

9.14 Questions on chapter 1 of *Brain Structure and Its Origins*

- 1) What do you already know about brain structures and their organization? What do you expect to learn from this book (class)? Should brain structures and their organization make sense to you? What kind of sense? (See p. 4.)
- 2) What coordinates are used by anatomists in discussing distances and directions within the brain? What are the most common synonyms for the words used?
- 3) What are the commonly used planes of section through the brain?
- 4) Beginning at the caudal end of the central nervous system (CNS), what are the names of the major subdivisions?
- 5) Why is the hindbrain called the “rhombencephalon”?
- 6) What kind of tissue constitutes the CNS? This can be answered by using the name of the tissue in the embryo that gives rise to the developing CNS.
- 7) What is meant by the phrase “primitive cellular mechanisms” in a discussion of the nervous system?
- 8) Contrast the meanings of “synapse” and “bouton” in descriptions of neuronal structures.
- 9) What is a dorsal root ganglion?
- 10) What membrane structures had to evolve in order for action potentials in axons to evolve?
- 11) Contrast excitatory and inhibitory post-synaptic potentials.
- 12) Contrast the nature of conduction in a dendrite and in an axon.
- 13) What is the functional purpose of an active pumping mechanism in the axonal membrane?
- 14) What is the major function of a myelin sheath? In what animal groups is myelin not found?
- 15) What cell types form the myelin of the CNS? And the PNS?
- 16) What is “saltatory” conduction?
- 17) Many sensory receptor cells are not actually neurons. How are they different from neurons, and how do they interact with neurons?
- 18) What kind of molecule are actin and myosin? When is actin found most abundantly in neurons?

- 19) Describe the dream of Otto Loewi that led him to make one of the greatest discoveries of neuroscience in the early twentieth century. What was the discovery?
- 20) Describe the major characteristics of a synapse when tissue of the CNS is examined with an electron microscope? What are some of the various synaptic arrangements seen with the electron microscope?
- 21) Describe active transport mechanisms within the axons of neurons. How are the directions of such transport described?
- 22) What is endogenous activity of a neuron or an organism? Describe examples.

9.14 Questions on chapter 2 of *Brain Structure and Its Origins*

- 1) What are some techniques used to prepare brain tissue for cytoarchitectural studies? Describe some findings of such studies.
- 2) What are some techniques used to prepare brain tissue for fiber-architectural studies? Describe some findings of such studies.
- 3) Define immunohistochemistry. Describe a use of immunohistochemistry for neuroanatomical studies.
- 4) How has histochemistry been used for help in identifying comparable forebrain structures in mammals and birds?
- 5) Describe advantages and disadvantages of using the Golgi method for tracing interconnections of structures in the CNS.
- 6) Who was Ramon y Cajal?
- 7) How did Ivan Pavlov's discoveries make the S-R model of behavior more comprehensive?
- 8) Describe an argument made by Karl Lashley against the adequacy of an S-R model for explaining all human behavior.
- 9) How was the phenomenon of retrograde degeneration used in experiments on animals to establish the existence of a major pathway taken by visual information to the neocortex? What belief was destroyed by the experiments?
- 10) What electrophysiological method can be used to verify the existence of a direct axonal pathway from one location to another in the CNS? It was used by Sherrington and others.
- 11) What was a major difference between the tract-tracing methods of Marchi and Nauta?
- 12) At MIT in the 1960s, Fink and Heimer altered the Nauta method to make it much more sensitive for the tracing of axons. For many pathways, axons could be traced with the new methods to their terminal enlargements (the boutons where synapses are made). Describe another, newer technique that can be used for such tract tracing from neuronal cell bodies to their endings. What problem with all degeneration methods did the newer method overcome?
- 13) What is HRP, and how can it be used for tract tracing?
- 14) Describe advantages of using fluorescent molecules for tract tracing. They have become increasingly used as the sensitivity of fluorescence microscopy has improved.
- 15) What is the method of diffusion tensor imaging? What are its advantages and its limitations?

9.14 Questions on chapter 3 of *Brain Structure and Its Origins*

- 1) Describe some basic, multipurpose actions that every animal, even one-celled animals, must be able to perform.
- 2) How can conduction between cells occur without synaptic connections? Such conduction is found in sponges and in Cnidarians like Hydra.
- 3) In the very early stages of nervous system evolution envisioned by George Parker and George Mackie, there were only one or two cell-cell connections between the sources of sensation and contractile cells that caused movements. What was the addition emphasized by Nauta?
- 4) Define primary and secondary sensory neurons and motor neurons. What is the intermediate network?
- 5) Where are neuronal cell bodies of the peripheral nervous system located?
- 6) How are the words “nerve” and “tract” used in the naming of axon bundles?
- 7) What animal is often called “the simplest living chordate”?
- 8) What is the Bell-Magendie Law? Is it always true?
- 9) What is meant by “primary brain vesicles”?
- 10) In which subdivision of the CNS do visual inputs enter? Describe or name the two visual inputs found in many chordates.
- 11) Summarize the basic rule that governs the process of evolution.
- 12) What are “ongoing background activities”? What type of nervous-system mechanism controls them?
- 13) Approach and avoidance (or flight) movements are controlled by sensory inputs plus one other important thing. What is that other thing (of great importance in the evolution of the CNS)?

9.14 Questions on chapter 4 of *Brain Structure and Its Origins*

- 1) There are no fossils of the brains of ancient or extinct animals. So how can we learn anything about brain evolution?
- 2) In the very early evolution of the chordate neural tube, what led to changes at the rostral end? What kinds of changes?
- 3) Hindbrain expansions in chordates resulted from the evolution of adaptive sensory and motor functions. Give examples of these sensory and motor functions.
- 4) Compare the specializations for taste senses of two fish, the fresh-water buffalofish and the catfish, and how the hindbrain is affected.
- 5) Explain the proposal concerning the first expansion of the forebrain in evolution: What sensory input played a key role? What was special about connections in the striatum?
- 6) What structure in the midbrain has become greatly enlarged in most predatory teleost fish. Contrast the motor functions of two major outputs of this structure, one involving descending axons that cross the midline and the other involving an uncrossed descending projection.
- 7) Why do the pathways from each eye to the midbrain cross to the opposite side?
- 8) What is likely to have led to a second major expansion of the forebrain in evolution?
- 9) A third major expansion of the forebrain has occurred in mammals, apparently because of the evolution of what structure?
- 10) Describe the method of comparing brain size in the various major groupings of chordates. Describe a major result of such comparisons, from comparative studies.

