Neural networks

Feedforward neural network - biological inspiration

NEURAL NETWORK

Topics: multilayer neural network

- Could have L hidden layers:
  - layer pre-activation for $k>0$ $(\mathbf{h}^{(0)}(\mathbf{x}) = \mathbf{x})$

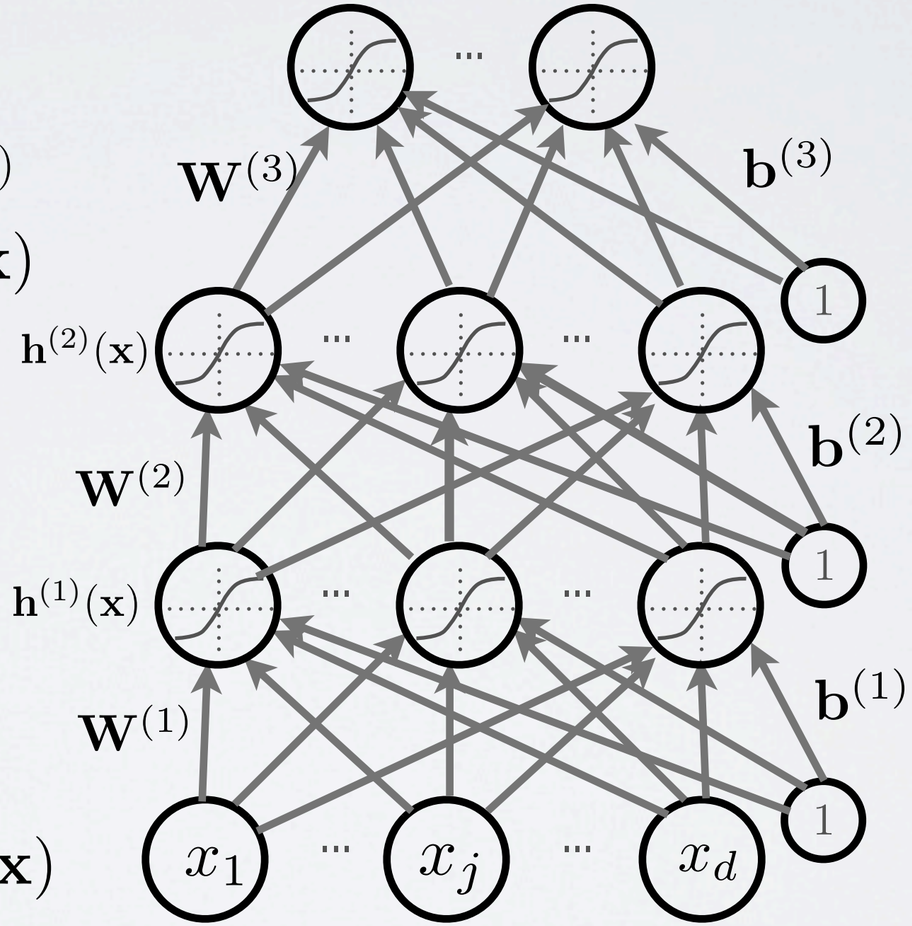
$$\mathbf{a}^{(k)}(\mathbf{x}) = \mathbf{b}^{(k)} + \mathbf{W}^{(k)}\mathbf{h}^{(k-1)}(\mathbf{x})$$

  - hidden layer activation (k from 1 to L):

