I. SHORT ANSWERS (6 points each for a total of 30 points)

1. Describe two contributions made by Ramon y Cajal (1852-1934) in terms of understanding how the brain works.

He proposed the Neuron Doctrine, which states that neurons are independent units and that there are gaps between cells through which they communicate via neurotransmitters.

He also proposed the Law of Dynamic Polarization which views the dendrites as the input area, the cell body as that which integrates the input, and the axon as the area carrying the output signal to other neurons.

2. Describe three properties of the brain that define it as a self-organizing system.

A. The absence of centralized control and the presence of competition among many of the parts that make up the brain.

B. An insensitivity to damage or a high degree of redundancy

C. Capacity for self repair or maintenance

3. During the differentiation phase of brain development, axons must find their way to their targets. Briefly describe three strategies for long-distance targeting.

A. Chemotropism: diffusible chemical gradients that attract or repel the neuron

B. Guide post cells or distributed positional cues: cells or cues that are strategically located in various areas of the developing brain to guide the neuron in a stepwise fashion

C. Preformed pathways or labeled lines: These are formed by things like the radial glial cells or pioneer neurons, which form neural scaffolding that helps guide cells to their destination

4. Describe the Hebbian learning rule that may be the basis for the ‘withdrawal’ of synaptic connections.

Synaptic efficacy decreases if there is uncorrelated activity in the pre- and post-synapse

5. Describe the roles that mitochondrial damage and inhibitory apoptosis proteins play in programmed cell death.

Damage to the mitochondria produces the release of a substance called Diablo (or Smac) which removes the inhibition that the inhibitors of apoptic proteins have on caspases. Removal of that inhibition essentially activates the caspases to start programmed cell death.
II. **DIAGRAM** (total of 20 points)

6. (5 pts) In the sagittal view above, please label each of the following areas with the appropriate letter: a) superior temporal gyrus; b) central sulcus; c) area V1; d) parietal cortex; e) inferior frontal gyrus.

7. (5 pts) In the coronal view of the brain above, please label each of the following areas with the appropriate letter: a) lateral ventricles; b) Sylvian fissure; c) cortex; d) basal ganglia; e) medulla.

8. (5 pts) In the diagram below, please match the following terms with the specific layer or phase: A. G2 phase; B. Ventricular zone; C. G1 phase; D. Marginal zone; E. S phase.

<table>
<thead>
<tr>
<th>Ventricular zone</th>
<th>Marginal zone</th>
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<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
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- **S**
- **G2**
- **G1**
9. (5 pts) In the drawing of the neural tube below, please list a functionally specific brain area that arises from each of the specified regions (each is a distinct answer).

III. **MULTIPLE CHOICE** (One correct answer per question. A total of 10 pts)

10. Which of the following is a lesson about the brain that we have learned from studying evolution:
   A. The current (brain) model is the result of hundreds of years of evolution.
   B. Evolution has a master plan.
   C. **New capabilities have been added on to existing hardware.**
   D. The brain is organized and specialized in at least four dimensions.
   E. Solutions to problems are optimal

11. RELN is a protein whose absence during brain development produces:
   A. Lack of closure of the head area of the neural tube
   B. Hydrocephaly
   C. **Absence of exhuberancy during synaptogenesis**
   D. Migration problems
   E. Unprogrammed cell death

12. During the differentiation phase of brain development:
   A. Cells acquire a phenotype
   B. Synaptogenesis begins
   C. **Cells in the ventricular zone migrate to the cortical plate**
   D. The neural plate becomes the neural groove and that becomes the neural tube
   E. Cells begin to divide at a very fast rate

13. Once uninhibited, these molecules chew up cell proteins and DNA during apoptosis
   A. Caspases
   B. IAPs
   C. Diablo proteins
   D. Bcl-2
   E. Microglia
14. It has been hypothesized that some primate brains became larger and smarter (through evolution) because of:
   A. Changes in body size
   B. Stay at home strategies
   C. Complexities in extracting food
   D. Larger digestive system
   E. None of the above

15. The Law of Dynamic Polarization states that:
   A. The brain is composed of cells that are structurally connected
   B. Electrical conduction of information flows in one direction
   C. The brain is composed of cells that are structurally disconnected
   D. Cells are not functionally independent
   E. Electrical conduction of information can flow in both directions