9.14 Questions on chapter 5 of *Brain Structure and Its Origins*

- 1) Does ontogeny really recapitulate phylogeny? What is a “phylotypic stage”? Explain the terms and discuss the concepts in terms of reliable data.
- 2) What is a Cynodont? Why are cynodonts important in the story of brain evolution?
- 3) From memory, list all the major brain subdivisions of the kind of brain an early Cynodont must have had.
- 4) What are three different types of structures of primary sensory neurons? Where are these three types found in a mammal?
- 5) What are the different types of muscle cells?
- 6) What secondary sensory nuclei receive input from axons of the eighth cranial nerve?
- 7) What are the two main types of motor neuron depicted in this introductory chapter?
- 8) Discuss the term “interneuron.” It has a broader meaning and also a more commonly used meaning in discussions of neuroanatomy.
- 9) What is a local reflex channel of conduction, in its strictest sense?
- 10) What is a dermatome? Why are maps of the human dermatomes important in clinical neurology? Why is the face not included in dermatome maps?
- 11) What is the oldest ascending somatosensory pathway that reaches the brain? Contrast this pathway with another pathway that ascends from the spinal cord—a pathway that has often been called the “paleolemniscus” (the ancient ribbon).
- 12) Describe the hypothesis presented in chapter 5 concerning why the cerebellum evolved.
- 13) It is generally true that the larger the cerebral hemispheres, the larger the cerebellum. However, there are a few species of animals without large cerebral hemispheres in which a greatly enlarged cerebellum is found. Which animals? What are the functions for which the cerebellum is important in those animals?

9.14 Questions on chapter 6 of *Brain Structure and Its Origins*

- 1) What cranial nerves carry information from electroreceptors in certain fish? Why is electroreception so useful for these fish? Why is their visual sense not adequate?
- 2) No placental mammals have electrosensory abilities, but one non-placental mammal does have such an ability. Which one? How are this animal's electroreceptive inputs different from electrosensory fish in the cranial nerves involved?
- 3) Another sense that is not highly developed in mammals is infra-red detection. In what animals is this particularly important? Which cranial nerve is involved?
- 4) Bats are not the only mammal with echolocation ability. In what other mammal is it found? Which cranial nerve is greatly enlarged in that animal?
- 5) What is a brain manifestation of the specialization of primates for vision?
- 6) What is a brain manifestation of the specialization of small rodents for using their vibrissae (whiskers) so well? Describe other somatosensory specializations in some mammals/.
- 7) What may be a brain manifestation of the human abilities for complex social interactions?
- 8) What is a striking specialization (specific function unclear) in the brain of the Echidna (the spiny anteater of Australia)?
- 9) What other specializations might have noticeable brain manifestations? Try to think of something not mentioned in chapter 6.

9.14 Questions on chapter 7 of *Brain Structure and Its Origins*

- 1) What is the major reason for the very different effects of forebrain removal in cats and rats?
- 2) Why was forced feeding required to keep decerebrate cats alive after the surgery?
- 3) Describe the behavior that shows how a cat without a forebrain shows no hunger motivation and yet will eat when food is placed in its mouth.
- 4) Is it true to say that the cat's forebrain has "taken over" more functions than the rat's forebrain? Is this the best way to describe the results of experiments?
- 5) What are some of the unlearned behavior patterns exhibited by pigeons that had suffered a disconnection of the forebrain from the midbrain, except for the connections from the eyes to the dorsal midbrain?
- 6) What is meant by "stability in time" and "stability in space"? In which of these is the forebrain most important?
- 7) What, in a simple phrase, is meant by diaschisis? Describe an example. Why is an understanding of this phenomenon so important in the interpretation of species differences in brain lesion effects?
- 8) What part of the forebrain is most involved in the changes that occur during habit formation, or procedural learning (implicit learning)?
- 9) According to the suggestions in this chapter, what is a reason why sensory pathways ascending to the forebrain almost always have a connection in the thalamus?
- 10) The limbic system is characterized by close interconnections with what portion of the upper brainstem?
- 11) Olfactory input dominated the ancient chordate endbrain, the predecessors of the limbic endbrain structures of mammals. This input was most likely important for two different types of learning, that later in evolution have come to depend just as much or more on inputs of other sensory modalities. Describe the two types of learning.
- 12) Within the endbrain of the first mammals or in their immediate predecessors, within the pallial structures, the neocortex evolved. With this evolution there was an expansion of a rapidly conduction pathway from the spinal cord carrying somatosensory information. It is sometimes called the neolemniscus. Describe or draw this pathway, indicating the location of the cell groups where synapses occur, and the location of a decussation.

- 13) With neocortex, there also evolved long descending connections from somatosensory areas, one of which evolved into the motor cortex. Describe or draw the pathway of corticospinal axons, indicating where it decussates.
- 14) What characterizes the sensory and motor functions of the neocortex?
- 15) In general, what other type of functions depend on the neocortex?