$$\mathbf{h}^{(k)}(\mathbf{x}) = \mathbf{g}(\mathbf{a}^{(k)}(\mathbf{x}))$$

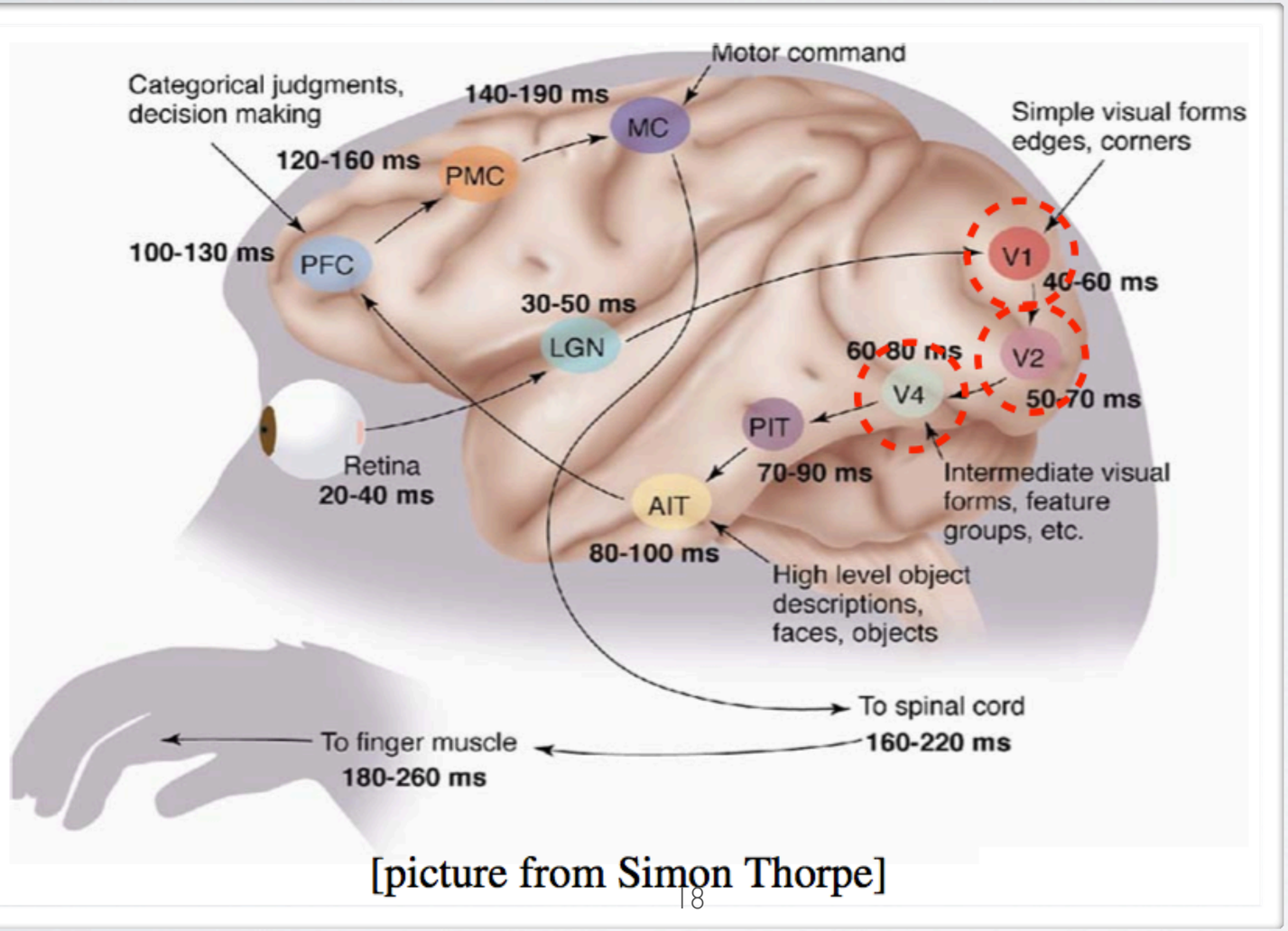
  - output layer activation ($k=L+1$):

$$\mathbf{h}^{(L+1)}(\mathbf{x}) = \mathbf{o}(\mathbf{a}^{(L+1)}(\mathbf{x})) = \mathbf{f}(\mathbf{x})$$



NEURAL NETWORK

Topics: parallel with the visual cortex



[picture from Simon Thorpe]

