Neuroscience Questions – Greg Bruss, Knowledge Engineering yr1, UM.

Lecture 1: The Nervous System

Basic questions (Full coverage of concept checklist)

1. Are there more neurons or glial cells in the nervous system?
2. Astrocytes are a type of glial cell. What is their function?
3. Explain in words the structure and function of the axon. Must mention axon hillock, nodes of ranvier, directionality, terminal, signal, transmission, and intermediate structures
4. What are cortical columns? How are neurons within a specified column related?
5. What is the PNS? It is made up of two systems, name and describe them.

4. subdivisions of the cortex, they encode a similar feature
5. somatic: voluntary control. and autonomic: invluntary control

6. Neuroanatomy can be looked at on many scales of analysis. What are these scales? Give each scale and brief description (long question)
7. Explain the planes we talk about when describing the brain
8. What is white matter?
9. What are ventricles, and what is their function?
10. What makes up the Diencephalon? (2 structures)

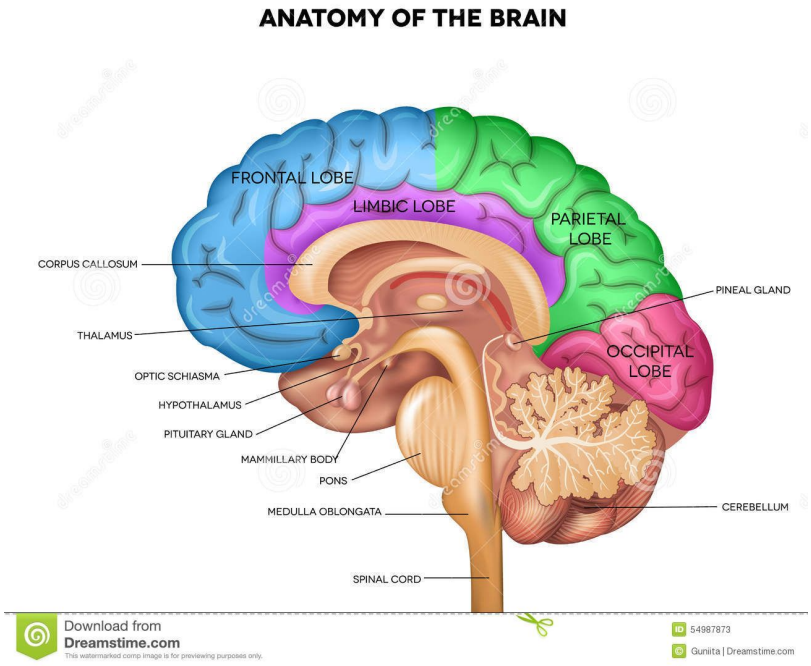
11. What is the telencephalon, and what is the important system it contains? function of basal ganglia
12. What are gyri and sulci?
13. We talk about the cortex as being layered. How many layers?
14. Give all the lobes of the cerebral cortex, and their function
15. What is grey matter?

16. What is the brain stem? How is it located (Rostrally, caudally, dorsally, ventrally)
17. Give one descriptive word for each region: pons, midbrain, cerebellum, medulla
18. The brain stem is one of the most important structures of the brain. What is its main function?
19. What is the hindbrain? What is its function?
20. What is the midbrain? What is its function?

21. Schwann cells are types of glial cells. Where are they located? What system do they support?
22. What were Brodmanns areas? Give an example of them (eg. Vision 17)
23. The thalamus is very important as it is the relay station of the brain. What does it really do, though?
24. What would happen if a persons brain stem was damaged?
25. What makes up the CNS?

Additional questions (Information given in the readings, good to know but not essential. Some of these questions are *hard.*)

- In terms of neuronal activity, what is convergence and divergence?
- Acetylcholine is the neurotransmitter of the sympathetic/parasympathetic nervous system and increases/decreases heart
- Norepinephrine is the neurotransmitter of the sympathetic/parasympathetic nervous system and increases/ decreases heart rate
- What is the main benefit to the cortex being so folded?
- There is *topographic* correspondence between cortical regions and body surfaces. In fact, topographical mapping is a *common* feature of the nervous system - The auditory cortex has *tonotopic* organization. The somatosensory cortex has *somatotopic* organization. How is it useful? What benefit is there?



Lecture 2: Nervous system continued

Basic Questions

1. Give the overall structure of a neuron. Must mention dendritic spines, soma, axon
2. What are terminal boutons?
3. What is *neuronal signalling?*
4. What determines the voltage of any given neuron?
5. What is the function of oligodendrocytes?

