

# Zoo400 Final Exam: May 13, 1999

NAME:

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There is only 1 best answer per question. (1 pt each)

1. A 3x7 feedforward matrix can be alternatively represented as a full-connectivity matrix of what dimension?
  - (A) 7x7
  - (B) 3x3
  - (C) 7x3
  - (D) 3x7
  - (E) 10x10
  
2. Reduced firing below spontaneous rate resulting in reduced release of neurotransmitter GABA is indicative of the following state\*weight multiplication according to slow potential theory:
  - (A)  $1 * -1 = -1$
  - (B)  $-1 * 1 = -1$
  - (C)  $1 * 1 = 1$
  - (D)  $-1 * -1 = 1$
  - (E)  $0 * -1 = 0$
  
3. In the physical limulus eye, wraparound
  - (A) provides for wider peripheral vision
  - (B) allows for the neurons to inhibit further
  - (C) produces Mach bands
  - (D) is nonexistent
  - (E) is responsible for lateral inhibition
  
4. According to the Cajal neuron doctrine
  - (A) Calculations are performed in dendritic subdomains
  - (B) Coincident firing of pre- and postsynaptic cells will lead to increased synaptic strength between them
  - (C) Dendrites are inputs and axons are outputs
  - (D) Signals back-propagate up dendrites
  - (E) Calculations are done in a neuropil syncytium

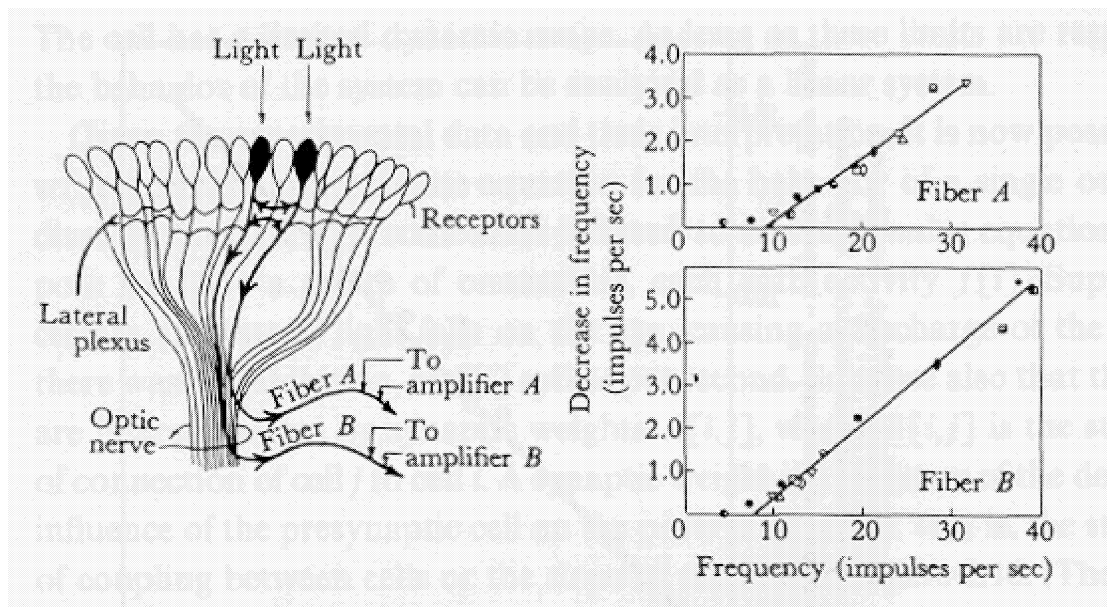
5. The physiological basis for the rate coding interpretation of the squashing function is:
- (A) neurons fire faster as input increases then reach a maximum firing state and decrease their rate at higher levels
  - (B) neural firing shows monotonic decrease in rate with increasing input
  - (C) neurons cannot fire faster than a certain rate and there is no negative firing rate
  - (D) the slow potential of the neuron nullifies the summation procedure, resulting in a paradigm conflict which may continue unresolved for generations, ultimately terminating with mach bands.
  - (E) neurons are binary: either they fire or don't fire at any given time
6. All of the following are properties of a Hopfield network EXCEPT
- (A) Ability to clean up noisy inputs.
  - (B) Ability to function despite minor damage to the network.
  - (C) Ability to perform pattern completion.
  - (D) Attractor dynamics.
  - (E) Feedforward information flow.
7. Which vector operation is analogous to the multiplication of the incoming states times weights onto a single neuron in a neural network?
- (A) inner (dot) product
  - (B) outer product
  - (C) derivative
  - (D) integral
  - (E) summation
8. Which units show symmetrical connectivity (unit 1 projects to unit 2 with the same strength as unit 2 projects to unit 1) in the following weight matrix?