9.14 Questions on chapter 8 of *Brain Structure and Its Origins*

- 1) What are the four basic cellular events that result in transformation of the very early embryo from fertilized cell to morula to blastula to gastrula? (These were summarized by Lewis Wolpert in his book, *Triumph of the Embryo*.) Give examples of what is meant by each event.
- 2) What is the notochord, and what is its role in neurulation? Describe the process of neurulation.
- 3) Who discovered the phenomenon of induction of CNS formation? (There were two of them, but only one received most of the recognition. Why?)
- 4) What are neural crest cells, and what do they become?
- 5) Where does closure of the neural tube begin? Where are the last regions to close?
- 6) Define the terms: neural plate, neural groove, alar plate, basal plate, roof plate and floor plate, sulcus limitans.
- 7) What is sonic hedgehog, and what are two major roles it plays in spinal cord development?
- 8) Describe the two types of cell division that occur adjacent to the ventricular surface of the neural tube.
- 9) How did neuroscientists come to know that there are at least two major modes of cell migration in the embryonic central nervous system? Describe the two modes.
- 10) In his studies of development of the embryonic chick CNS, how did Ramon y Cajal recognize the initial stages of dorsal and ventral root development?

9.14 Questions on chapter 9 of *Brain Structure and Its Origins*

- 1) How do the dorsal, lateral and ventral columns of the spinal cord change from cervical to sacral levels? Why?
- 2) What did Bror Rexed add to the way anatomists describe spinal cord sections stained for cell bodies?
- 3) Describe some differences in cytoarchitecture of the dorsal horn and the ventral horn of the spinal cord. At what levels are these differences greatest?
- 4) What is the lateral horn?
- 5) Where do the largest axons in the dorsal roots originate? Describe two of their terminate sites within the spinal segment of their dorsal root.
- 6) Describe the axons and connections of a withdrawal reflex (flexion reflex).
- 7) Describe the origins of the spinothalamic tract within a section of the spinal cord. Contrast this with the origins of the spinoreticular tract.
- 8) Where do the longest axons of the dorsal columns originate and where do they terminate?
- 9) Explain how there is an organized representation of the surface of the entire body in cell groups at the dorsal-most end of the spinal cord.
- 10) Describe the sources of axons terminating in Clarke's column (nucleus dorsalis) of the spinal cord from the lower limbs. What ascending fiber tract originates in Clarke's column?
- 11) What are propriospinal fibers?
- 12) Movements of the limbs and other movements are controlled by a number of axonal groups that descend from the brain. What can you remember about these? (such as names and where they originate, and how many such pathways there are)
- 13) The peripheral nervous system innervates glands and smooth muscles, also cardiac muscle, as well as skin and striated muscles. What is the system called that innervates the visceral tissues? What are the two divisions of that visceral nervous system?
- 14) Contrast the functions of the two systems. Briefly describe some examples.
- 15) Striated muscles have synaptic innervation, whereas smooth muscles and glands have paracrine innervation. Explain the difference. Where are the neurons located that give rise to the axons that innervate the glands and smooth muscle?

- 16) Compare and contrast the neurotransmitters used by the two divisions of the visceral nervous system.
- 17) What is meant by the enteric nervous system?
- 18) Briefly describe the hierarchy of central control of body temperature.

9.14 questions on chapter 10 of *Brain Structure and Its Origins*

- 1) How is the hindbrain embryologically very similar to the spinal cord?
- 2) The obex is a landmark in the hindbrain viewed from the dorsal side. What is the obex?
- 3) The hindbrain is known to be an essential controller of “vital functions.” What vital functions are involved?
- 4) In what other “routine maintenance functions” is the hindbrain important or even essential?
- 5) How is the hindbrain involved in human speech?
- 6) Nauta and his collaborator Ramon-Moliner (in Moliner, the emphasis is on the last syllable, which rhymes with “air”) described what they called the isodendritic core of the brainstem. What is the difference in the shape of isodendritic neurons and idiodendritic neurons?
- 7) Describe segmentation of the hindbrain and the evidence for it. Compare the expression of hindbrain segmentation with segmentation of the spinal cord.
- 8) Compare and contrast the columns of secondary sensory and motor neurons of the hindbrain and spinal cord.
- 9) What is a sensory placode? Contrast neural-crest and placodal origins of secondary sensory neurons.
- 10) How many cranial nerves are there? Discuss this in terms of comparative anatomy. [Note: students should study table 10.1 a number of times so that soon you will memorize the numbers, names and basic functions.]
- 11) Look at figure 10.10 of the adult caudal hindbrain (the medulla oblongata). Which sensory modalities are represented at this level of the brainstem? See also figure 10.11.
- 12) Which cranial nerve carries somatosensory input from the face into the brain? Give the number of the nerve as well as its common name. Where are the primary sensory neurons of this nerve? Where are the secondary sensory neurons?
- 13) Contrast trigeminal nerve and trigeminal lemniscus.
- 14) What was most likely the most ancient ascending pathway from the secondary sensory neurons of the trigeminal system?
- 15) Describe the hypothesis for how the somatosensory and visual system pathways to the midbrain and forebrain evolved to become predominantly crossed.

- 16) What is the meaning of the term “pons”? (See the end of chapter 5.) What is a major input, and what is the major output, of the cells of the pontine gray matter?
- 17) What causes quantitative distortions of the basic structural layout of the hindbrain? What is the major distortion that occurs in the development of the hindbrain of humans and other primates?
- 18) What is the role of the “rhombic lip” – a structure seen during the development of the rostral hindbrain?
- 19) Try to describe the critical roles of the hindbrain in feeding behavior.

9.14 questions on chapter 11 of *Brain Structure and Its Origins*

- 1) What are the two inputs carrying information about light levels into the CNS?
- 2) What are three major types of multipurpose movement controlled by descending pathways that originate in the midbrain? What structures in the midbrain give rise to these pathways?
- 3) What two regions of the midbrain are called the limbic midbrain areas? What is the neuroanatomical basis for this designation?
- 4) There are motor neurons located in the midbrain. What movements do those motor neurons control? (These direct outputs of the midbrain are not a subject of much discussion in the chapter.)
- 5) The roof of the midbrain includes two pairs of structures (colliculi, meaning little hills) that show a great amount of variation in size among various species. Give examples for each pair. (You may want to refer to chapter 6 also.)
- 6) Name two pathways that originate in the midbrain and descend to the spinal cord.
- 7) At the base of the midbrain (ventral side) one finds a fiber bundle that shows great differences in relative size in different species. Give examples. What are the fibers called and where do they originate?
- 8) A decussating group of axons called the brachium conjunctivum also varies greatly in size in different species. It is largest in species with the largest neocortex but does not come from the neocortex. From which structure does it come? Where does it terminate? (Try to guess before you look it up.)
- 9) What two major instigators of action are discussed in this chapter on the midbrain? One involves sensorimotor pathways. What about the other one?
- 10) Because of differences in functions and connections, we can divide both midbrain and 'tweenbrain into two regions. What are they called in this chapter?