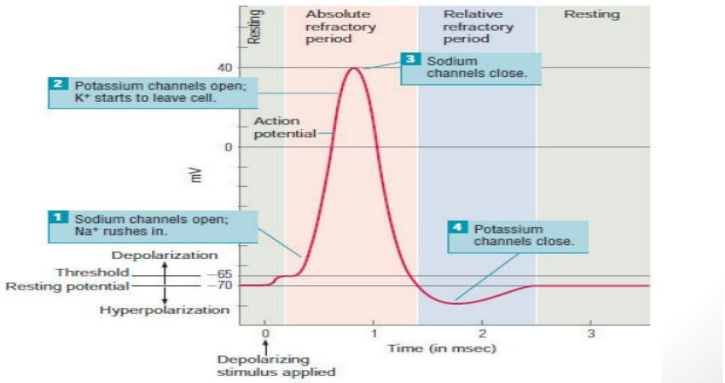
The resting potential is determined by concentration gradients of ions across the membrane and by membrane permeability to each type of ion

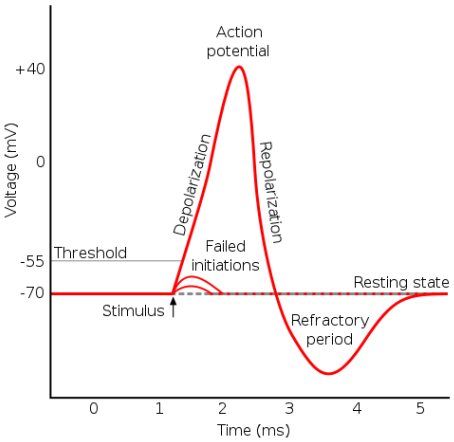
6. What are voltage-gated ion channels? What is the difference between these and passive ion channels?
7. What does "resting potential mean" – what is its technical definition?
8. What is the role of microglia? Brain's immune system, eat up pathogens
9. Why is the blood brain barrier important?
10. What is the sodium potassium pump?
    a. What ions are pumped out of the cell, and how many?
    b. What ions are pumped into the cell, and how many?
    c. Physical processes (like this pump) require energy. Where does the energy for this pump come from?
    d. The resulting pump leads to an imbalance, what happens next?

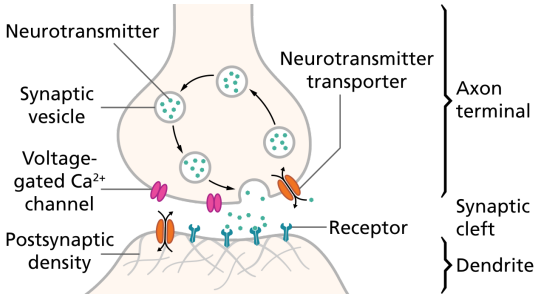
11. We are told the brain is a parallel computer. Explain the term parallel in this context
12. Within neurons the communication is electrical/chemical. Between neurons the communication is electrical/chemical
13. There are two forces which act on all ions – *Concentration Gradient,* and *electrostatic pressure* Explain these two forces.
14. There is a negative charge on the inside/outside of the membrane, and a positive charge on the inside/outside of the membrane.
15. Explain the role of EPSPs and IPSPs, and how they are triggered.

16. The resting potential has gone from -70mV to -65mV. Was this an EPSP or an IPSP?
17. To reach the *threshold* at the axon hillock, EPSPs must sum both s_____ and t_____.
    What do these terms mean?
18. PSPs exhibit something known as *grading*. What does this term mean?
19. EPSPs trigger/prevent an action potential. IPSPs trigger/prevent an action potential. The more IPSP's occur, the more/less likely an action potential will occur

20. What is the refractory period of an action potential?
    a. What is the difference between a relative refractory period and an absolute refractory period?
21. We know that action potentials travel faster and further through myelinated axons. Given this information, explain *saltatory conduction*.
22. Action potentials explain the movement of information through a neuron. Between neurons, this happens with *synaptic transmission*. Fill in the blanks:
    a. An AP reaches the end of the Ax____Ter____, leading to the De_____of the Terminal Membrane, causing Voltage Gated Ca channels to open.







Additional:

- How random are synaptic events?
- What are neuromodulators? How do they work and where do they fit in?

