CISC 3250
Systems Neuroscience

Perception (Vision)

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JMH 328A

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

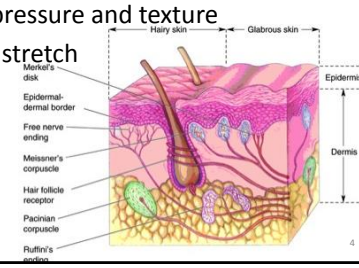
Touch/"Tactile"

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

Touch: Inputs

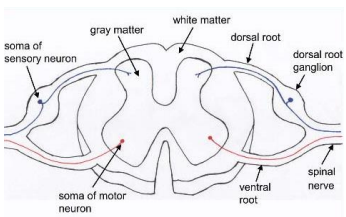
Mechanoreceptors in skin

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

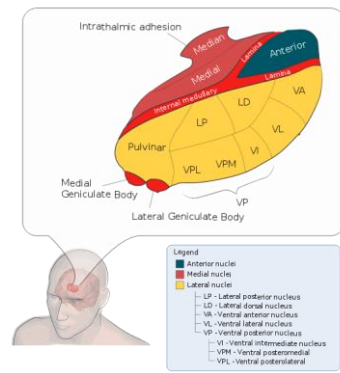


Communications in the spinal cord

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



Thalamus – the "relay" station

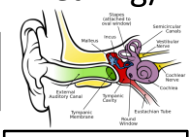


Region names largely based on location

VPL for somatosensation

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

Hearing/"Auditory"



Cochlea

Cochlear nerve

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

Brain stem

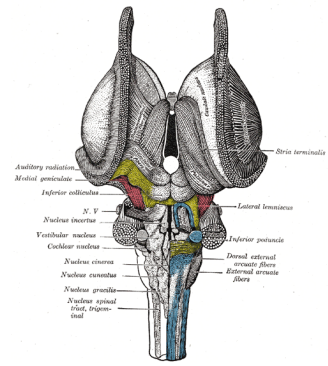
Thalamus

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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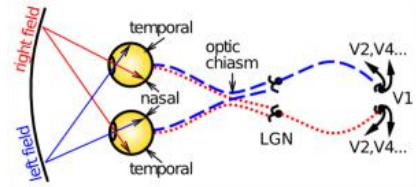
Lateralization

Flipping of right and left in vision

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



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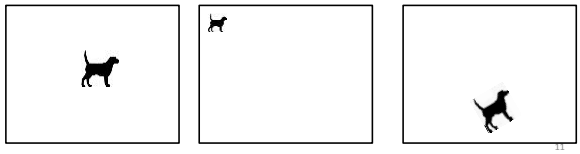
Sensitivity to perceptual variations

- V1: Surround-suppression for shifted edges

- PFC: Same object detected at diverse locations and scales



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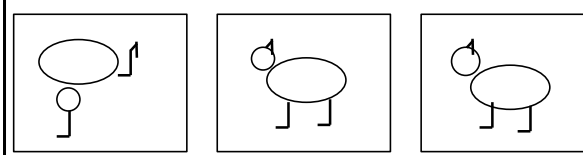
Selectivity to perceptual variations



- More complex percepts invariant to greater spatial transformations

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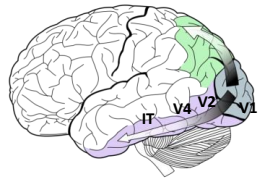
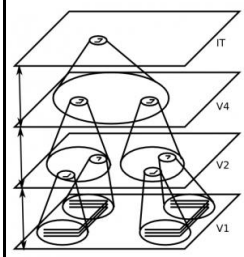
HMAX – model of hierarchical vision



- 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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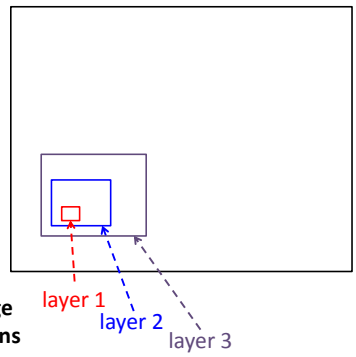
Higher HMAX layers cover more space



Example coverage for layer *x* neurons

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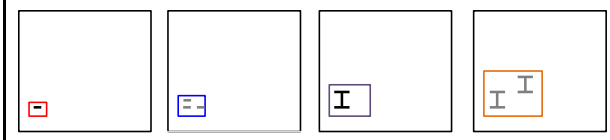
Functions of HMAX layers