$$\begin{pmatrix} 0.4 & -0.2 & 0.1 & 2 \\ 0.2 & -1.3 & 0.7 & -1.1 \\ 0.3 & 0 & -.2 & -.2 \\ -3 & -1.1 & 1.1 & -.7 \end{pmatrix} \begin{pmatrix} a \\ b \\ c \\ d \end{pmatrix}$$

- (A) a and b
- (B) a and c
- (C) b and c
- (D) c and d
- (E) b and d

9. According to Hebb's rule
- (A) Calculations are performed in dendritic subdomains
  - (B) Coincident firing of pre- and postsynaptic cells will lead to increased synaptic strength between them
  - (C) Dendrites are inputs and axons are outputs
  - (D) Signals back-propagate up dendrites
  - (E) Calculations are done in a neuropil syncytium
10. Which of the following is **NOT** true about lateral inhibition?
- (A) In the limulus eye, inhibitory effects add up linearly.
  - (B) Lateral inhibition produces Mach bands because highly excited cells at one side of a steep luminance gradient strongly inhibit neighboring weakly stimulated cells on the other side and are in turn weakly inhibited by these cells
  - (C) Lateral inhibition is an effective model for edge detection.
  - (D) Inhibition between receptors in the lateral inhibition network of the limulus eye is primarily from medial receptors to more lateral receptors.
  - (E) Lateral inhibition can clean up messy input(i.e. spillover of light to neighboring receptors.)
11. When viewing a portion of a particular object, we can recall or visualize the entire object (i.e. I see rosy cheeks and a button nose and I think of Santa). This is an example of
- (A) heteroassociative memory
  - (B) autoassociative memory
  - (C) pattern completion
  - (D) lateral inhibition
  - (E) graceful degradation

The following question refers to the following figure presenting a limulus experiment.

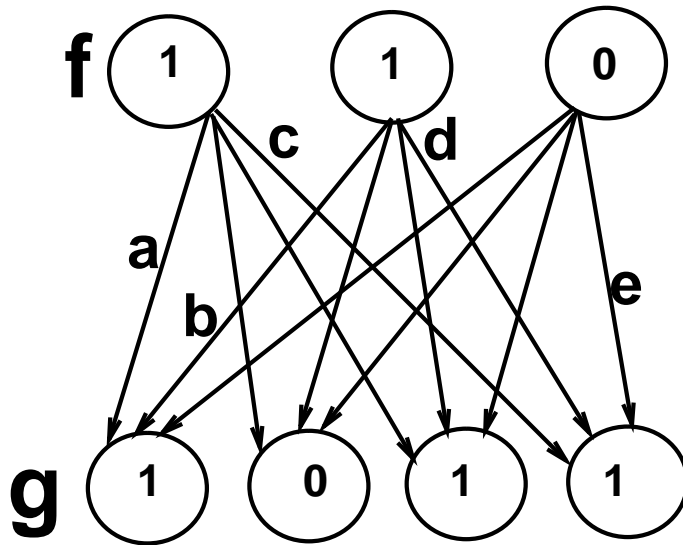


12. The figure illustrates
  - (A) One way inhibition  $A \rightarrow B$
  - (B) One way inhibition  $B \rightarrow A$
  - (C) Mutual inhibition
  - (D) Wraparound inhibition
  - (E) Mutual excitation
  
13. The following are all methods used for looking at physiology EXCEPT:
  - (A) CAT scan (computerized axial tomography)
  - (B) Intracellular electrical recording
  - (C) Extracellular electrical recording
  - (D) Patch clamp
  - (E) PET scan
  
14. A cell in the limulus eye more strongly inhibits those cells that are
  - (A) at greater distance from it
  - (B) nearest to it
  - (C) at intermediate distance
  - (D) even multiples of units away
  - (E) odd multiples of units away
  
15. Summation of associative memory matrices constructed from outer-products is a linear-algebra algorithm to produce a multi-memory matrix. This is a non-local procedure. The corresponding local procedure in a network of processing units would use:
  - (A) Slow potential theory
  - (B) Dendritic back-propagation

