1. Multiple choices. (Total points 40pts = 4pts x 10, +2 bonus questions)

(1) Which one of the following statements is NOT true?

A. Each brain hemisphere is concerned primarily with sensory and motor processing of the contralateral side of the body.

B. The brain hemispheres are similar in structures and functions.

C. Different brain regions are specialized for different functions.

D. The Brodmann areas of cortex are mainly defined based on structural information rather than functions.

(2) What is NOT part of a typical neuron?

A. cell wall   B. dendrite   C. axon   D. nucleus

(3) The release of presynaptic neural transmitter vesicles is triggered by ( ).

A. Ca^{2+} B. Na^+ C. ATP   D. ligands

(4) The main ionic contributor of the membrane resting potential is ( ).

A. Chloride ion influx   B. Calcium ion influx

C. Sodium ion influx   D. Potassium ion outflow

(5) Which of the following does NOT contribute to the resting potential?

A. Concentration of ATP

B. The existence of Na^+- K^+ pump

C. Permeability of membrane to various ions

D. Ion concentration difference inside and outside the membrane

(6) Which of the following does NOT contribute to the diversity of information transmission?

A. The same type of ion channel will have different subtypes.

B. Cascade process of signal from presynaptic membrane to postsynaptic membrane.

C. There are different types of neurotransmitters, including acetylcholine, GABA, glutamate, etc.

D. Acetylcholine receptor has N type, M1 type and M2 type.

(7) Which scientist(s) provided the first complete description of ionic mechanisms underlying action potentials?

A. Ramon y Cajal   B. Charles Sherrington

C. Hodgkin and Huxley   D. Hubel and Wiesel

(8) The absolute refractory period of frog myelinated nerve fibers lasts for 2ms. Theoretically, the number of action potentials generated per second cannot exceed ()

A. 50   B. 500   C. 100   D. 200

(9) Which is the main contributor to the membrane hyperpolarization after action potentials?

A. Na^+ channels   B. K^+ channels   C. Ca^{2+} channels   D. Na^+- K^+pumps

(10) Which of the following is always stable/constant over time?

A. The duration inter-spike interval of a single neuron.

B. The number of spikes from a V1 neuron counted in a fixed time window after seeing the same stimulus in repeated trials.

C. The widths of action potentials detected by an intra-cellular recording electrode at soma.

D. The heights of action potentials detected by an extra-cellular recording electrode.

(11) According to the exponential distribution family, what is incorrect?

$$p(x|\eta) = h(x)\exp\left\{\eta^T T(x) - A(\eta)\right\} = \frac{1}{Z(\eta)}h(x)\exp\left\{\eta^T T(x)\right\}$$

A. for Poisson distribution $P(\lambda)$, $\eta = \log(\lambda)$

B. for Gaussian distribution with k different variables, $h(x) = (2\pi)^{-k/2}$

C. for Gaussian distribution with k different variables, $T(x) = \text{vec}(xx^T)$

D. $A(\eta)$ is convex.

(12) The following figure is a demonstration of the data likelihood decomposition in the EM algorithm. What is the question mark "?" part representing?

A. The prior likelihood $q(Z)$.

B. The posterior likelihood $p(Z|X,\theta)$.

C. The joint likelihood $p(X,Z|\theta)$

D. The Kullback-Leibler divergence $KL(q||p)$.
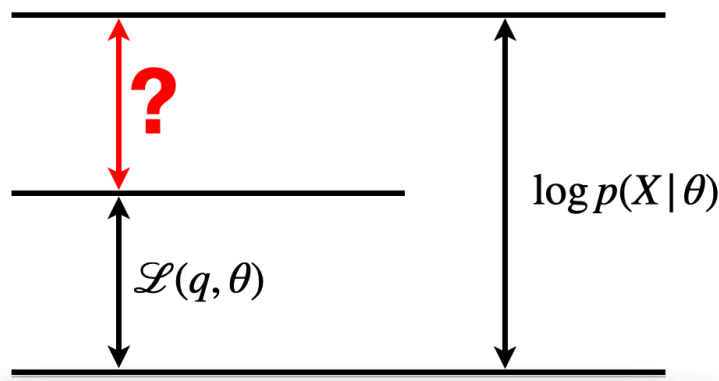
2. Briefly answer the questions. (Total points 60pts = 6pts x 10, +4 bonus questions)

(1) Circle out the occipital lobe on the cortex and describe its major cogitive function.
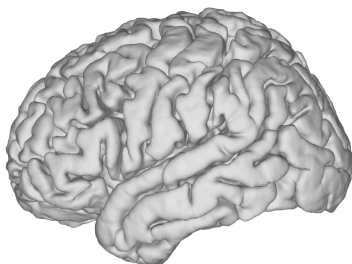
(2) What are the two cell classes of the nervous system? What's the major functional difference between the two?

(3) Describe how action potential is generated.

(4) Describe how action potential is propagated between neurons in a chemical synapse?

(5) What is a spike train? Name two different ways to estimate a time varying firing rate from a spike train.

(6) How to generate a homogeneous Poisson process with rate λ and total length T?

(7) What is the difference between short-term and long-term depolarization?

(8) What is inter-spike interval? Are ISI's in real neuronal data strictly exponentially distributed? Why?

(9)   What is a graphical model? What do a node and a link respectively represent in a graphical model?

(10) Name three spike sorting algorithms introduced in class. Pick one and describe how it works.

(11) What is the difference between classification and clustering?

(12) What is the optimization objective of support vector machines?

(13) How to find a better K in K-means clustering?

(14) What's the major difference between the two clustering algorithms introduced in class: K-means and Gaussian mixtures?

3. (Bonus problem, 20 pts)

(Exponential Mixture). Consider the mixture of exponentials model:

$$P(Z = k) = \pi_k$$

$$P(X \mid Z = k) = \text{Exp}(\lambda_k) = \lambda_k \exp(-\lambda_k X)$$

1) If you are given supervised data examples $\{X_n, Z_n\}, n = 1, 2, \dots, N$. Find the closed form maximum likelihood estimates of the model parameters $\{\lambda_k, \pi_k\}, k = 1, \dots, K$.

2) If you are only given observations $\{X_n\}, n = 1, \dots, N$, and Z is latent variable, derive the E-step and M-step equations for the EM algorithm for finding maximum likelihood estimates of the parameters $\{\lambda_k, \pi_k\}, k = 1, \dots, K$.