Lecture 3: Sensation and Perception

Basic:

1. Do humans see the entire light spectrum? Explain.
2. What is the cornea of the eye?
3. What is the primary function of the lens of your eye?
4. The retina has many aspects:
    a. The 2 photoreceptors of the retina are *rods* and *cones*. Rods help us see in dim/bright light, and cones help us see in dim/bright light.
    b. There are three types of cones. What are they?
    c. The photoreceptors contain light-sensitive proteins called photopigments. When these are exposed to light, they become unstable and split apart. What does this cause?
    d. The reason you can read or drive is because you have very sharp central vision – this is because there exists an area in the eye with a very high density of cones. What is this area called?
    e. Ganglion cells collect visual information from *polar cells* and *amacrine* cells, and do what with it?
    f. Why are polar cells named polar cells? What is their main function?
    g. Horizontal cells are responsible for allowing eyes to adjust to see well under both bright and dim light conditions. How do they go about accomplishing this?

5. Lateral inhibition is the capacity for an excited neuron to inhibit the activity of other surrounding neurons. Explain **how**, in the visual system, this leads to the perception of sharper images. (Pretty tough question)

6. What is the optic chiasm. What is the net result of the optic chiasm?
7. More than 90% of the axons in the optic nerve connect to the Lateral Geniculate Nucleus. Where is the LGN located? dorsal part of the thalamus
8. In the visual cortex V1, there are many types of cells. Describe the function of each:
    a. Simple Cells
    b. Complex Cells
    c. End-stopped Cells
    d. Orientation Columns
9. The visual system has two defining features: Contralateral projection, and upside down projection. Explain these two concepts.
10. There are many visual pathways, explain what each one helps us to do:
    a. Magnocellular pathway
    b. Parvocellular pathway
    c. Koniocellular pathway

Other features, such as color and shape, are initially encoded together but subsequently analyzed by separate areas of the brain. Despite this separation, in perception the brain must represent which features belong to the same object. This is the binding problem.

11. What is the binding problem with respect to perception?
12. There are multiple computational problems to deal with when we think about perception. Explain further what each of these mean:
    a. Object constancy
    b. Recognition is view-invariant
    c. The brain is able to encode shapes
    d. 2D-3D representation
    e. Grandmother cell vs Ensemble Coding

13. There are different ways perception can fail: Explain each
    a. *Apperceptive agnosia*
    b. *Associative agnosia*
    c. *Integrative agnosia*
    d. *Category specific agnosia*
14. Encoding refers to the problem of how stimuli are represented in neural activity. A person imagines a big elephant, the encoding problem is how can we determine how the idea of an elephant will show up in signals of the brain. Explain the reverse process, decoding, in words.

<u>Additional</u>

- The left hemisphere of the brain processes the right visual field, and the right hemisphere processes the left visual field. So is there one or two visual cortexes?
- *The receptive field* for a neuron is the region of the retina where the action of light will alter the firing of that neuron. It is known that neurons in V1 have some of the smallest receptive fields of any region in the brain. Give a reason why.

Lecture 4: Attention

Basic:

1. Obviously, attention serves many functions. Explain each of these:
    a. Vigilance
    b. Search
    c. Selective attention
    d. Divided attention
2. Signal Detection Theory:
   What does "high sensitivity" mean in this context?

Signal	Detect a Signal	Do Not Detect a Signal
Present	Hit *The screener recognizes a box cutter in the luggage.*	Miss *The screener fails to see the box cutter in the luggage.*
Absent	False alarm *The screener thinks there is a box cutter in the luggage when there is none.*	Correct rejection *The screener recognizes that there is no box cutter in the luggage, and there is indeed none.*

3. Searching for something can be made harder when there are "distractors" around your target object. In addition, there is something called the "Array Size" Effect. Explain this
4. Feature search (Searching for a distinguising feature amongst distractors) is in general, more efficient than conjunction search. What is the main reason for this?
5. Give one example of selection attention