- (C) Hebb's rule
  - (D) Spontaneous firing
  - (E) Dot products
16. One potential problem with the local procedure described in the previous question that would not be found with the non-local algorithm would be:
- (A) Crosstalk due to non-orthogonal input vectors.
  - (B) Crosstalk due to non-orthogonal output vectors.
  - (C) Co-activations from old memories interfering with recording of new memories.
  - (D) Driving all weights to their maximum values.
  - (E) Driving all states to their maximum values.
17. The original Hebb's rule states that ONLY coincident activity in pre- and postsynaptic neurons produces an augmentation in synaptic strength between the neurons. Which of the following is not consistent with the original Hebb's rule in the context of an outer-product associative memory model:
- (A) Use of a sigmoidal activation function.
  - (B) Use of a sharp threshold for an activation function.
  - (C) Use of -1/1 vectors
  - (D) Use of positive weights
  - (E) Use of 0/1 vectors
18. Biological systems are typically adapted to have maximal responsiveness to particular types or patterns of stimuli that are salient (important) for the organism. From what we know of limulus eye physiology, which of the following is likely to be particularly salient:
- (A) Diffuse light
  - (B) A strongly focused point of light
  - (C) Infrared light
  - (D) A pulsating light
  - (E) A strongly contrasted edge

19. Consider a connectivity matrix for a 7 unit limulus simulation with symmetrical inhibition but without wrap-around with a maximal projection distance for any given unit of 3 units to either side. All of the following are locations of 0s in this matrix except: [Hint: draw the matrix, row and column numbering starts with 1]
- (A) 1,7
  - (B) 7,1
  - (C) 7,3
  - (D) 7,4
  - (E) 6,2
20. The brain doesn't use matrices and vectors. The process of using matrix algebra to understand memory is an example of
- (A) bottom-up design
  - (B) side-to-side design
  - (C) poor design
  - (D) top-down design
  - (E) design from first principles
21. According to rate coding theory, neurons can encode negative values so long as they have:
- (A) dendrites
  - (B) slow potentials
  - (C) IPSPs
  - (D) a spontaneous rate
  - (E) Hebbian synapses

The following questions refer to the heteroassociative network constructed with an outer product using  $f$  as an input and  $g$  as an output:



22. Which of the weights is 0?
- (A) a
  - (B) b
  - (C) c
  - (D) d
  - (E) e
23. Utilizing a linear activation function without squashing ( $f(x)=x$ ) for this heteroassociative matrix, presentation of the  $f$  will yield:
- (A)  $g$
  - (B)  $0.5 * g$
  - (C)  $0.25 * g$
  - (D)  $2 * g$
  - (E)  $4 * g$
24. The correct output in this case can be obtained by normalization or by thresholding or both. Appropriate normalization in this case requires dividing by:
- (A) The number of memories
  - (B) The average dot product of the inputs
  - (C) The average dot product of the outputs
  - (D) The average dot product of the input and output
  - (E) No normalization is needed

25. In an heteroassociative memory, what property of multiple vector pairs prevents crosstalk between memories?
- (A) Orthogonality of input vectors
  - (B) Orthogonality of output vectors
  - (C) Orthogonality between each input vector and its corresponding output vector
  - (D) An inner product between each input vector and its corresponding output vector equal to 0
  - (E) An outer product between each input vector and its corresponding output vector equal to 0
26. Which of the following is not true in standard linear algebra:
- (A) A row vector times a column vector gives the dot product
  - (B) A row vector times a column vector gives a scalar
  - (C) A column vector times a row vector gives a matrix
  - (D) A column vector times a row vector gives the outer product
  - (E) The transpose of a vector has the same elements in opposite order
27. Maximum rate of neuron firing is limited by the duration of the action potential. An approximate value for maximum rate would be:
- (A) 50 Hz
  - (B) 100 Hz
  - (C) 200 Hz
  - (D) 1000 Hz
  - (E) 5000 Hz

The following refers to the vectors  $A = [1010]$  and  $B = [1101]$ .