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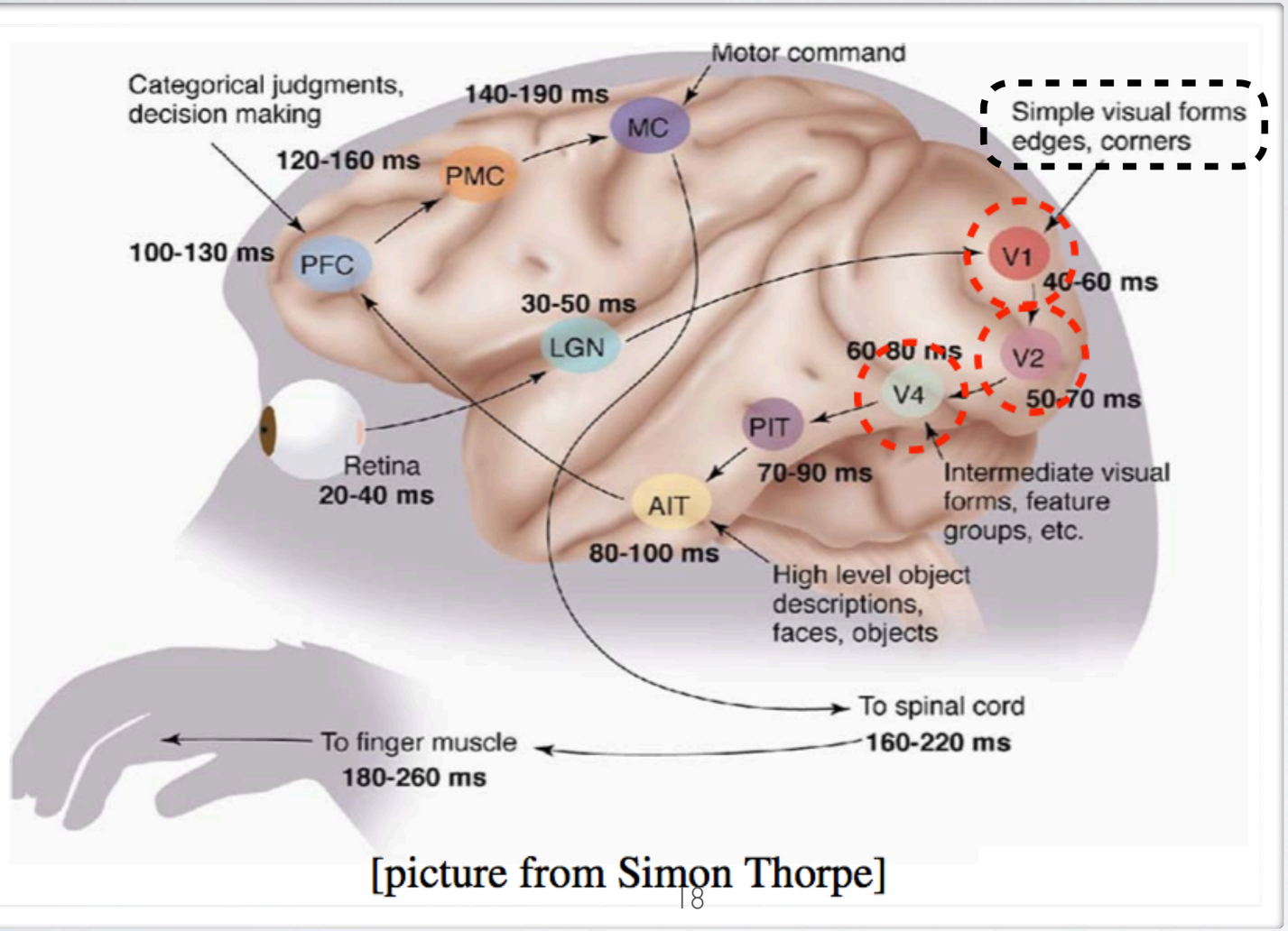

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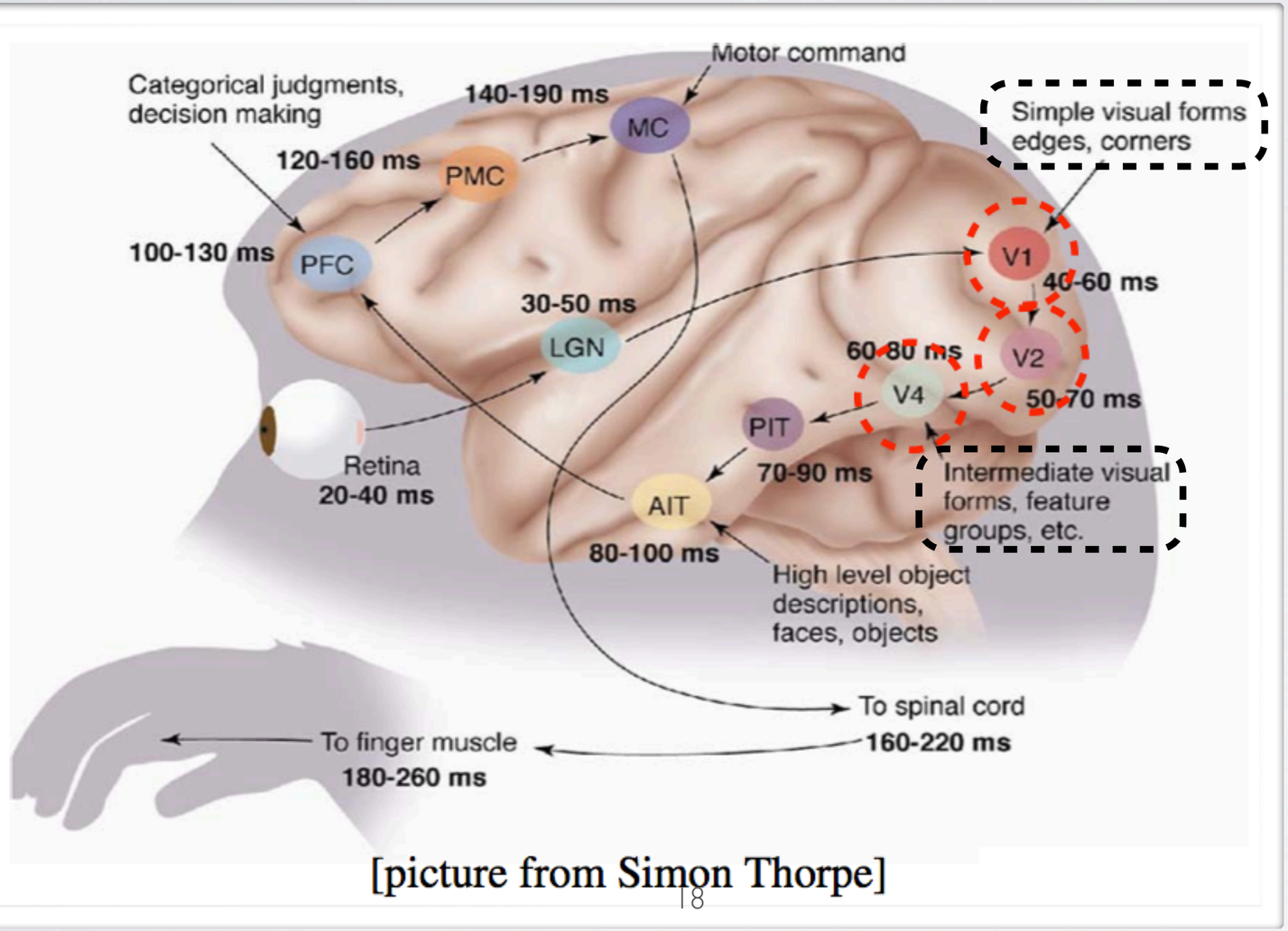
Topics: parallel with the visual cortex