6. Explain what Similarity theory is, in terms of searching for an object
7. Explain what guided search theory is

people are attracted by similar people

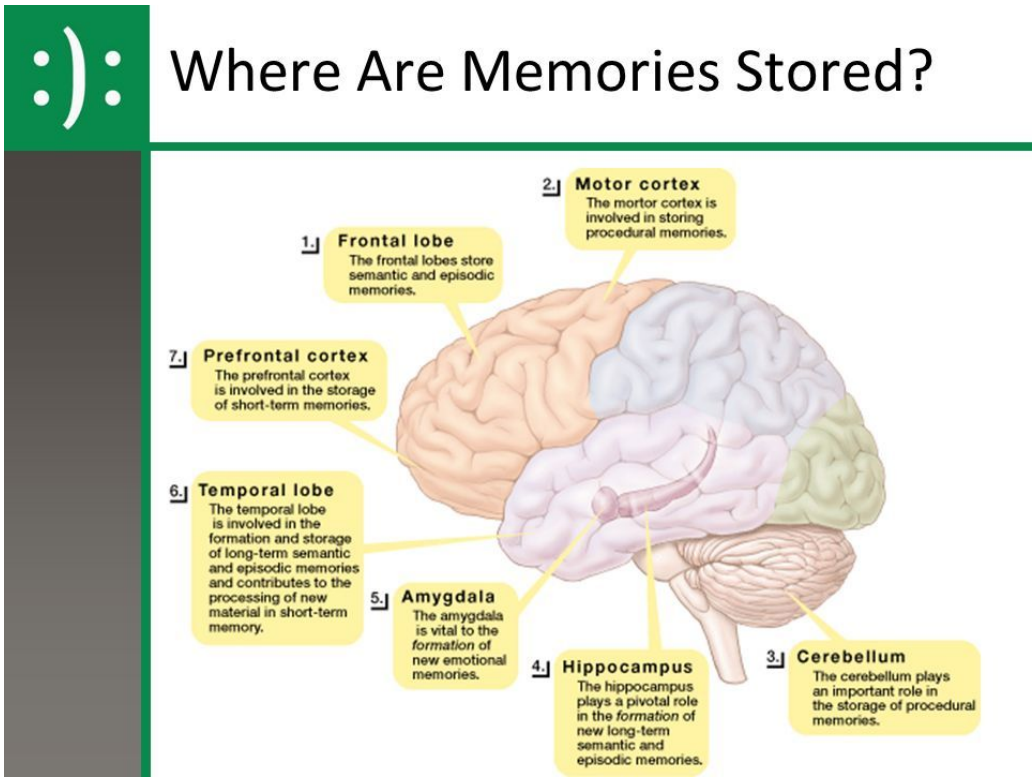
8. Are dichotic listening tasks normally successful?
9. What does a posner cuing task measure? Reaction time
10. What is early filtering? Compare it to late filtering

Tewe first process multiple basic features simultaneously across a large field, we then look for one specific element or combination of basic features at a time in a smaller area xt

11. What is the difference between voluntary attention and reflexive attention?
12. Explain the difference between covert and overt attention
13. The superior frontal gyrus dictates what form of attention (Bonus: Where is the superior frontal gyrus located?)
14. Name the 3 parts of the brain most involved in attention

15. Some people have problems with their attention. Name the (probably) most common one
16. What is change blindness?
17. What part of the brain, if damaged, can lead to spatial neglect? Give an example of spatial neglect
18. When you ride a bike for the first time, you pay a lot of attention to keeping your balance. Later, after moving to the netherlands, you find you pay very little attention

to keeping your balance. In fact, you don't even need to think about the mechanics of riding the bike. What is this an example of?



Lecture 5: Memory

Basic:

1. Give the definitions for learning and memory
2. Memory is a complex subject with many different stages. Explain these:
    a. Memory-encoding
        i. Acquisition
        ii. Consolidation
    b. Memory-storage
    c. Memory-retrieval
3. Give one structure contained in the *medial temporal lobe memory system*
4. The model modal of memory appears to be sequential in nature. Explain this sequential nature, using terms such as attention, rehearsal, short term memory, long term memory, sensory input, and sensory register.
5. It has become clear that there are different types of memory. Explain each of these, and explain its characteristic features:
    a. Short Term Memory
        i. Auditory
        ii. Visual
    b. Long Term Memory
        i. Declarative
        ii. Non-Declarative

6. What is echoic memory, and iconic memory in the short term memory system. Make reference to the concept of memory traces
7. What is *priming*, and what type of memory does it belong to?
8. Working memory helps explain how we do quick mental processes like multiplying numbers in our head. This requires *maintenance* and *manipulation*. Explain these terms.
9. Declarative Memory can be split into two parts, explain each part:
    a. Semantic Memory
    b. Episodic memory.