28. Let  $M$  be an outer product associative memory matrix with  $A$  as the input and  $B$  as the output. What is the result of multiplying  $M * C^T$  where  $C = [1001]$ .
- (A)  $[1\ 0\ 1\ 0]^T$
  - (B)  $[1\ 0\ 0\ 1]^T$
  - (C)  $[0\ 1\ 1\ 0]^T$
  - (D)  $[1\ 1\ 0\ 1]^T$
  - (E) I can't tell because of the crosstalk
29. Which of the following is not an accurate order-of-magnitude measure?
- (A) Dendrite:  $1\text{mm} \times 5\mu\text{m}$
  - (B) Soma diameter:  $30\mu\text{m}$
  - (C) Synaptic cleft:  $<1\mu\text{m}$
  - (D) Axon:  $1\text{m} \times 5\mu\text{m}$
  - (E) Brain:  $10\text{cm}$  across



30. Converting a matrix representation of an associative memory to pictorial form can be done by [NB: assume vector on right  $W^*s$ ]
- (A) mapping the elements of each matrix row as convergence onto the corresponding unit
  - (B) mapping the elements of each matrix column as convergence onto the corresponding unit
  - (C) mapping the elements of the vector as convergence onto the corresponding unit
  - (D) mapping the elements of the vector as divergence onto the corresponding unit
  - (E) transposing the matrix and then mapping the elements of each row as convergence onto the corresponding unit
31. Which of the following is indicative of reduced activity [according to neurobiology/rate coding theory/slow potential theory.]
- (A) depolarization
  - (B) GABA transmitter release
  - (C) decrease in interspike intervals (spike firing period)
  - (D) an excitatory postsynaptic potential (EPSP)
  - (E) increase in firing frequency
32. Dale's law states that each neuron only uses 1 primary neurotransmitter for all of its projections. An easy way to address Dale's law in an artificial neural network is:
- (A) Use a sigmoidal activation function.
  - (B) Use a sharp threshold for an activation function.
  - (C) Use -1/1 vectors so that multiplication yields a Hebb's rule variant with synaptic augmentation based on coincident inactivity
  - (D) Assume that all processing units are excitatory and add an interneuron in synaptic series for negative projections
  - (E) Use 0/1 vectors so that multiplication yields the classical Hebb's rule.
33. Which of the following sequences would **NOT** represent the ordering of sensory transduction in the limulus eye?
- (A) Generator potential before action potentials
  - (B) Physical stimulus before chemical reaction
  - (C) Activation of the spiking eccentric cell after activation of the nonspiking photoreceptor
  - (D) Spike firing before lateral inhibition
  - (E) Change in spike frequency in a cell before a voltage change in that cell.

A large dendrite is  $500 \mu$  long and has a diameter of  $4 \mu\text{m}$ . Calculate the following using the assumption that the dendrite is a cylinder.

**NB:** use  $\pi = 3$  **Area of a cylinder** =  $\pi \cdot \text{diam} \cdot \text{length}$ .

**Volume of a cylinder** is  $\pi \cdot \text{diam}^2 \cdot \text{length}/4$ .

34. The area of the dendrite in  $\text{cm}^2$  is:

- (A)  $1\text{e-}8$
- (B)  $1\text{e-}4$
- (C)  $6\text{e-}5$
- (D)  $6\text{e}3$
- (E)  $3\text{e-}5$

35. The volume of the dendrite in  $\text{cm}^3$  is:

- (A)  $7.5\text{e}3$
- (B)  $6\text{e}3$
- (C)  $6\text{e-}9$
- (D)  $7.5\text{e-}12$
- (E)  $7.5\text{e}12$

36. If depolarization of the membrane allows calcium ions to enter the dendrite at a rate of  $6\text{e}10 \text{ ions/s} \cdot \text{cm}^2$  what will be the average concentration of ions (in  $\text{ions}/\mu^3$ ) in the cytoplasm after 25 ms (assume uniform distribution and no diffusion out of the dendrite)

- (A) 2
- (B) 5
- (C) 10
- (D) 15
- (E) 20

37. A content addressable memory
- (A) Uses pointers to access information.
  - (B) Can perform pattern completion.
  - (C) Is exemplified by random access computer memory.
  - (D) Must use attractor dynamics.
  - (E) Is a necessary property of a parallel distributed processing (PDP) system
38. The delta rule reduces error in a memory matrix by:
- (A) Minimizing crosstalk
  - (B) Gradually increasing the strength of all matrix elements
  - (C) Utilizing an outer product of outputs and inputs
  - (D) Changing the strength of matrix elements depending on an error between desired and target outputs
  - (E) Back-propagating error through the layers of a feedforward network
39. Increasing the length constant of inhibition in the limulus model will tend to have the following effect following stimulation by a spatial step luminance function (low light level on one side with sharp boundary to high light level on other side)
- (A) Reduced activity in strongly stimulated units only
  - (B) Reduced activity in weakly stimulated units only
  - (C) Increased activity in weakly stimulated units only
  - (D) Increased activity in strongly stimulated units only
  - (E) Reduced activity in all units
40. The following are all likely to be aspects of central nervous system function EXCEPT
- (A) asynchronous updating
  - (B) content addressability
  - (C) analog signals
  - (D) labeled lines
  - (E) random access memory

