Short Answer/Terminology (1 pt each except where noted, 35 pts total)

1. What makes a cell a ‘target cell’ for a particular hormone?
   It has receptors for that hormone.

2. Briefly, what does the term ‘signal transduction’ refer to in general terms with respect to the actions of protein hormones? Relate this to the term ‘second messenger’. (2 pts)
   These hormones cannot cross the membrane and so need a ‘second messenger’ (like cAMP or IP$_3$) inside the cell to convey (transduce) the signal into the cell.

3. Match the letters for the items on the left here with the description that best matches each on the right. Note that a letter may be used for more than one description. (2.5 pts)
   - A. Adenylyl cyclase
     - F: Found in the plasma membrane where it directly interacts with hormones
   - B. Inositol triphosphate
     - E: Enzyme responsible for IP$_3$ production
   - C. cAMP
     - B: Interacts with the endoplasmic reticulum to cause calcium ion release
   - D. Stimulatory G-protein
     - A: Enzyme responsible for cAMP production
   - E. Phospholipase C
     - D: Directly interacts with receptor leading to increased cellular activity typically
   - F. Receptor

4. Briefly, what explains the following observation? Epinephrine acts quickly to induce the breakdown of glycogen in intact liver and muscle cells, but is ineffective if these tissues are homogenized and placed in a test tube with glycogen and glycogen phosphorylase. (2 pts)
   Epinephrine must interact with its membrane receptor to activate a second messenger system. When the tissue (and therefore the membrane) is ground up, it is no longer possible for epinephrine to interact with the receptor and activate the second messenger system.

5. Give one example of negative feedback regulating hormonal levels from among those we discussed (or others if you know them). (2 pts - 1 pt for indicating what stimulates release of the hormone or hormones and 1 pt for describing how negative feedback occurs).
   Several are possible here: e.g., GnRH from the hypothalamus stimulates gonadotropins (LH, FSH) from the pituitary which stimulate the gonads and then gonadal hormones feedback negatively on the hypothalamus and pituitary to reduce GnRH and gonadotropin release. Substitute TRH/TSH/thyroid hormones for the thyroid system or CRH/ACTH/glucocorticoids, cortisol for the stress hormone system.
6. What is the role of the hypothalamo-pituitary portal system (why is it important for endocrine function in mammals, birds, reptiles and amphibians?) (2 pts)
The portal system delivers hormones from the hypothalamus to the pituitary (1 pt) and is important in this way in controlling release of hormones at the pituitary (1 pt).

7. What is the difference between sex determination and sexual differentiation?
Sex Determination is the process that ‘decides’ which sex an organism will be while Sex Differentiation is the process of developing as that sex.

8. If you sampled a population of insects and found that all individuals were females, what type of reproductive pattern would you suspect for this species? (give a term here)
Parthenogenesis

9. What does the term ‘bioaccumulation’ mean?
This occurs when an organism can be exposed to low levels of something (e.g., a toxin), but accumulate it in its tissues.

10. The myelin sheath on many neurons is produced by what basic cell type? (you can also give the more specialized name here instead if you prefer) Would you find a myelin sheath on motor neurons in a butterfly? (2 pts)
- glial cells (also acceptable: Schwann cells, oligodendrocytes)
- No, no myelin sheath in invertebrates like butterflies (vertebrate characteristic here)

11. What does it mean to say that an ion channel is ‘voltage gated’?
This means that the opening of the channel depends on the membrane potential (electrical differences across the membrane)

12. Use the figure of an action potential below to answer the questions along the left side. At each of the indicated points, note whether the ion channel gates in question are open or closed. (1/2 pt ea, 4.5 pts for table below, total of 8.5 points for this question).

<table>
<thead>
<tr>
<th>Gate Type</th>
<th>Point A</th>
<th>Point B</th>
<th>Point C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activation gate of voltage-gated sodium channel</td>
<td>Closed</td>
<td>Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Inactivation gate of voltage-gated sodium channel</td>
<td>Open</td>
<td>Open</td>
<td>Closed</td>
</tr>
<tr>
<td>Voltage-gated potassium channel</td>
<td>Closed</td>
<td>closed</td>
<td>Open</td>
</tr>
</tbody>
</table>

Now, if you were to add potassium ions to the extracellular space around this neuron, would you expect the membrane potential at point A to become more or less negative (more or less polarized, 1 pt) and why? (1 pt).

Less negative (1 pt), decreased concentration gradient so less K⁺ diffusion from inside to outside. (1 pt)

Time (msec)
Finally for this question, the action potential is said to be an ‘all or none’ phenomenon. Specifically referring to what is happening at point ‘B’, explain why the action potential is ‘all or none’. (2 pts)
The increasing membrane potential (increasingly less negative) is causing the opening of Na\(^+\) channels, which further depolarize the membrane, which opens more channels, which further depolarizes the membrane and so on. This cycle continues until all the Na\(^+\) channels are open and this is therefore ‘all or none’ (i.e., no ‘in between’ state is possible here).