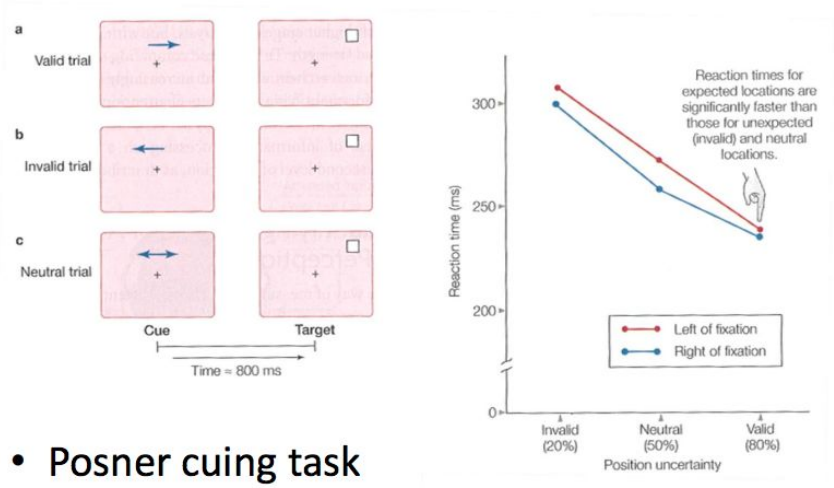
10. When is non-declarative memory revealed?
11. Procedural memory is a sub-category of memory. Is it declarative or non-declarative?
12. What is a flashbulb memory?
13. There are experiments where people are asked to remember many things. In these experiments, people show the *primacy effect*, and the *recency effect.* Explain these terms.
14. Explain the following sentence: Distributed practice is more effective than massed practice.
15. Explain the following sentence: Memory is not just reconstructive, it is also constructive. (This is actually a very deep question, the answer could be over a page long)

16. Give an example of memory-encoding specificity
17. Anatomy of memory:

a. What is absolutely 100% essential for memory consolidation
b. What is the standard consolidation theory (Squire)
c. What is the function of place and grid cells?

18. Explain the following Memory Deficits:
    a. **Anterograde amnesia:**
    b. **Retrograde amnesia:**
    c. Do people with retrograde amnesia have working short term memory? How would they fair in a digit span test?
19. In the modal model of memory, information can be lost by *decay* and *interference*. What do these terms mean?

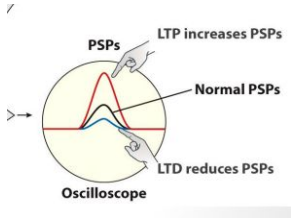
Selective spatial attention

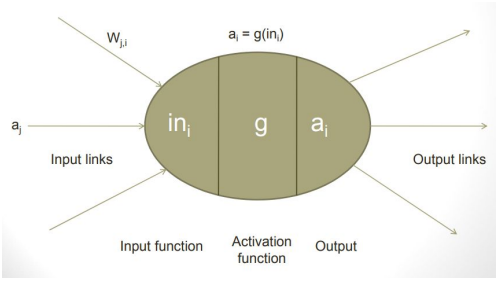


- Posner cuing task

Lecture 6: Learning

Basic:

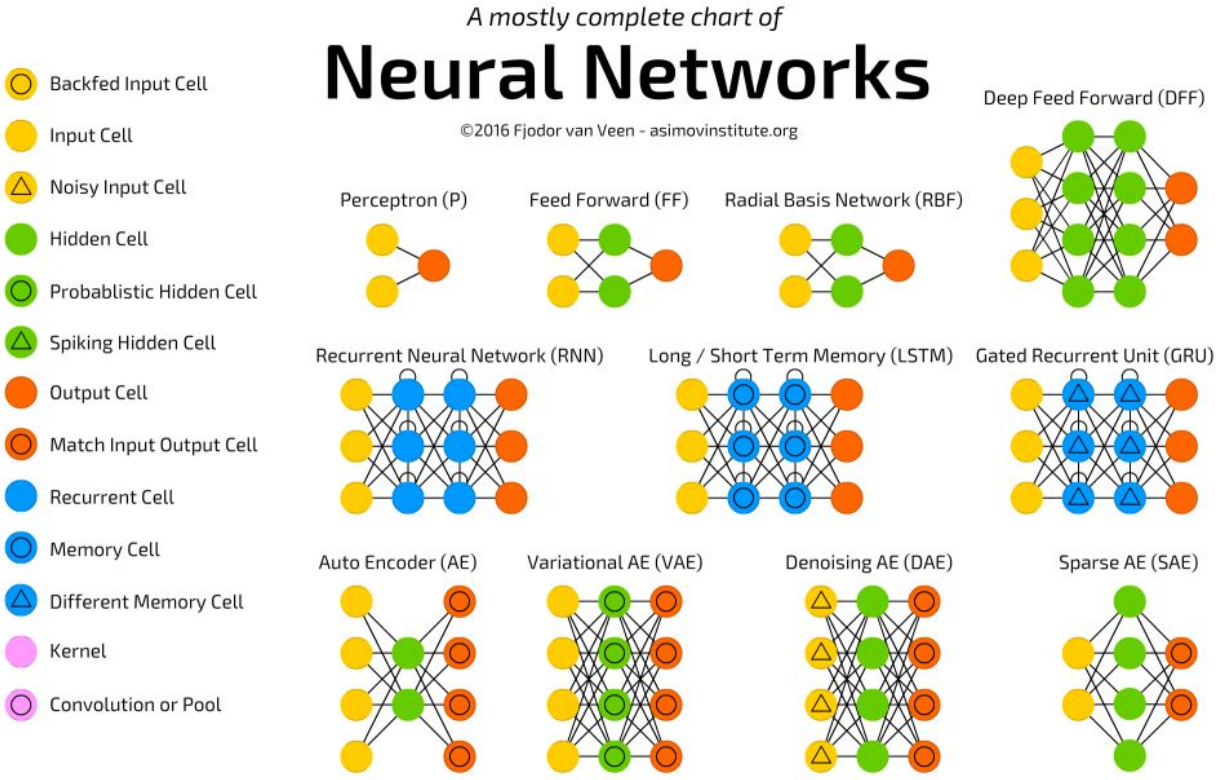
1. What is hebbian learning? What is hebb's rule?
2. Someone practices a skill for a long time. Is this LTP, or LTD?
    a. Would the relative strength of an EPSP increase or decrease when this neural circuit is activated
    b. Is the synapse getting stronger or weaker?
    c. 