41. The linearity observed in the limulus retina is relatively unusual for sensory systems. A logarithmic relation is more common. What is the primary advantage of the logarithmic relation?
- (A) It improves the response to strong contrasts across the sensory field
  - (B) A given magnitude of sensory stimulus increase will always produce the same magnitude increase in response
  - (C) Doubling the sensory stimulus will still produce the same magnitude increase in response even with a strong initial stimulus.
  - (D) The response to a greater stimulus will be less than the response to a lesser stimulus.
  - (E) There will be a threshold above which sensory responses are strongly increased.
42. Which is an example of a “hack” on the PDP8
- (A) Using the JMP command to place a particular value in the program counter
  - (B) Decrementing an ADD command to obtain a HLT (halt) command
  - (C) Adding 2 numbers in the accumulator
  - (D) Using the SKP command to augment the program counter
  - (E) Using a loop to multiply 2 numbers using repeated ADDs

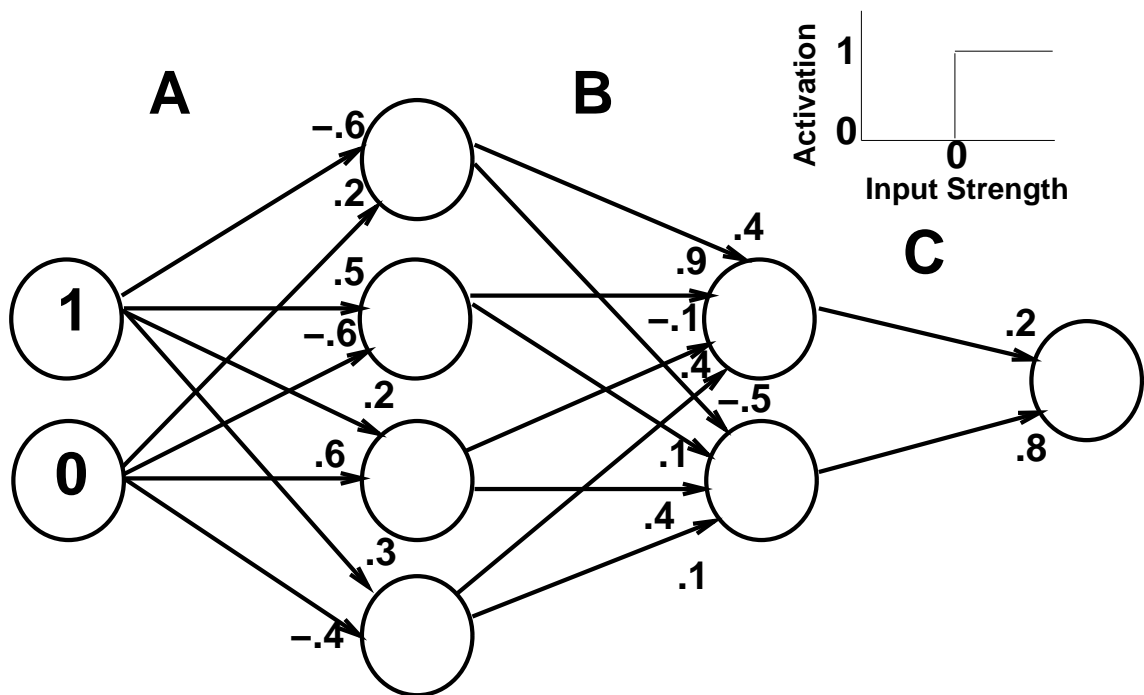
**Interspike intervals: 8 ms, 12 ms, 16 ms, 8 ms, 9 ms**