9.14 questions on chapter 12 of *Brain Structure and Its Origins*

- 1) What are the ganglionic eminences of the developing endbrain?
- 2) What are the two largest subdivisions of the diencephalon? Identify also two additional subdivisions. Which of the subdivisions are mostly somatic in nature (connections, functions) and which are mostly limbic in nature?
- 3) In the telencephalon, what are the two major divisions of the pallium (cortex)? What are the two major divisions of the subpallium (striatum)?
- 4) This division of pallial and subpallial regions of the endbrain is supported by the existence of two pathways followed by their output axons, as well as by axons coursing in the opposite direction. What are these two groups of axons called by embryologists and comparative neuroanatomists? What are other names used for all or parts of these two systems in the adult mammal?
- 5) What is a striking difference in the outputs from the neocortex on the one hand and from the corpus striatum on the other?
- 6) What are neuromeres? What are prosomeres?
- 7) Describe the neuromeres of the diencephalon.
- 8) What subpallial structure in sauropsids (reptiles and birds) has connections that are like the connections of the neocortex of mammals? What connections?
- 9) The neocortex has layers that are not present in the dorsal cortex of reptiles and amphibians. The layers are the more superficial layers 2-4. Those layers contain many inhibitory interneurons that do not arise from the ventricular layer of the developing cortex. Where do they come from?
- 10) The lateral ventricular angle region of the mammalian embryonic brain is at least partly homologous to the dorsal ventricular ridge of sauropsids. There is some evidence from Golgi studies that some neuroblasts from this region migrate into neocortex, but such studies, and also gene expression studies, indicate that they migrate into non-neocortical structures as well. Which structures?

9.14 questions on chapter 13 of *Brain Structure and Its Origins*

- 1) Ramon y Cajal described the axonal growth cone from his Golgi studies of developing chicks and mammals. However, he never saw a living growth cone. How was this first accomplished, and by whom?
- 2) To see growth cones in histological material, methods other than the Golgi stain can be used. Give an example.
- 3) What technical advances in neuroembryology can attributed to Ross G. Harrison ? How did Speidel's method differ from Harrison's?
- 4) Describe membrane incorporation in the growing axon.
- 5) Study the model of a growth cone depicted in figure 13.3. Describe the dynamics of axon growth using the concepts of fundamental cellular events named by Lewis Wolpert (chapter 8).
- 6) The study of axonal growth was advanced by a discovery by Rita Levi-Montalcini and Victor Hamburger. Describe the discovery. What did it lead to?
- 7) How do axons that originate in the distal part of the leg of a grasshopper appear to find their way to a central ganglion in a consistent pattern?
- 8) Can the same mechanisms explain the pattern of growth of the mammalian optic tract?
- 9) What is the major result in Hibbard's experiment on transplanted amphibian Mauthner cells?
- 10) There is much evidence that chemical guidance is a major factor in the growth of axons. However, there are multiple types of chemical guidance, with involvement of many different molecular substances. Describe major types of chemical guidance.
- 11) Contrast tropic and trophic effects on growing axons.
- 12) How could the same molecule be critical for both axonal attraction and axonal repulsion?
- 13) What is meant by exuberant axonal projections?
- 14) Describe how optic-tract axons, and no doubt other types of axons, shift from one mode of growth to another mode of growth during development.
- 15) Describe the role of ephrins and ephrin receptors in the development of retinal projections to the midbrain tectum.
- 16) Describe two factors that can increase the competitive growth vigor of a developing axon.

- 17) Describe a phenomenon of plasticity of the map of developing projections from the retina to the midbrain.
- 18) What is collateral sprouting in the development of CNS axons? Describe the phenomenon and two factors which affect when, where and in what axons it can occur. What can modulate the amount of collateral sprouting?
- 19) What is apoptosis?
- 20) Contrast two major possible purposes in naturally occurring neuronal death.
- 21) Describe what happens to regeneration of CNS axons in mammals early in development as the animal grows older. In brief, why does it happen?
- 22) Describe a method that has shown some success for eliciting CNS axon regeneration.

9.14 questions on chapter 14 of *Brain Structure and Its Origins*

1. The overview of the motor system begins with a description of general purpose movements that are used for many different purposes. Name the three types of movements described.
2. Before a neocortex evolved, the midbrain had evolved structures for controlling the three types of general-purpose movements. Name the structure where the output pathway for each of these movements originates.
3. Locomotion is often initiated because of activity generated in what diencephalic structure?
4. Grasping with the hands in large primates is largely controlled by neocortex. What brainstem structure appeared earlier in evolution and controlled this kind of movement?
5. What other kind of grasping is common in animals, including mammals? Describe a pathway from the midbrain that might be involved (a speculation that could guide anatomical experiments). What type of non-midbrain pathway is likely to be involved?
6. What two sensory modalities most strongly shaped the evolution of the forebrain?
7. Discuss the type of connections that the early forebrain must have used to influence the general-purpose movements referred to in questions one and two.
8. Where are the innate circuits underlying the locomotor patterns we call “gaits”? Discuss the pathways whereby a locomotor gait is initiated.
9. Maintaining balance of the body during standing or locomotion depends on reticulospinal pathways from the hindbrain, and on two other descending pathways. What are they?
10. What primary sensory neurons project directly to the cerebellar cortex?
11. Describe major inputs to the red nucleus of the midbrain.
12. What are the two portions of the red nucleus, and how are they different in their major outputs? How are they different in large primates on the one hand and cats or rodents on the other?
13. Where are the most rostral somatic motor neurons located?
14. Name a movement pattern in an animal or human that is largely under the control of hindbrain and spinal cord structures and is centrally generated, once it is triggered.