    d. Associative Long Term Potentiation has three properties: Explain each:
        i. Co-operativity
        ii. Associativity
        iii. Specificity
3. The glutamate receptor, NMDA (N-Methyl-D-Aspartate), is extremely important for its role in synaptic plasticity. Why exactly is it central to producing long term potentiation? *
4. There are different paths in the hippocampus**
5. There are different types of learning, explain each of these types:
    a. Supervised Learning
    b. Reinforcement learning
    c. Unsupervised Learning
6. There are also different timescales of learning, explain each of these timescales:
    a. Developmental learning
    b. Behavioral learning
    c. Evolutionary learning
7. Neural Networks are used a lot in machine learning. What are some of the main benefits/advantages of using them?
8. There are different structures for neural networks, explain each of these:
    a. Feed forward
    b. Fully connected
    c. Recurrent network
9. 

10. In neural networks, a linear weighted sum is transformed by a non-linear activation function. Why is it crucial that this activation function is non-linear?
    a. ANSWER: Activation functions cannot be linear because neural networks with a linear activation function are effective only one layer deep, regardless of how complex their architecture are. Non-linearity is needed in

activation functions because its aim in a neural network is to produce a nonlinear decision boundary via non-linear combinations of the weight and inputs

11. Describe the perceptron. The type of network, the number of layers, the type of learning, the type of activation function, the type of architecture.
12. Describe the algorithm used in the perceptron in words. This is an important question.
13. Under what cases will the perceptron converge?
14. Which class of problems can be represented by a 2-layer perceptron
15. Why can't the XOR-function be successfully classified with a perceptron?
16. The XOR-function can be classified if we add more layers to our perceptron. What are some of the disadvantages of the multi-layer perceptron? Give three.



Lecture 7: Methods of cognitive neuroscience

Basic Questions:

1. There are two fundamental types of experiment. These are *correlational* and *experimental*. What is the difference between the two?
2. Computer models are used throughout neuroscience. What are the pro's and cons?
3. Lesion studies are used in neuroscience. What are the pro's and cons?
4. What is the difference between single dissociation and double dissociation, and how can we use these to infer dependent and independent processes

Much closer to Marr's implementation level, which eventually will lead to neuromorphic computing (where a computer can change its own network). CONS: oversimplify, not biologically plausible,…