43. Given the interspike intervals above (in ms), we would say that the firing rate of the cell is most likely about:
- (A) 20 Hz
  - (B) 100 Hz
  - (C) 200 Hz
  - (D) 400 Hz
  - (E) 600 Hz
44. If we wish to detect rates down to 5 Hz, we need to use a slow potential (EPSP) with a total duration of about: [hint: this is total duration, not tau from the alpha function] [double hint: need to be able to detect multiple spikes]
- (A) 10 ms
  - (B) 20 ms
  - (C) 50 ms
  - (D) 200 ms
  - (E) 500 ms
45. If we use the slow potentials needed for the low frequencies mentioned in the previous question, the integration of high frequencies may result in:
- (A) Unmeasurably low potentials
  - (B) Unrealistically high potentials
  - (C) No integration
  - (D) No distinction between different high frequencies
  - (E) No distinction between low and high frequencies

46. The following are all essential parts of a PDP8 digital computer EXCEPT
- (A) program counter
  - (B) accumulator
  - (C) central processing unit
  - (D) floppy disk
  - (E) instruction register
47. The point attractors of a Hopfield network represent
- (A) Initial stimuli that serve as inputs to the system.
  - (B) The stored memories.
  - (C) Continuous repeating cycles in the dynamics of the network.
  - (D) The activation functions for the individual units.
  - (E) Final fixed values for the weights between the units.
48. Assuming that a cell does not have endogenous (internal) firing mechanisms, the following condition is necessary to produce a spontaneous rate consistent with rate coding theory:
- (A) Hebbian synapses
  - (B) strong IPSPs
  - (C) ongoing inhibition > excitation
  - (D) ongoing excitation > inhibition
  - (E) dendritic back-propagation
49. To fully define a dynamical system requires knowledge of all of the following EXCEPT:
- (A) State variable values for different times
  - (B) Parameters
  - (C) Initial conditions
  - (D) Differential equations
  - (E) Dimensionality
50. Which of the following statements is true about orthogonal vectors (NB a/b vector means a binary vector consisting of numbers that are either a or b)
- (A) 1/2 vectors must be of odd length in order to be orthogonal
  - (B) 0/1 vectors must be of even length in order to be orthogonal
  - (C) 0/1 vectors must be of odd length in order to be orthogonal
  - (D) -1/1 vectors must be of even length in order to be orthogonal
  - (E) -1/1 vectors must be of odd length in order to be orthogonal

51. Ascii and bitmaps are 2 alternative ways of encoding the letter 'A'. An advantages of a bitmap for encoding letters is that
- (A) It's likely to be more compact (require fewer bits)
  - (B) It will be relatively easy to convert 'A' to 'a'
  - (C) It can be more easily compared to other coded letters to determine if one of them is also an 'A'
  - (D) A graphical representation of the letter 'A' can be readily generated directly from the code
  - (E) There is less room for ambiguity arising from alternative encodings for the same letter

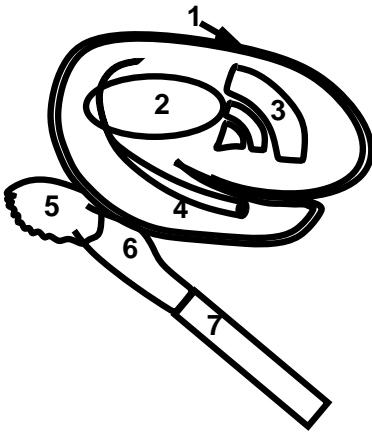
The following questions refer to this network:



52. If we represent the feedforward network with 3 matrices, the following are the correct matrix dimensions:
- (A) A:5x5;B:3x2;C:1x4
  - (B) A:2x4;B:4x2;C:2x1
  - (C) A:4x4;B:2x2;C:1x1
  - (D) A:4x2;B:2x4;C:1x2
  - (E) A:2x2;B:4x4;C:2x2
53. If we represent the entire network with a single matrix, the following is the correct matrix dimension:
- (A) 7x7
  - (B) 9x7
  - (C) 7x9
  - (D) 9x9
  - (E) 6x6

