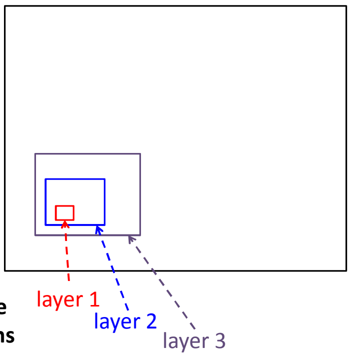
Higher HMAX layers cover more space



Example coverage for layer *x* neurons

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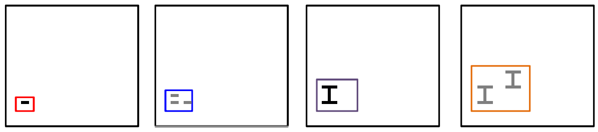
Functions of HMAX layers

- Odd layers (layer 1, 3, 5, …) look for specific combinations of lower-level features
- Even layers (layer 2, 4, 6, …) provide invariance to some feature changes (e.g., shift in position)



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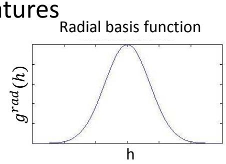
Functions of HMAX layers

- Odd layers (layer 1, 3, 5, …) look for specific combinations of lower-level features

$h=\sum_j w_j r_j^{in}$ $\quad r^{out} = g^{rad}(h)$

Radial basis function



- Even layers (layer 2, 4, 6, …) provide invariance to some feature changes (e.g., shift in position)

$$r^{out} = \max([r_1^{in} \quad r_2^{in} \quad \cdots \quad r_J^{in}])$$

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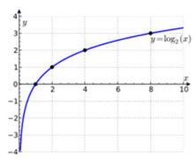
Estimating the max

- Earlier models: $r^{out}=g(\sum_i w_i r_i)$
- What if g() were log()?
  - log(100+4+5)≈log(100)
  - log(20+5+2) ≈log(20)



- Logarithms in nature:
  - Sound with 100x greater magnitude sounds ~3x louder
  - Sigmoid function $g^{sig}(x)=1/(1+\exp(-x))$ … exp is $\log^{-1}$

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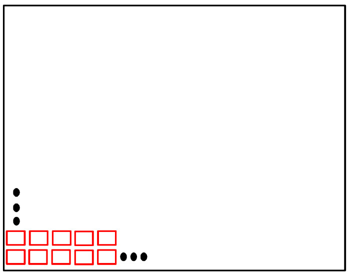
Each combination layer "tiles" visual space

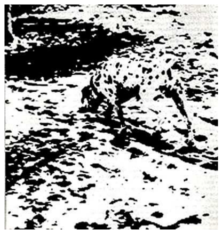


Compute weighted sum (combination) at every location

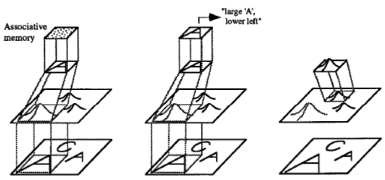
Called "**convolution**"

Visual attention

- Emphasize details currently of interest



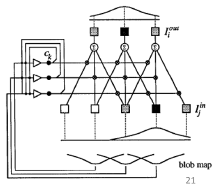
Model of Attention/Recognition



Find blob -> Focus on blob

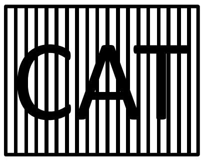
Match blob w/memory

Inhibit blob



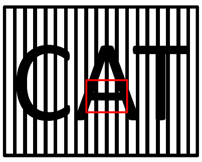
Olshausen et al., 1993

Attention when percepts overlap



Cocktail party problem

Attention when percepts overlap



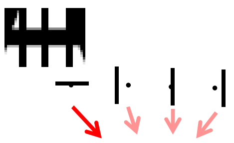
Attention to A dims effects of other inputs; ignoring bars dims their effects

h = $\sum_i w_i a_i^{in} r_i^{in}$

w – weight on input

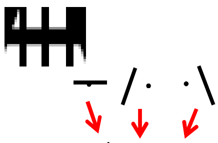
r – current strength of input

a – attention to input



H detector

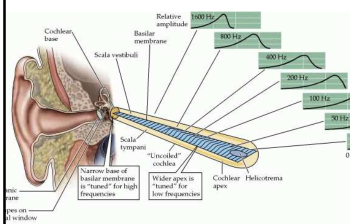
no firing

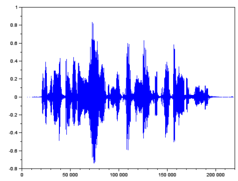


A detector

firing

Attention when percepts overlap





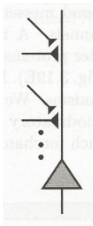
Can attend to one of two voices (e.g, high-pitched voice or low-pitched voice)

Modulating inputs through multiplication

Algorithm: “Sigma-Pi Node”

- Multiply rates to modulate each input
- Sum to compute output rate

$$h_i = \sum_i w_i r_i^{att} r_i^{in}$$



- r_i^{att} - attention input
  - $r_i^{att} = \sum_j r_{ij}^{att}$ - can sum over multiple attention inputs

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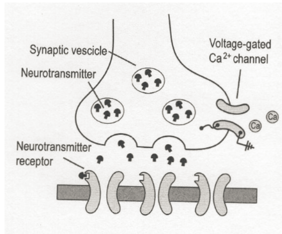
Dynamic synaptic reweighting

Voltage-dependent NT-receptors (e.g., NMDA):

1. Other nearby receptor decreases voltage
2. Voltage dependent receptor detects NTs



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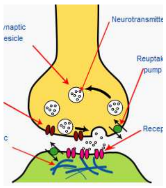
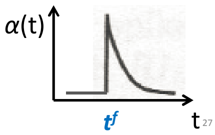
Dendrite input

Pre-synaptic neuron spikes
↓
Neurotransmitter (NT) released
↓
NT received by **post-synaptic** dendrite at time t^f
↓
Post-synaptic voltage rises and then fades, *α(t)*

$$I(t) = \sum_j w_j \alpha_j\,(t)$$





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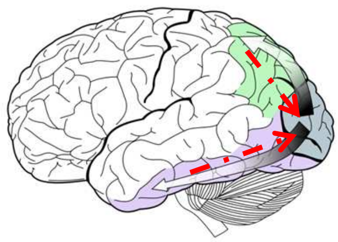
Complexity of cortical networks

- *Feedback*: connections in both directions along cortical “pathways”



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