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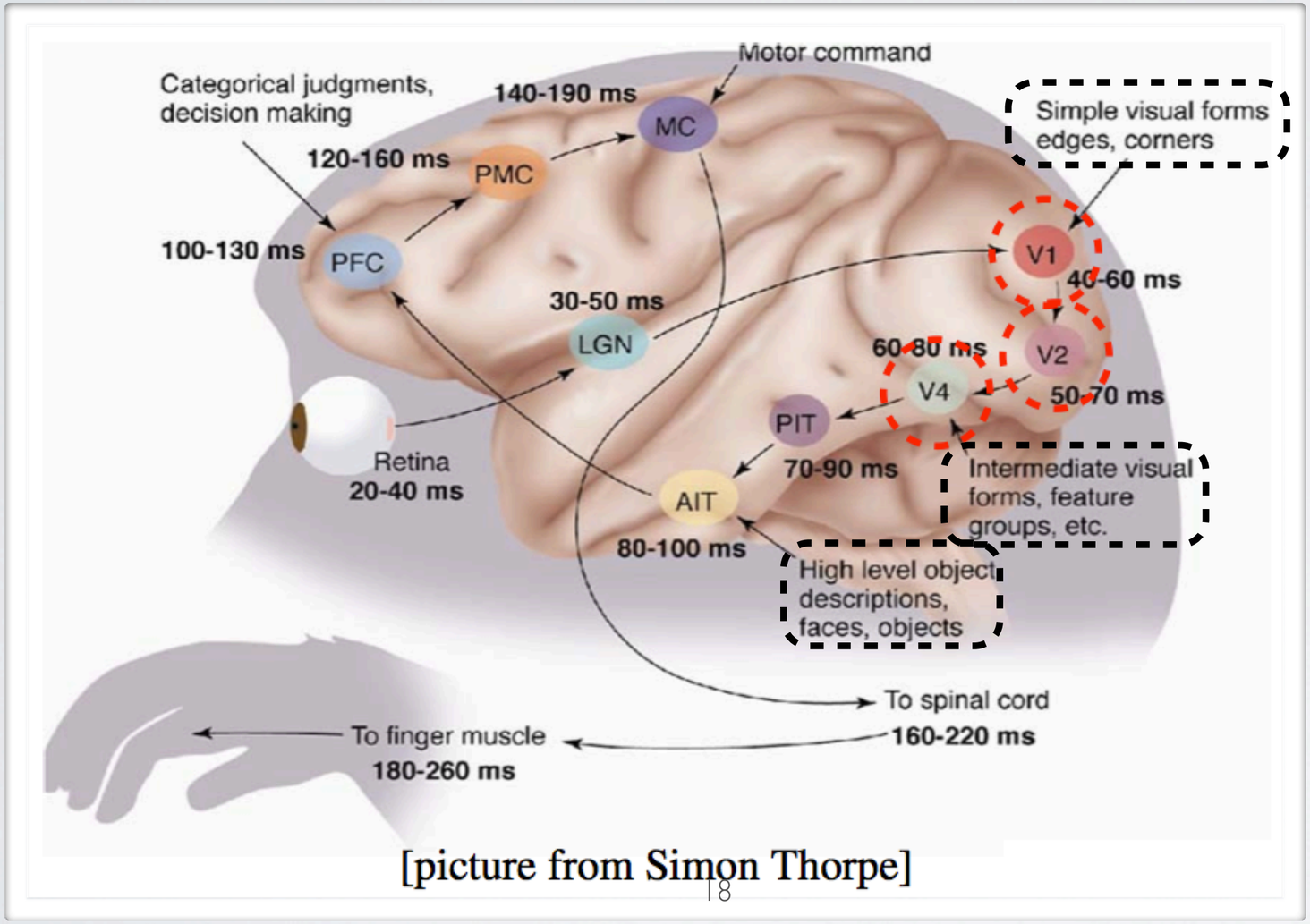
Topics: parallel with the visual cortex