9.14 questions on chapter 15 of *Brain Structure and Its Origins*

1. What is the basic spatial layout of motor neurons at one of the spinal cord enlargements?
2. Describe the three lesions in the Lawrence and Kuypers study of the descending motor system pathways.
3. Describe functions of the three major pathways or groups of pathways that were separately destroyed in the study.
4. Why would diaschisis effects of lesions of one of the descending pathways in the study be greater in humans than in the monkeys? What are major manifestations of such effects?
5. What are the major symptoms of a lesion of most of the pathways from the brain to the spinal cord (sparing the pathways critical for breathing)?
6. There is no doubt that many dexterous movements are learned and that they depend on corticospinal connections. How are “fixed action patterns” different?
7. How might many learned movements depend on spinal modules more than on direct connections from cortex to motor neurons?
8. What are Betz cells? How are they related to the discovery by Fritsch and Hitzig (in 1870)?
9. How can neuroanatomical experiments determine whether primary somatosensory neocortex overlaps fully or partially with primary motor cortex? Describe examples.
10. What is Deacon’s rule? What does it predict about the projections (outputs) of the optic tectum in birds, with a very large tectum, when compared to these projections in nocturnal mammals, with a much smaller tectum?
11. Neuroanatomical experiments indicate that the primary motor cortex of rhesus monkeys contains a rostral older part and a more caudal newer part. How are these two parts different?
12. What is the “highest” level of motor control? This question can be answered in various ways. Try to answer it after defining what you assume to be highest.

9.14 questions on chapter 16 of *Brain Structure and Its Origins*

- 1) How can the concept of reflexes, or of stimulus-response (S-R) connections that underlie the fixed action patterns of innate behavior, be used to explain complex sequences of behavior that last much longer than any single reflex or S-R event?
- 2) What was the basic argument in Karl Lashley's paper in 1917 called "The problem of serial order in behavior"?
- 3) Name a movement pattern in an animal or human that is largely under the control of hindbrain and spinal cord structures and is centrally generated, once it is triggered. How is it different from a reflex (even though it may be called a reflex by neurologists)?
- 4) Similarly, name a movement pattern that is largely under the control of the spinal cord, and completely so in many species.
- 5) How is central generation of a temporal pattern possible? What two types of mechanism other than S-R circuits are described in the chapter?
- 6) How can a single neuron generate a temporal pattern of electrical activity?

Questions on Schneider chapter 17: Brain States

- 1) What are two different types of mechanisms whereby the overall state of all or much of the brain can be changed?
- 2) Describe four axonal systems that are very widely projecting—systems where activity changes may change the overall state of the brain.
- 3) How have changes in brain state been measured by the recording of electrical potentials? (This is not much discussed in the textbook.)
- 4) How might brain-state control magnify the processing power of the neocortex? (This is a discussion question, touched on in some of the comments on suggested readings at the end of the chapter.)

Questions on Schneider chapter 18: Taste

- 1) In comparative neuroanatomical studies, the taste system provides some of the most dramatic examples of mosaic evolution (illustrated in chapter 4). Explain the meaning of mosaic evolution and describe examples.
- 2) Describe the functions of the innervation of the tongue by four different cranial nerves.
- 3) Describe the pathway for taste impulses from tongue to neocortex.
- 4) What other routes to the endbrain can activity generated by taste inputs follow? What functions might such pathways serve?
- 5) Describe a reflex pathway that goes through the gustatory nucleus of the hindbrain.

Questions on Schneider chapter 18: Olfaction

- 1) What were the structures that very likely shaped the early evolution of the forebrain? Three are mentioned at the beginning of the chapter, including two sensory inputs.
- 2) What are the major differences between the projections of the olfactory bulbs in a primitive vertebrate like the sea lamprey and in tetrapod vertebrates (amphibians, reptiles and mammals)?
- 3) What is a glomerulus (plural: glomeruli)? What are the major components of the olfactory glomeruli in the olfactory bulb?
- 4) Describe the difference between the main olfactory bulb and the accessory olfactory bulb: Inputs to the two portions of the bulb, and differences in their projections to the cerebral hemispheres.
- 5) Contrast the very orderly organization of the olfactory nerve axons to the olfactory bulb, with the nature of the mitral cell projections to the olfactory cortex.
- 6) Contrast: “compensatory sprouting” and “compensatory stunting” of lateral olfactory tract axons.
- 7) What intrinsic factor may explain the phenomena named in question 6?

Questions on Schneider chapter 20: Visual Systems: Origins & Functions

- 1) What was in all likelihood the first functional role of the visual sense? Describe the nature of the most primitive projection of the eyes to the brain.
- 2) Light controls the daily rhythm of secretion of melatonin by the pineal gland. How is this control accomplished? Describe two different pathways in different animals, one much more ancient in evolution than the other.
- 3) Recall the hypothesis using Darwinian logic concerning the evolution of a predominantly crossed representation of visual space.
- 4) Contrast two types of visual orienting: i) the type of visual orienting for which the midbrain tectum (superior colliculus) has become dominant in most species, and ii) the visual orienting for which the pretectal area, independent of the midbrain tectum, is important in some species.
- 5) Distinguish between two very different visual functions of the midbrain tectum, each involving a different output pathway. For which of these functions is precise acuity more important?
- 6) What are the two main methods that have been used by neuroscientists to map the topography of the representation of the visual field or of the retina in the superior colliculus? What are two functions of a precise topographic representation?
- 7) The superior colliculus of the midbrain and the visual cortical areas are each important for identification of a visual stimulus. However, there was a great expansion in visual identification abilities with the expansion of the neocortex. Why?
- 8) Visual pathways to the endbrain follow multiple routes. Describe at least three such routes, beginning at the retina.

