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

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

2 Synapse onto neurons in thalamus

3 Synapse onto cortical neurons in "primary ____ cortex"

4+ Further cortical processing

Touch/"Tactile"

Skin

Spinal cord

Dorsal horn

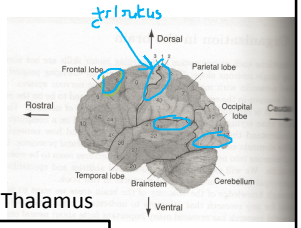
spinal cord

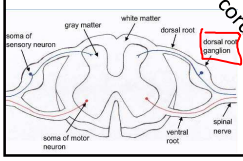
Thalamus

Ventral postero-lateral (VPL) nucleus

Cortex

Post-central sulcus (MI)

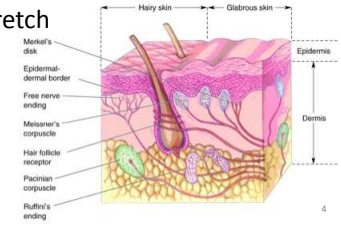




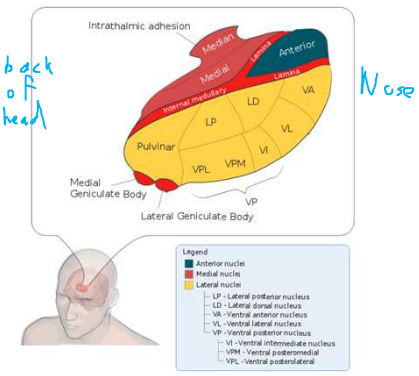
Touch: Inputs

Mechanoreceptors in skin

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



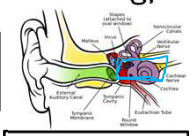
Thalamus – the "relay" station



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

Hearing/"Auditory"

Cochlea



Cochlear nerve

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

Brain stem

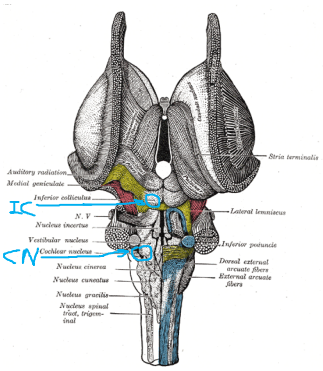
Thalamus

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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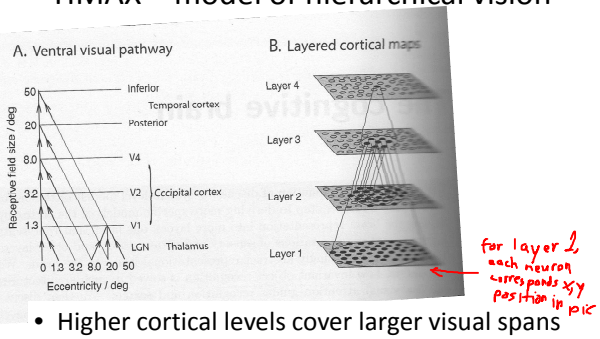
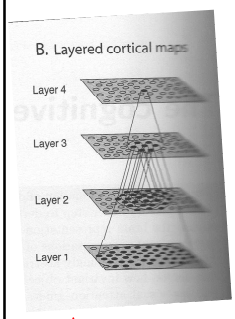
HMAX – model of hierarchical vision



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

HMAX – model of hierarchical vision

Hierarchical "max" computation



V1 - each neuron has location & orientation

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

hi wt / lo wt / 0 wt

wt sum → max → wt sum → max → wt sum → ...
lay 1 lay 2 lay 3 lay 4

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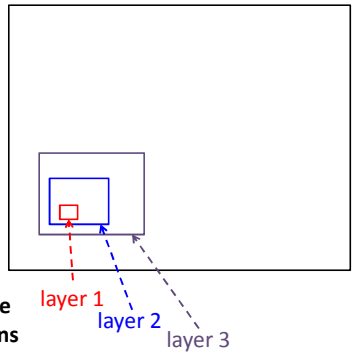
Higher HMAX layers cover more space



Example coverage for layer *x* neurons

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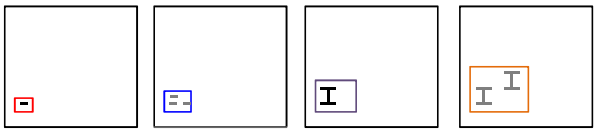
Functions of HMAX layers

- 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)



layer 1

layer 2
Fire for 1⁺ lines

layer 3

layer 4
Fire for 1⁺ Is

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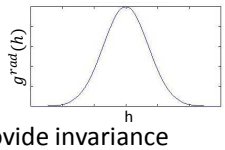
Functions of HMAX layers

- 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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Visual attention

- Perceive objects one at a time
- Ignore irrelevant details

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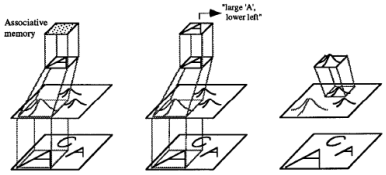
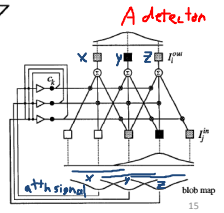
Model of Attention/Recognition



Olshausen et al., 1993



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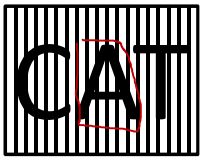
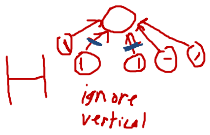
Non-spatial attention





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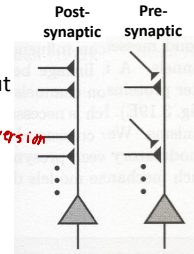
Modulating inputs through multiplication

Algorithm: "Sigma-Pi Node"

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

$$h_i = \sum_{jk} w_{ijk} r_j^{in} r_k^{in}$$



Biology

- Pre-synaptic: acetylcholine causes axon to release more Ca^{2+}, which increases NT release rate
- Post-synaptic: voltage-dependent NT-receptors (like NMDA receptors) will detect NTs only when membrane voltage increased by other NT receptors

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