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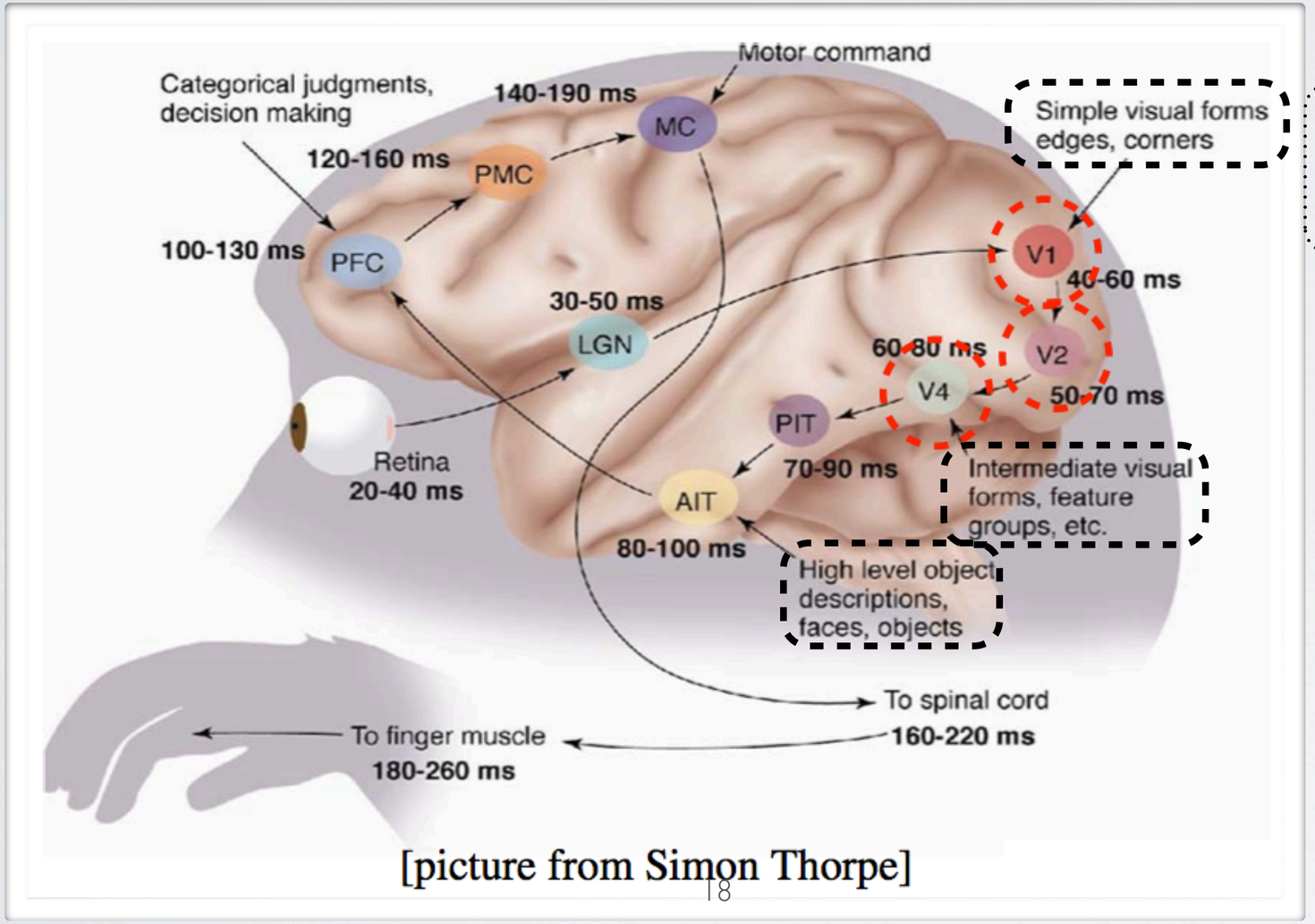
Topics: parallel with the visual cortex