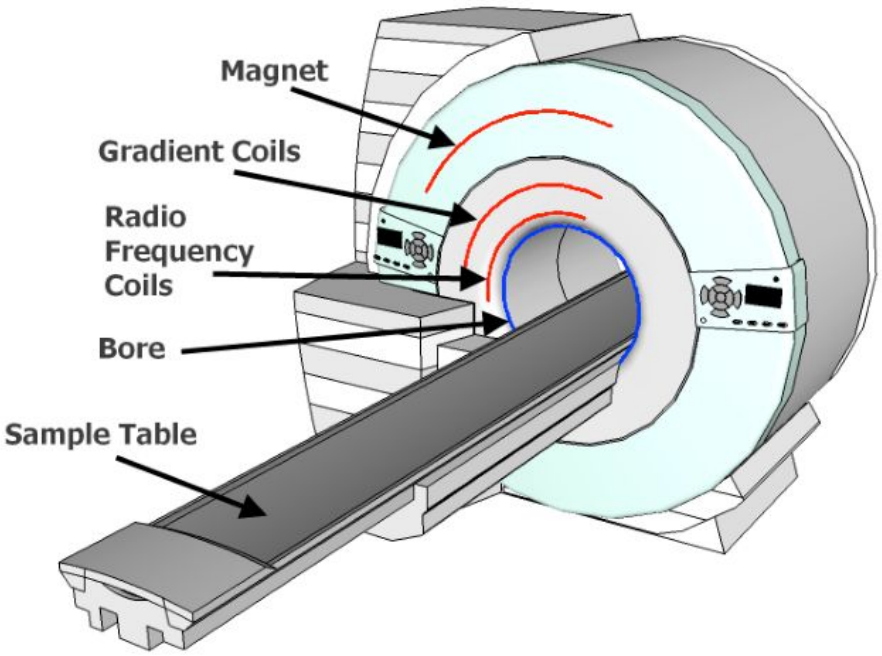
5. A CT scan (computed tomography) uses x-rays. What is the principle behind why it works? What do x-rays do?
6. How does an MRI work? Mention the following:
    a. How atoms are before the MRI
    b. How they are when they enter the magnetic field produced by the MRI
    c. What happens when a radio frequency is applied in addition to the magnetic field
    d. What happens when the radio frequency is then turned off, and how the energy signal of these atoms is captured to form an image
7. MRI scanners are classfied by their Tesla. (1.5T - 9.4T). What does this number mean? When would you want a 9T as opposed to a 5T
8. What is diffusion MRI?
9. What is Larmour frequency?

10. The gyromagnetic ratio is the ratio between Hertz/Tesla. In terms of a single particle, the gyromagnetic ratio is the ratio between the particles magnetic moment and its _____?
11. What is anistropic diffusion? What are the pro's and cons?
12. Single cell recording is what allows us to do cortical mapping, and to create brain-machine interfaces. What are the pro's and cons of single cell recording?
13. What is the difference between temporal resolution and spatial resolution?
14. EEG allows us to measure brain activity by using cheap electrodes to measure groups of neurons that fire in parallel. They are cheap, and have high temporal resolution, but low spatial resolution. Why?

15. We need to do time-frequency analysis with EEGs. Why?
16. Electro-encephalogram is one way of measuring brain activity. Magneto-encephalogram is another. Why is this in some ways better than EEG? Better spatial resolution
17. PET scan is very different from CT scan or EEG/MEG. Why is it different? What are some of the disadvantages?

Questions on fMRI which are by far the most important part of this section:

1. Nonexistent. Here's a picture of an MRI

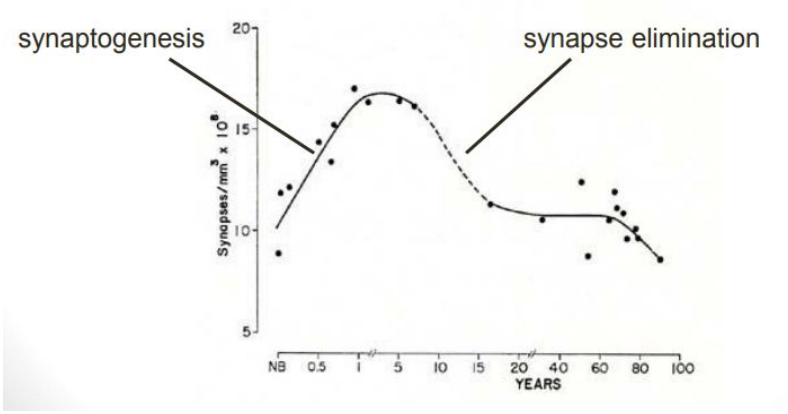


Lecture 8:

Basic:

1. What 2 main problems does the Radial unit hypothesis address?
    a. Brain size ratio:
    b. Columnar nature of the cortex:
2. What is the process of the radial unit hypothesis?
    a. Proliferation:
    b. Migration
    c. Specialization
    d. Synpatic pruning and neural death