Questions on Schneider chapter 21: Visual Systems: Retinal Projections

- 1) What is the first structure reached by axons from retinal ganglion cells? Name the forebrain subdivision and the major retinal terminal nucleus in that subdivision.
- 2) What is the major difference in the nature of the projections of the dorsal thalamus on the one hand and the ventral thalamus (subthalamus) or the epithalamus on the other?
- 3) In this chapter, the epithalamus is described as a caudalmost diencephalic neuromere that includes cell groups where the optic tract has dense terminations. What is this terminal area called?
- 4) Name the five main optic-tract termination areas in the order they are reached by the optic tract. What additional areas receive sparse retinal projections from the main optic tract?
- 5) Inputs from the right and left eyes terminate in distinct areas, a separation that is especially important for creating binocular disparity cues to depth of visually perceived objects. Describe the appearance of the distinct areas in the diencephalon of a small rodent and of a monkey.
- 6) What is the name used for axons that leave the main optic tract and terminate in small cell groups (up to 3 of them)?
- 7) Study figures 21.5, 21.6 and 21.7. Next, cover the labels written above and below the photo of figure 21.7, and see if you can remember the names of structures to which the blue lines are pointed.
- 8) Do the same for figure 21.8, covering up the names between the two photographs.
- 9) Which structures can you recognize in figures 21.9 and 21.10? What would make this more difficult during a neurosurgical procedure?
- 10) Describe at least four different anatomical methods that can be used to uncover distinct layers within the optic tectum or superior colliculus.
- 11) Name three animals or groups of animals that have a very large optic tectum? (See also chapters 6 and 11.)
- 12) Why is the term “optic tectum” misleading about this structure?

Questions on Schneider chapter 22: The Visual Endbrain Structures

- 1) Deacon's rule ("large equals well-connected") is an important rule of thumb in brain evolution. What does this rule suggest in the discussion of multiple routes to the forebrain for visual information?
- 2) What are the two routes to the endbrain taken by visual information that are usually considered the major ones in present-day mammals, reptiles and birds?
- 3) What is the most rapid route from retina to endbrain, the route that has become the most dominant of the multiple visual pathways to the endbrain in the primates?
- 4) Describe one other unimodal pathway taken by visual information to the endbrain that is also probably of major importance in modern mammals.
- 5) What visual areas of the neocortex are believed to be the most primitive?
- 6) What causes the "temporalization" of the cerebral hemispheres? In development and in evolution it is correlated with the expansion of one group of thalamic nuclei. Which nuclei?
- 7) What are the optic radiations, and what happens to them in animals with relatively large temporal lobes?
- 8) What are two methods used by neuroscientists to map multiple visual areas in the neocortex? Why is it believed that the human brain contains more visual areas than the 32 described for the rhesus monkey?
- 9) Why might there be so many visual areas in mammals with large brains?
- 10) Visual inputs to most, probably all, visual areas in neocortex come via two types of pathways. What are the two types?
- 11) Contrast the functions of the three transcortical pathways described in chapter 22, from primary visual cortex in primates and probably in other mammals as well. Also describe major anatomical differences in these pathways.

Questions on Schneider chapter 23: Auditory system

- 1) As in the case of the visual system, an important function early in evolution of audition must have been avoidance and escape from predators. Describe an example of a fixed action pattern triggered in a small mammal by sounds of a predator.
- 2) Two closely related questions on ascending connections of the auditory system:
 - a) Instinctive aversive behavior in response to loud noise, and learned fear responses to specific sounds, depend on different ascending connections. Contrast the connections.
 - b) Fear in response to detection of specific auditory stimuli, even if very low in amplitude, can be learned. Such learning in rodents appears to depend on a pathway from the medial geniculate body of the thalamus direct to a subcortical structure. What structure? (This pathway may be considerably larger in mammals with a relatively smaller neocortex.)
- 3) What transformation of the middle ear apparatus occurred in very early mammals that gave them an advantage in avoiding reptilian predators? What did the evolution of these changes accomplish for auditory function?
- 4) How is a “place code” used for encoding of sound frequency information? Describe the apparatus at the level of the periphery and at the level of the secondary sensory neurons.
- 5) Why do some of the auditory nerve axons that terminate in the ventral cochlear nucleus end in a giant terminal enlargement, the endbulb of Held? Answer with a description of the distribution of synapses formed by such axons. (Note the importance of spatial summation and convergence in the triggering of action potentials.)
- 6) What is the trapezoid body? Describe one important function of a trapezoid body cell group in extracting information from the auditory input.
- 7) Distinguish between two prominent pathways of the auditory system: the lateral lemniscus and the brachium of the inferior colliculus.
- 8) Where does information about location of sounds and sights converge in the subcortical structures of the CNS? What happens if the auditory and visual maps get out of register?
- 9) Characterize two separate functions of auditory system pathways ascending through the brainstem. How is the separation of these two functions expressed in the endbrain—in transcortical pathways?
- 10) Describe several properties that have enabled investigators to distinguish multiple neocortical auditory areas in the cat.

11) How are ablation effects in auditory cortex of the cat related to “word deafness” after certain cortical lesions in humans?

12) What is the area in birds that is comparable to the auditory neocortex of a mammal?

Questions on Schneider chapter 24: Forebrain evolution

- 1) What was most likely the earliest part of the forebrain? Recall the earlier discussion of the invertebrate chordate Amphioxus (*Branchiostoma*).
- 2) What cranial nerves are attached to the forebrain? Two of these are not among the 12 that are usually named for human brain.
- 3) Long after removal or disconnection of the forebrain, animals are missing major segments of normal behavior, even if an island of hypothalamus remains attached to the pituitary. Describe missing aspects of behavior. (See also chapter 7.)
- 4) What studies in recent years have provided evidence for the old hypothesis that the endbrain in early chordate evolution was dominated by olfaction? (See also chapter 19.)
- 5) Contrast the suggested early functional roles of the medial pallium and the corpus striatum.
- 6) In most chordate groups, brain size increases in evolution, but in a few groups, it decreases. Why would it ever decrease? (See also: Striedter readings.)
- 7) What, in evolution, was the major cause of the differentiation of dorsal and ventral parts of the corpus striatum?
- 8) From what part of the primitive endbrain did the neocortex evolve? What kinds of data support this?
- 9) Name several mammals now living that have a very small neocortex.