13. In a classic experiment, Otto Loewi stimulated the vagus nerve of a frog serving the heart and slowed the heart beat. He let the fluid bathing the heart receiving the stimulation flow out and bathe a second frog heart that was not connected to the stimulating electrode. The second heart also slowed down. What did the slowing of the second heart demonstrate? (2 pts)
This showed that the organ (the heart in this example) did not have to be directly innervated (1 pt) and that there was some diffusible substance (a neurotransmitter) that was actually transmitting the nerve message. (1 pt)

14. You find what you think is a new neurotransmitter. List three things you would need to demonstrate to convince other scientists that this really is a neurotransmitter. (3 pts)
Four are possible:
- The substance should be present at the synapse (and released on stimulation)
- The substance should cause either excitation or inhibition (i.e., in the post-synaptic neuron on release)
- If introduced to the synapse, the substance should cause excitation or inhibition
- There must be a mechanism for reuptake or degradation of the neurotransmitter

15. What is the mechanism that allows an action potential to travel down an axon? (1 pt) Does axon diameter affect the speed at which action potentials travel and, if so, in what way? (1 pt, 2 pts total).
- The current generated by moving ions at the site of the action potential spreads down the axon and depolarizes adjacent sections of axon, allowing the action potential to travel.
- Yes (diameter does affect speed), with larger axons conducting APs more quickly

16. What are the five basic structural divisions of the vertebrate brain? (1/2 pt each, 2 pts, 4/5 gets full credit)
Telencephalon, diencephalon, mesencephalon, metencephalon, myelencephalon

Bonus: What is unusual about nitric oxide as a neurotransmitter and made the discovery that it was indeed a neurotransmitter worth of a Nobel prize in medicine? (1 pt)
Nitric Oxide is a gas that can diffuse through membranes. (noting that it is a gas is good for a point). This was an unusual and revolutionary discovery.

Multiple Choice Questions (1 pt each, 15 points total)

1) I am writing version ___ of this exam.
   a) A
   b) B
2) Protein hormones are ____ and are ______.
   a) Lipid soluble, polypeptides  
   b) **Non-lipid soluble, polypeptides**  
   c) Lipid soluble, lipid based  
   d) Non-lipid soluble, lipid based  
   e) Water soluble, lipid based

3) You would expect the hormone-receptor complex formed by a protein hormone binding its receptor would then bind the promoter region of target genes in the cell nucleus.
   a) True  
   b) **False**

4) The presence of the protein vitellogenin in the blood of male fish is a good indicator of exposure to endocrine disrupting compounds because:
   a) This protein is an important hormone in male reproduction  
   b) This protein is an important hormone in female reproduction  
   c) This protein is an important component of yolk in eggs  
   d) **This protein is usually produced under the influence of estrogen in females.**  
   e) This protein is usually produced under the influence of testosterone in males.

5) You isolate two new hormones from the hypothalamus. Hormone 1 acts on cells in the anterior pituitary gland while hormone 2 acts on cells in skeletal muscle and the skin. Which of the following statements is true?
   a) Neither of these hormones is a tropic hormone  
   b) Hormone 1 is not a tropic hormone, but hormone 2 is a tropic hormone  
   c) **Hormone 1 is a tropic hormone, but hormone 2 is not.**  
   d) Both hormones are tropic hormones

6) Diabetes can result from:
   a) Lack of insulin receptors in tissues  
   b) Lack of insulin production  
   c) Lack of glucagon production  
   d) **Both A and B are true**

7) Gonadotropin-releasing hormone (GnRH, also known as LHRH) is produced in the:
   a) Pituitary gland  
   b) Gonads  
   c) Pancreas  
   d) **Hypothalamus**  
   e) Adrenal glands

8) Neurons are the most common cell type in our brain.
   a) This statement is true  
   b) **This statement is false**
9) Neurons receive information primarily at the _____, perform basic maintenance functions in the ____, and send signals out with the _____.
   a) Dendrites, soma, axon
   b) Dendrites, axon, soma
   c) Soma, dendrites, axon
   d) Axon, soma, dendrites

10) The figure to the right here shows the membrane potential of a neuron. At time point A, the neuron receives synaptic input. The effect of this synaptic input can be seen from the change in the membrane potential after point A. In this case, the membrane potential has been __________ making it _____ likely that the neuron will undergo an action potential.
   a) Depolarized, more likely
   b) Depolarized, less likely
   c) Hyperpolarized, less likely
   d) Hyperpolarized, more likely
   e) Non-polarized, more likely

11) The type of synaptic effect shown here is referred to as a:
   a) Excitatory post-synaptic potential (EPSP)
   b) Inhibitory post-synaptic potential (IPSP)
   c) ESP (extrasensory perception - don’t pick this)
   d) Synaptic reuptake mechanism
   e) Sodium/Potassium pumping mechanism

12) The point at which a neuron will definitely generate an action potential is referred to as the:
   a) Membrane potential
   b) Resting potential
   c) Reversal potential
   d) Channel potential
   e) Threshold potential

13) The drug Riluzole blocks voltage-gated sodium channels. If you applied Riluzole to a neuron, you would expect that:
   a) It would not show a negative resting membrane potential
   b) An action potential could begin in this neuron, but the membrane potential would not decrease after the spike
   c) An action potential could not be initiated in this neuron
   d) An action potential could be initiated in this neuron, but it could not release neurotransmitters.

14) Ancestrally, the forebrain was associated with processing _____ information.
   a) Auditory, b) Visual, c) Balance, d) Olfactory, e) Touch
15) The figure to the right here shows the relationship between whole brain size and body size for a number of animals. Changes in which part of the brain account for most of the difference between birds and mammals on the one hand (ellipse A) and fish, reptiles and amphibians on the other (ellipse B)?

a) Forebrain
b) Midbrain
c) Hindbrain
d) All of the above