3. What is more important for intelligence: brain size or brain connectedness?

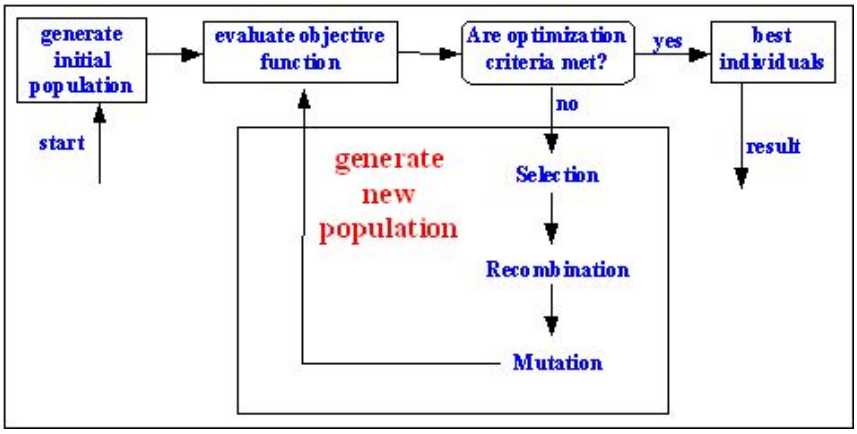
4. The human brain, specifically the frontal cortex, has specific specializations which make it function better. What are these specific specializations, in terms of dendrites and number of connections?
5. What is synaptic pruning?
    a. 

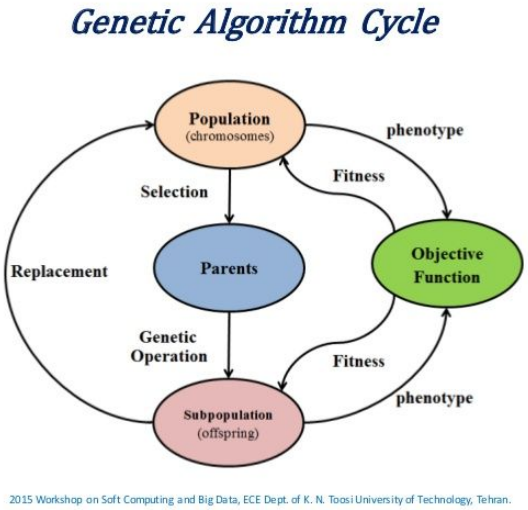
6. The myelination of axons in humans continues far into life. Is this a random process or do certain groups of axons myelinate in a specific order? What is prioritized?
7. Give an example of neural plasticity in the human brain (blind people + fingertips example)
8. Define the following terms in Genetic Algorithms:
    a. Cross-over:
    b. Mutation:
    c. Fitness value (in what range is this value?)
    d. Population
    e. Genotype / Individual

9. Define the following methods of selection:
    a. Elitist selection:
        i. What is the advantage/disadvantage? (important question)
    b. Roulette Wheel selection:
        i. What is the advantage/disadvantage?
        ii. In what case may this actually approximate elitist selection?

c. Tournament selection
    i. What is the advantage/disadvantage?

10. Write a short paragraph on the pros and cons of genetic algorithms. Must mention applicability, implementability, local minima, compare it to backprop, variation, difficulty of encoding fitness, parallelization.





Lecture 9: Language

Basic:

1. Explain the components of language: Syntax and Semantics.
2. What is overextension error? Give an example (Helicopter gets called an Aeroplane)
3. What does it mean when we say language is recursive?
4. The rate of language acquisition changes across demographics (T/F)
5. There is no critical period in a human lifespan to learn a new language (T/F)
6. Multilingual children may have some advantages over monolingual children. Give one possible advantage.
7. What is a morpheme in language
8. What is a phoneme
9. What is a grapheme
10. Language is left lateralized in the brain. What exactly does this mean?
    a. What are the main areas in the brain that handle language? (The language 'hardware')
11. Explain the following language/speech deficits:
    a. Broca's Aphasia:
    b. Wernicke's Aphasia: (Fluent aphasia):
12. What is coarticulation?
13. What is transformational grammar, as introduced by Chomsky?
    a. It follows from this is that grammar is recursive. What does this mean?
14. Rewrite the following sentence in normal english:
    a. Prosody can help alleviate the segmentation problem brought about by excessive coarticulation of phonemes.
    b. Why is speech perception, in general, harder than reading perception?
15. Explain the 'pandemonium' aspect of Selfridge's pandemonium model, with respect to reading the letter R
16. What is the invariance problem?