[picture from Simon Thorpe]

edges
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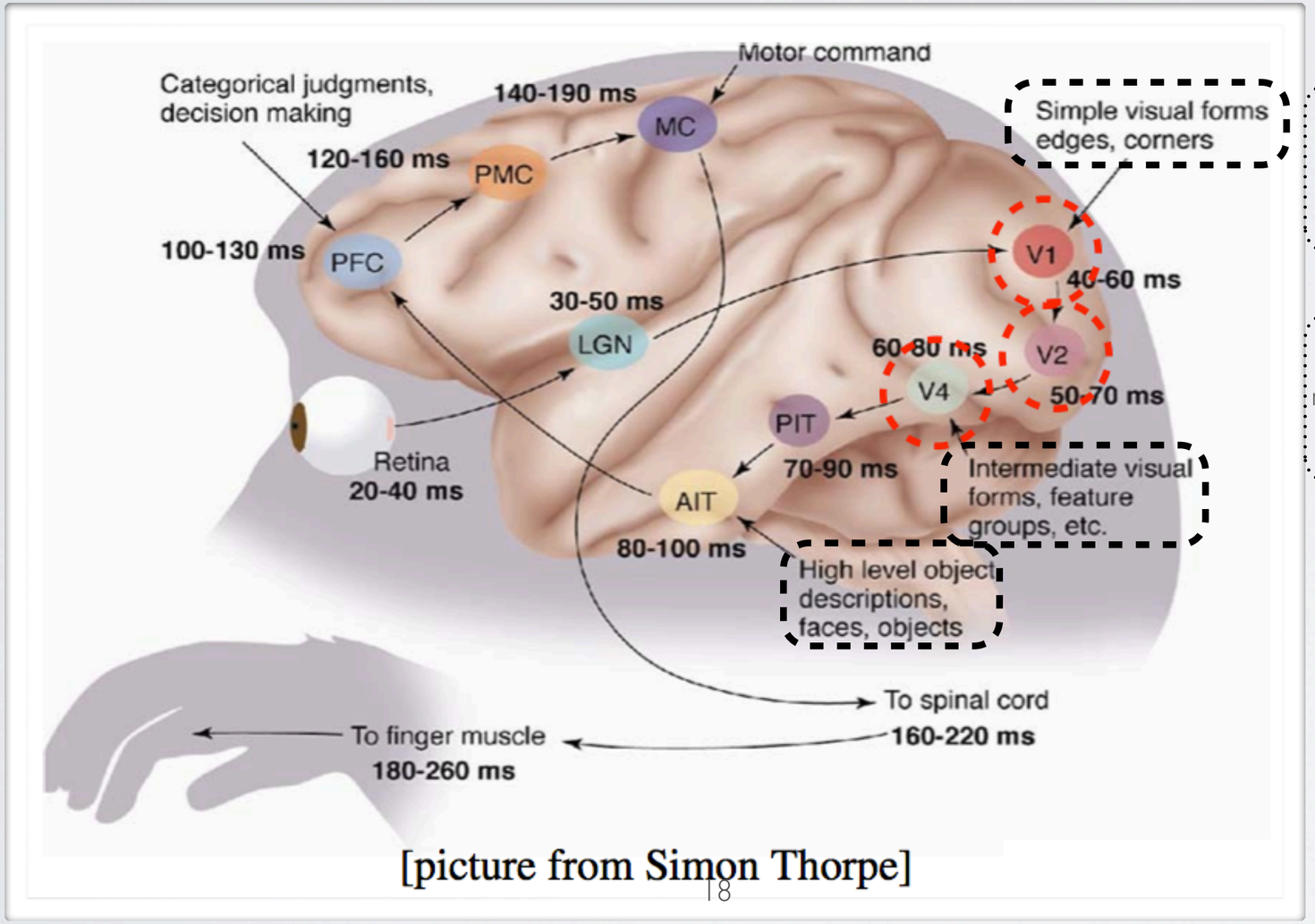
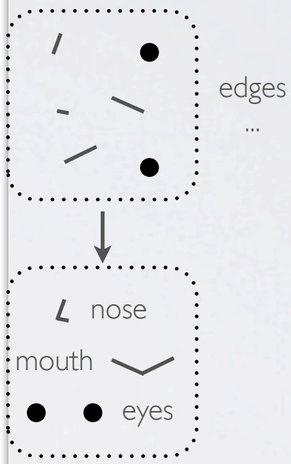
NEURAL NETWORK