16. The meninges are composed of 3 layers arranged in the following order from outside (next to skull) to inside (next to brain):
   A. Dura, pia, arachnoid
   B. Pia, arachnoid, dura
   C. Arachnoid, dura, pia
   D. Arachnoid, pia, dura
   E. Dura, arachnoid, pia

17. The evolution of the central nervous system from Cnidaria (e.g., jellyfish) to flatworms was characterized by:
   A. Moving of the eyes to the front of the head
   B. The ability of mammals to climb trees
   C. The appearance of 3-layer networks
   D. Increased segmentation and specialization
   E. None of the above

18. Myelination does NOT:
   A. Occur in the PNS (peripheral nervous system)
   B. Insulate the axon
   C. Speed up conduction
   D. Save energy
   E. Stop postnatally (after the baby is born)

19. The reorganization of the ocular dominance columns in V1 due to loss of input from one eye is an example of:
   A. Neural Darwinism
   B. Radial glial function
   C. Neurogenesis
   D. Cell differentiation
   E. Apoptosis

IV. FILL-IN-THE-BLANK (1 point per answer for a total of 15 points)

20. Follistatin, noggin, and chordin inhibit **BMP2/4** in specific parts of the ectoderm, ultimately influencing those areas to become **neural** tissue.

21. Layer 4 of cortex receives input from **thalamus**; Layer 1 contains primarily **axons**; and Layer 6 sends output to **thalamus**.
22. **Actin** molecules are found on the surface of the **filopodia** of the growth cone.

23. **Exhuberancy** refers to the increase in redundant connections made by a neuron during **synaptogenesis** - some of which are later retracted.

24. Accumulation of CSF in the ventricles results in a condition known as **hydroencephaly**.

25. **Sulci** refers to folds in the cortex, while **gyri** refers to the outer surface areas that are not folded.

26. Fasciculation is the process in which **CAMS** (name of molecules) help bind growing axons together as they migrate to their target destinations.

27. The endoplasmic reticulum plays a role in **protein synthesis**, while the **mitochondria** (organelle in the cell body) are mainly involved in energy production.

V. **TRUE/FALSE** (1 point for each answer for a total of 10 points).

28. Cell death via apoptosis during the life of a human being is considered normal. __T__

29. Class 1 structures formed during migration lack laminar organization __F__

30. Homologous areas refer to those that have similar function but evolved independently __F__

31. CSF is important as a transport mechanism for migrating axons. __F__

32. Increased brain complexity in evolution produces increased cortical lamination of cortex. __T__

33. The corpus callosum are axonal fibers responsible for conducting information from one cortical hemisphere to the other __T__

34. Encephalization refers to the fraction of gross brain size that represents neuronal processing capacity that is not related to body size __T__

35. Radial glial cells are the primary guidance mechanisms early in migration. __T__

36. The choroid plexus is found inside ventricles and is involved in producing cerebral spinal fluid. __T__

37. The Neuron Doctrine states that cells in the brain are bioelectrically driven __F__

VI. **MATCHING** (1 point per answer for a total of 15 points).

38. Match the phases of development with the processes going on during that phase.

   _f_ Migration (a. neural plate → neural groove → neural tube
   _d_ Differentiation (b. G1-S-G2-M
   _a_ Neurulation (c. ocular dominance columns
   _b_ Proliferation (d. acquiring phenotype
   _e_ Synaptogenesis (e. growth cone
   _c_ Synaptic rearrangement (f. radial glia

39. Match the glial cell with its function

   _e_ oligodendrocyte (a. myelination of axons in PNS
   _e_ astrocyte (b. lines ventricles/ involved in CSF production
   _d_ microglia (c. myelination of axons in CNS
   _b_ ependymal (d. mediators of immune response
   _a_ schwann (e. source of CAMs and growth factors

40. Match the type of mapping with the closest associated structure/function

   _d_ retinotopic (a. A1 area
   _a_ tonotopic (b. touch
   _c_ mototopic (c. homunculus for movement
   _b_ somatotopic (d. V1 area