- 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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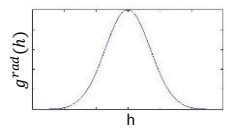
Functions of HMAX layers

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

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



- 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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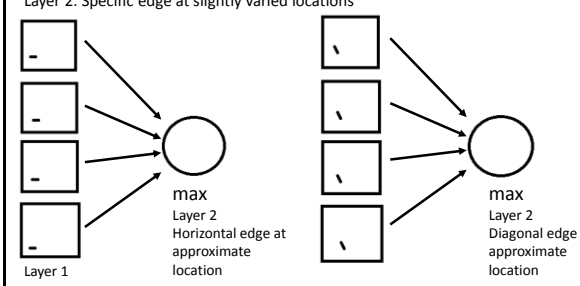
Detecting triangles: layer 2

Neuron outputs 1 if desired image viewed, otherwise 0

Layer 1: Specific edge at specific location

Layer 2: Specific edge at slightly varied locations



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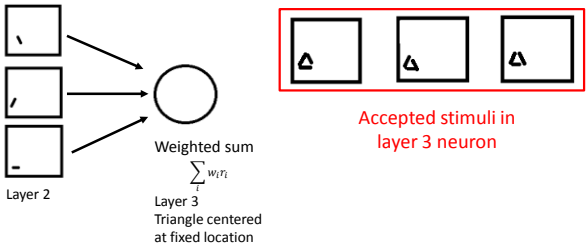
Detecting triangles: layer 3

Neuron outputs 1 if desired image viewed, otherwise 0

Layer 2: Specific edge at slightly varied locations

Layer 3: Combination of edges



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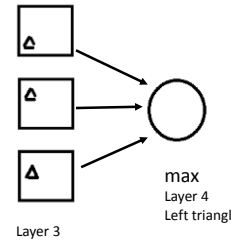
Detecting triangles: layer 4

Neuron outputs 1 if desired image viewed, otherwise 0

Layer 3: Combination of edges

Layer 4: Triangle on the left



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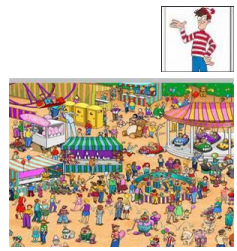
Visual attention

- Emphasize details currently of interest



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Attention when percepts overlap

Cocktail party problem

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Attention when percepts overlap

Attention a

Ignore vertical edges: $a_| = 0$

Pay attention to all other edges: $a_- = a_/ = a_\backslash = 1$

Rate r

If feature present: 1

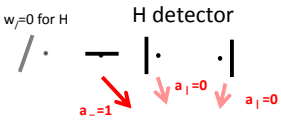
If feature not present: 0

In this example, |, –, /, \ present

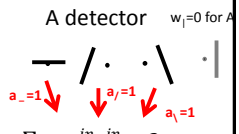
Weights w

H-detector looks for | and –: $w_| = w_- = 1$ $w_/ = w_\backslash = 0$

A-detectors looks for / , \ , –: $w_- = w_/ = w_\backslash = 1$ $w_| = 0$



$\sum_i w_i a_i^{in} r_i^{in} = 1$



$\sum_i w_i a_i^{in} r_i^{in} = 3$

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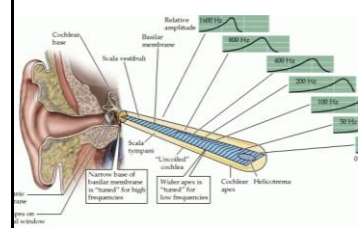
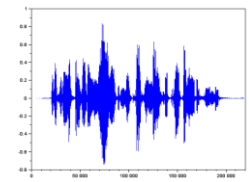
Attention when percepts overlap





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

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Modulating inputs through multiplication

Algorithm: "Sigma-Pi Node"

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

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

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

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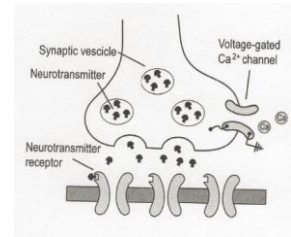
Dynamic synaptic reweighting

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

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



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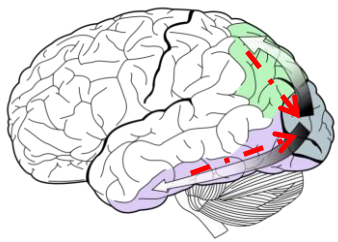
Complexity of cortical networks

- *Feedback*: connections in both directions along cortical "pathways"



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