54. In matrix B, the value at row 1, col 2 (numbering from 1) is:
- (A) -.5
  - (B) .2
  - (C) .9
  - (D) .5
  - (E) .8
55. Assuming the activation function shown, what would be the summed input (ie before application of the activation function to that unit) for the output (rightmost) unit after the information feeds forward (NB  $f(0)=0$  for the activation function):
- (A) 1
  - (B) 0
  - (C) .2
  - (D) .8
  - (E) .16
56. Assuming the activation function shown, what would be the state of the output (rightmost) unit after the information feeds forward (NB  $f(0)=0$  for the activation function):
- (A) 1
  - (B) 0
  - (C) .2
  - (D) .8
  - (E) .16
57. The primary cause of crosstalk in an associative network is:
- (A) nonorthogonal input vectors
  - (B) nonorthogonal input/output pairs
  - (C) using 0/1 vectors instead of 1/-1 vectors
  - (D) lateral inhibition
  - (E) iterative solution
58. Mach bands in the limulus simulation demonstrate the phenomenon of
- (A) edge enhancement
  - (B) crosstalk
  - (C) analog inaccuracy of neuron coding
  - (D) the limulus is old. it needs to evolve.
  - (E) non-linear squashing

59. Given  $n$  element 0/1 vectors with  $p$  1 values (and  $n - p$  0 values), how many mutually orthogonal vectors can be constructed? [hint: try it with some example short vector]
- (A) not enough information to answer
  - (B)  $2^p$  orthogonal vectors
  - (C)  $2^{n-p}$  orthogonal vectors
  - (D)  $2p$  orthogonal vectors
  - (E)  $n/p$  orthogonal vectors



60. A motor area involved in sequencing

- (A) structure #1
- (B) structure #2
- (C) structure #3
- (D) structure #4
- (E) structure #5

61. structure #1

- (A) thalamus
- (B) basal ganglia
- (C) hippocampus
- (D) cortex
- (E) cerebellum

62. structure #5

- (A) thalamus
- (B) basal ganglia
- (C) hippocampus
- (D) cortex
- (E) cerebellum



63. Control of the face and a passageway from brain to body:
- (A) structure #2
  - (B) structure #3
  - (C) structure #4
  - (D) structure #5
  - (E) structure #6

64. Relaying of sensation up to consciousness:
- (A) structure #1
  - (B) structure #2
  - (C) structure #3
  - (D) structure #4
  - (E) structure #5

The following refer to the vectors  $A = [1111]$  and  $B = [1100]$ .

65. Suppose that the elements of A represent the input states to a neuron from neighboring cells. Suppose B is the weights of the connections. What is the total summed input to the neuron?
- (A) 0
  - (B) 1
  - (C) 2
  - (D) 3
  - (E) 4
66. When viewing a particular object, we can recall associations of that object (i.e. I see Santa and think of presents). This is an example of
- (A) heteroassociative memory
  - (B) autoassociative memory
  - (C) pattern completion
  - (D) lateral inhibition
  - (E) graceful degradation

**Here are 2 vector pairs**

**Pair 1 – Input ( $f_1$ ): (-1 1 -1 1) → Output ( $g_1$ ): (-1 -1 1 -1)**

**Pair 2 – Input ( $f_2$ ): (-1 -1 1 -1) → Output ( $g_2$ ): ( 1 -1 -1 1)**

67. If these 2 vector pairs are likely to have crosstalk problems, which of the following f/g pairs would not give crosstalk problems if combined with  $f_1/g_1$ ?
- (A) The 2 vector pairs given above will not have crosstalk problems.
  - (B) (1 1 1 -1) → (1 1 -1 1)
  - (C) (1 1 1 1) → (-1 1 -1 1)
  - (D) (-1 -1 -1 1) → (-1 1 -1 1)
  - (E) (-1 -1 1 -1) → (-1 -1 -1 -1)

68. Electron microscopy but not light microscopy can be used to see which of the following:
- (A) Dendrite
  - (B) Action potential
  - (C) Synapse
  - (D) Axon
  - (E) Dendritic spine
69. Which of the following supports the hypothesis that the central nervous system uses rate coding?
- (A) The existence of tonic and phasic responses.
  - (B) Burst firing
  - (C) Synchronous firing of different neurons
  - (D) Neurons that fire rarely
  - (E) Neurons that fire regularly at rest
70. Which of the following is NOT true of Marr's 3 levels of investigation?
- (A) The problem level defines what overall task a particular system is doing
  - (B) How a task is implemented in the brain must be understood before an algorithm can be devised
  - (C) The algorithm involves a step-by-step approach to solving the problem
  - (D) Implementation can be realized using either neurons or software
  - (E) In vision, Marr took the central problem to be recreation of the 3-D reality from the 2-D retinal representation