Topics: parallel with the visual cortex





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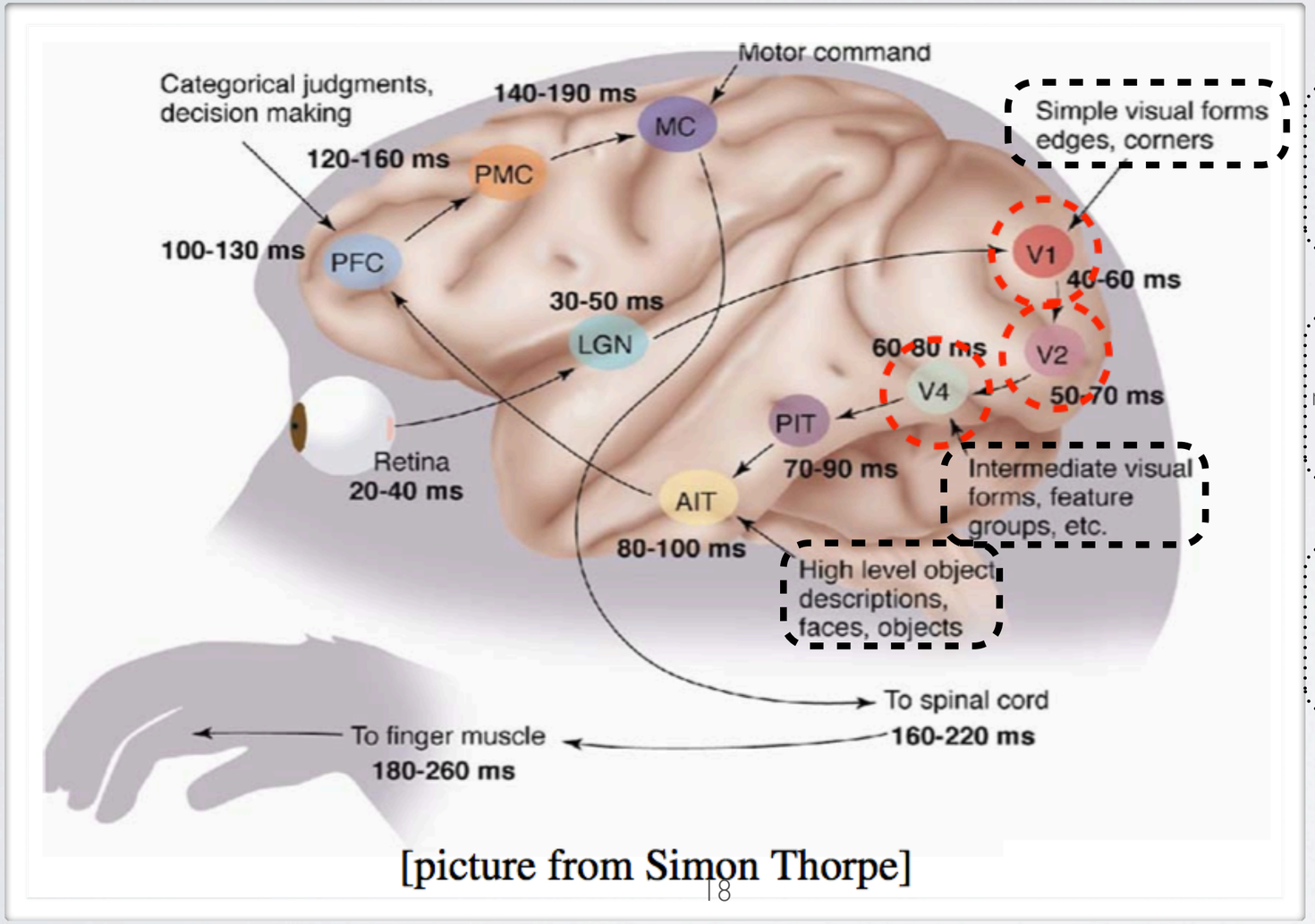
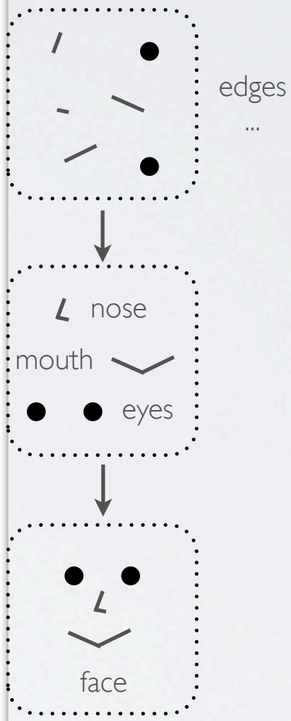