Questions on Schneider chapter 25: Hypothalamus intro

- 1) Where are the cortical areas that are grouped together as part of the limbic endbrain found in the cerebral hemispheres?
- 2) Compare the two arousal systems of the midbrain. What structures are involved? What are the major types of connections to these structures? What are the effects of electrical stimulation? Is there habituation to repeated stimulation?
- 3) Describe how hypothalamic neurons control secretions from each of the two divisions of the pituitary organ (the hypophysis).
- 4) What hormones are secreted into the bloodstream in the posterior pituitary (neurohypophysis)? Give examples of hormones secreted in the anterior pituitary (adenohypophysis).
- 5) What is diabetes insipidus?
- 6) What homeostatic mechanisms are associated with the hypothalamus? (Give examples.)
- 7) Give specific examples of appetitive and of consummatory behavior. Which parts of the CNS would you expect to be strongly involved in the control of these two types of behavior?
- 8) Where would you expect hunger and satiety cues to influence the CNS? Why?
- 9) What evidence indicates that attack motivation in cats is separate from hunger?

Questions on Schneider chapter 26: Core limbic system pathways

- 1) The hypothalamus has two major divisions, medial and lateral. What is a major difference between these two divisions?
- 2) Information about the internal environment of the body reaches the hypothalamus via two major means. What are they?
- 3) Describe the basic Papez' circuit. Why has there been a revival of interest in this circuit?
- 4) How are the Papez' circuit structures connected to non-limbic neocortical areas?
- 5) What is the "basal forebrain"? Name some structures of this region.
- 6) Describe two ways that the hypothalamus can influence the neocortex.
- 7) What is a major "reward pathway" in the mammalian CNS?
- 8) Contrast the effects of two means of disconnecting the hypothalamus from more caudal structures: i) surgical transection that is done in a single step, and ii) a more gradual surgical transection that is accomplished in many small steps.

Questions on Schneider chapter 27: Hormonal influences

- 1) What are three factors that are likely to play roles in the development of sex differences in the central nervous system of mammals including humans?
- 2) Neuroanatomical studies of sex differences in the human brain were initially focused on what region? More recent studies have used methods for imaging the brain of living persons. Give an example of findings using this method.
- 3) Name and describe the location of a cell group in the spinal cord where sexual dimorphism is very marked.
- 4) What appears to be a major cause of variation in sexual orientation in humans?
- 5) What were the striking findings made in Fernando Nottebohm's lab at Rockefeller University in their studies of canary brains? (There were two major findings, or pairs of findings.)
- 6) What in addition to hormonal factors may explain male-female differences in brain structure and function?

Questions on Schneider chapter 28: Hippocampus

1. Describe differences between place cells and head direction cells as recorded in rats. How are shifts in head direction signaled to the endbrain?
2. Describe the major difference between place cells in the dorsal and the ventral hippocampus in rats.
3. Contrast the learning manifest in the two major links between olfactory inputs and motor outputs as proposed for primitive vertebrates.
4. What is the major change in the configuration of the medial pallium of more primitive vertebrates and the hippocampus of mammals?
5. What is the difference in location of the hippocampus of large primates and its location in the rat or mouse? What explains this difference?
6. In a section cut across the longitudinal axis of the hippocampus, the cell layer is subdivided by anatomists into four sectors, CA1 to CA 4, with the dentate gyrus cupped around CA4 like the hem of a skirt. What do the letters CA stand for, and where did the name come from?
7. Describe the circuit that begins in the entorhinal cortex and can be followed through the hippocampus to the subiculum, from which a major output to the mammillary bodies of the hypothalamus arises.
8. Where is long term potentiation (LTP) found in the hippocampus?
9. Describe the type of anatomical plasticity seen in the hippocampus after specific lesions in adulthood.
10. How might neuromodulators affect the functioning of the hippocampus during waking and sleep?
11. Why is the neocortex of critical importance in the function of the hippocampus in mammals?

Questions on Schneider chapter 29: Limbic striatum and amygdala

1. What are the most direct routes (monosynaptic and disynaptic) from neocortex to the hypothalamus?
2. Describe the stria terminalis: its origins, course, and major connections.
3. What sensory inputs come to the cortical and medial nuclei of the amygdala without passing through the neocortex?
4. The lateral nucleus of the amygdala receives various sensory inputs via neocortical association areas. What sensory pathways come to the lateral amygdala directly from the thalamus?
5. The amygdala is involved in habit learning. What kind of habits?
6. Describe the lesions, made in monkeys by Downer, that produced a loss of learned fears (e.g., in social interactions) when one eye was closed and not when the other eye was closed.
7. What is the "basal forebrain", and what is its involvement in Alzheimer's Disease?
8. What kind of abnormal brain connections may be a cause of some types of schizophrenia? What could cause such abnormal connections to form?

Questions on Schneider chapter 30 and classes: Striatum 1

- 1) What are two major outputs of the corpus striatum via the globus pallidus (dorsal pallidum)? Which one of them is the larger one in mammals? (This explains the meaning of the statement that the major output of the extrapyramidal system is the pyramidal system.)
- 2) Contrast the major source of sensory inputs to the striatum in amphibians and in mammals.
- 3) What is the limbic striatum? How does it differ from the non-limbic striatum? What are several of the structures that it includes? (See also chapter 29.)
- 4) What is the "ansa lenticularis"?
- 5) What are the major "satellites" of the striatum? Which of these has direct outputs to midbrain structures that are important in controlling orienting movements and locomotion?
- 6) Contrast the pathways to motor cortex and the pathways to the superior colliculus from the dorsal striatum (caudate-putamen).
- 7) What is meant by "double inhibition" in pathways through the striatum and its satellites? What neurotransmitter is involved?
- 8) Contrast the neocortical projections to the putamen with the neocortical projections to the caudate nucleus.
- 9) The corpus striatum is involved in all, or nearly all, of the functions of neocortical areas. What neuroanatomical findings support this statement?
- 10) What are striasomes?
- 11) What is the lentiform nucleus? Describe its location in a human brain.
- 12) Thought question: Contrast different routes for sensory information to travel from primary visual cortex to motor output systems. Use information from previous chapters as well as the current one. Try to describe at least three routes.

Questions on Schneider chapter 31 and classes: Striatum 2 (see readings by Olanow et al., and on Kempermann and Gage)

1. Why might the topographic organization of connections not be a critical factor in the functioning of nigrostriatal connections from transplanted tissue?
2. Describe the critical nature of donor age in transplant procedures, and why this might be expected.
3. How can imaging of the living brain be used to assess transplant success?
4. How has neuroanatomical assessment been done using tissue obtained at autopsy? Describe a result.
5. What problem does the size of the human corpus striatum pose for transplant procedures? How far can axons grow from the transplants?
6. How is locus of a transplant within the striatum related to possible functional effects?
7. Why might the functional improvements after transplants have such a slow onset and slow progression?
8. What are alternatives, now or in the future, to transplants of tissue from human fetal substantia nigra?
9. Where has neurogenesis in the adult mammalian brain been discovered most certainly in research since the 1960s? What types of neurons are involved?

Questions on Schneider chapter 32 and classes: Neocortex 1

1. What sensory modality and what projections of this modality underlie the two major types of learning which were so important in evolution of the forebrain? Contrast the two types of learning.
2. From what part of the primitive pallium of pre-mammalian reptiles did neocortex evolve? What part of the mammalian cortex does this pallial region in modern reptiles most closely resemble?
3. What structure in the bird endbrain evolved in a way that resembles the way that neocortex evolved in mammals?
4. Describe three different types of axon projections in the neocortex that begin and end within the cortex.
5. The neurologist/neuroanatomist Marek Marsel Mesulam has pictured the paralimbic cortical areas as divided into two main regions related to the two major types of learning referred to in question 1. What did he call these two regions?
6. Discussion question: How does the hippocampal system facilitate the ability to anticipate the stimuli that an animal or person is about to encounter? What neocortical areas are primarily involved?
7. Contrast the anticipatory activity of the neocortical areas rostral to the primary motor cortex with the anticipatory activity of the multimodal association areas of the parietal and temporal lobes.
8. What was probably the earliest parcellation of the pallium in chordates?
9. Discuss factors that must have influenced thalamic parcellation during brain evolution.
10. Discuss the common belief that the multimodal association areas of the neocortex, including the posterior parietal areas and prefrontal areas, are recent products of brain evolution.

Questions on Schneider chapter 33 and classes: Neocortex 2
“Basic Neocortical Organization: Cells, Modules, and Connections”

1. Contrast some of the major neuronal cell types of the neocortex: first the spiny excitatory neurons, and second the non-spiny inhibitory neurons. What are the main neurotransmitters? What other characteristics can be used to differentiate them?
2. How have neuroscientists defined cortical layers and cortical columns? Name the most common methods.
3. Describe different methods for differentiating different areas of the mammalian neocortex. How did Brodmann do it?
4. What methods have been used, and are being used, to find functional differences between different cortical areas?
5. Following axons from the somatosensory and motor areas of the neocortex to the spinal cord, the name of the group of axons that includes them changes. Give the names of the axon groups in succession, beginning with the neocortical white matter.
6. Secondary sensory neurons of the olfactory system, the mitral cells of the olfactory bulb, terminate in the olfactory cortex, or paleocortex. How does olfactory information go from this cortex to the neocortex? Which region of the neocortex receives such information?
7. What thalamic cell groups project to the major territories of the human neocortex, namely, the central cortical regions, the prefrontal regions, and the posterior association cortex?
8. What is the nature of Mesulam’s idiosyncratic cortex, two types of homotypic cortex, and paralimbic and limbic areas? Answer by describing major functional characteristics. Also, describe the nature of transcortical connections connected to these areas.
9. What are the “association layers” of the neocortex? What is implied by the presence of the growth-associated protein GAP-43 in these layers of the adult human brain?
10. How can long transcortical projections found in experimental studies of monkeys be verified for the human brain, other than the use of postmortem dissection? What are some of the limitations of the method?
11. What are the two major ideas concerning the evolution of the thalamus summarized at the end of the chapter?

Questions on Schneider chapter 34 and classes: Neocortex 3
“Structural change in development and in maturity”

1. What is the subpial granular layer? When and where and in what animals is it found?
2. What is the difference between symmetric and asymmetric cell division, and what are the consequences for development?
3. Explain the importance of evolutionary changes in the periods of symmetric and asymmetric cell division in neocortical development, as postulated by Pasco Rakic.
4. Explain how Finlay and Darlington plotted the sizes of various brain structures in primates and other mammals, showing a kind of concerted evolution. What did their graphs show about the relative size of neocortex compared with other structures?
5. How do neurons that begin their migration from the ventricular zone in the neocortex reach their final destinations? What is meant by an “inside-out” pattern of migration?
6. Besides the ventricular zone, two other proliferative regions are the sources of other neurons that migrate into the developing cortical plate. Where are these two regions located, and what kind of neurons do these other cells become? (See p 230-231, 597, 607-608, 646-647, 651.)
7. Describe an example of how neuronal activity can affect the development of axonal connections even prenatally or before the eyes open, before there is any visual experience.
8. What evidence has been found in mammals for brain changes after blinding? Are the changes/anomalies necessarily structural in nature?
9. Describe experiments with mature monkeys in which changes in the primary somatosensory cortex were found. Describe the behavioral task and the nature of the changes found.
10. The important role of the hippocampus in the formation of new spatial or declarative memories has been made clear by effects of lesions. Where are the engrams underlying the long-term storage of these memories? Where are the cells that show an anatomical plasticity that is likely to be involved in the formation of such long-term memories?
11. What are two major types of transcortical inputs to the prefrontal areas that shape the planning of movements in the immediate future?