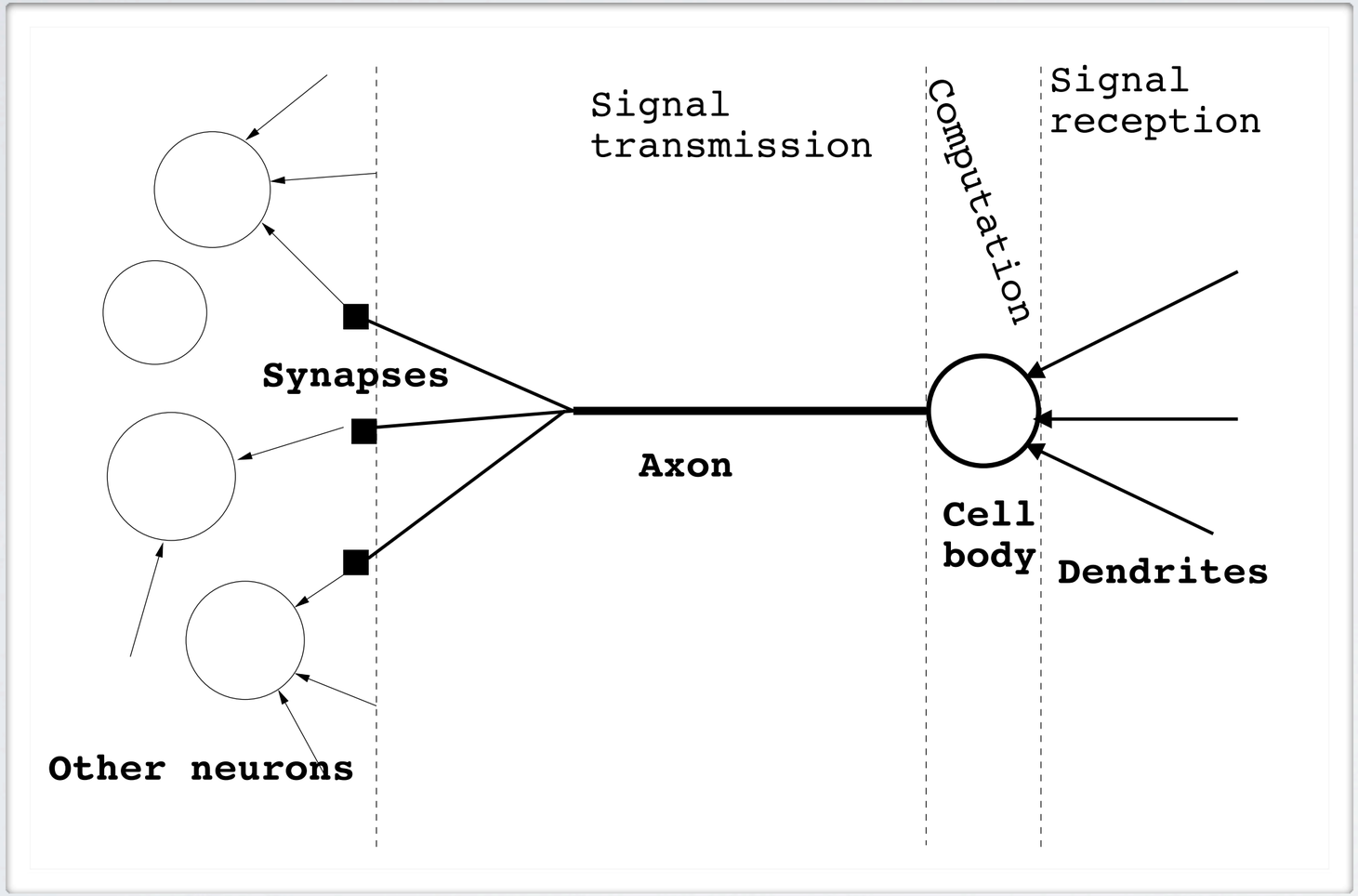
BIOLOGICAL NEURONS

Topics: synapse, axon, dendrite

- We estimate around 10^{10} and 10^{11} the number of neurons in the human brain:
  - they receive information from other neurons through their dendrites
  - the "process" the information in their cell body (soma)
  - they send information through a "cable" called an axon
  - the point of connection between the axon branches and other neurons' dendrites are called synapses

BIOLOGICAL NEURONS

Topics: synapse, axon, dendrite



(from Hyvärinen, Hurri and Hoyer's book)

BIOLOGICAL NEURONS

Topics: action potential, firing rate

- An action potential is an electrical impulse that travels through the axon:
  - this is how neurons communicate
  - it generates a "spike" in the electric potential (voltage) of the axon
  - an action potential is generated at neuron only if it receives enough (over some threshold) of the "right" pattern of spikes from other neurons

- Neurons can generate several such spikes every seconds:
  - the frequency of the spikes, called firing rate, is what characterizes the activity of a neuron
    - neurons are always firing a little bit, (spontaneous firing rate), but they will fire more, given the right stimulus

BIOLOGICAL NEURONS

Topics: action potential, firing rate

- Firing rates of different input neurons combine to influence the firing rate of other neurons:
  - depending on the dendrite and axon, a neuron can either work to increase (excite) or descrease (inhibit) the firing rate of another neuron

- This is what artificial neurons approximate:
  - the activation corresponds to a "sort of" firing rate
  - the weights between neurons model whether neurons excite or inhibit each other
  - the activation function and bias model the thresholded behavior of action potentials

BIOLOGICAL NEURONS

Hubel & Wiesel experiment

http://www.youtube.com/watch?v=8VdFf3egwfg&feature=related