(Provide the best response to each question. 32 questions, 1 point per question)

1. In the history of life on earth, the first animals with nervous systems appeared about how many years ago:

   ① 14 billion  ② 4.5 billion  ③ 3.5 billion  ④ 2 billion  ⑤ 1 billion
   ⑥ 600 million  ⑦ 200 million  ⑧ 100 million  ⑨ 0.6 million  ⑩ 0.1 million

2. In the evolutionary tree of life cnidarians appeared before ciliates?

   ① TRUE
   ② FALSE

3. In *Volvox*, cells on the brighter side of the colony tend to have a lower flagellar beat frequency?

   ① TRUE
   ② FALSE

4. Woodlice are small isopods that cannot tolerate prolonged periods of dryness. They, therefore, tend to aggregate in moist places, where they are rather motionless. On the other hand, in dry areas they exhibit increased locomotor activity, which enhances the probability of their finally reaching damper sites. This behavior can be considered as a form of orthokinesis.

   ① TRUE
   ② FALSE
5. Which one of the four Braitenberg vehicles approaches a light source and speeds up as it gets closer?

   ① ② ③ ④

6. What type of movement strategy involves simultaneous left-right comparisons between bilaterally symmetric sense organs?

   ① adaptive klinokinesis
   ② regular klinokinesis
   ③ orthokinesis
   ④ klinotaxis
   ⑤ tropotaxis

7. The behavioral response of *E. coli* to the onset of a step increase in external concentration of a chemical attractant should be a transient decrease in tumble probability.

   ① TRUE
   ② FALSE
8. The trajectory below is most likely generated by placing which of the following pairs of values in the two blank spaces in the following block of code? (Gray squares below represent pixels)

```java
this.speed = 1.0;
if (random(100) < ______) {
    this.heading += ______;
} else {
    heading += 0.1;
}
```

① 30; 30  
② 30; TWO_PI  
③ 30; random(TWO_PI)  
④ 1; random() - 0.5  
⑤ 1; TWO_PI  
⑥ 1; 30  
⑦ 0.3; TWO_PI  
⑧ 0.3; random() - 0.5  
⑨ 0.3; random(TWO_PI)

9-10. For each of the following scientific studies, indicate which aspects of the system is primarily under investigation using the following categories:

① syntactic  
② semantic  
③ pragmatic  
④ hedonic

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>9.</td>
<td>a study of biophysical interactions between calcium and potassium currents in generating patterns of burst firing in single neurons</td>
</tr>
<tr>
<td>10.</td>
<td>a study of how neurons in the frog visual system respond to various types of naturalistic stimuli, such as predators and prey</td>
</tr>
</tbody>
</table>
11. What’s the approximate number of neurons in the C. elegans nervous system?
   ①  100
   ②  300
   ③  1000
   ④  5000
   ⑤  100,000

12. The sense of hearing is thought to have its evolutionary origins in the solvent sensing mechanisms of single-celled organisms.
   ①  TRUE
   ②  FALSE

13. The *C. elegans* neuron shown to the right is most likely a
   ① sensory neuron
   ② primary (sensory) interneuron
   ③ secondary (pre-motor) interneuron
   ④ motor neuron
14-15. Consider an agent with left and right sensors (snsL and snsR). Heading angle increases toward the right (clockwise). Assume bot variables have been initialized to 0 in the setup code.

Indicate if the control algorithms below could best be described as a form of:

1. orthokinesis
2. simple klinokinesis
3. adaptive klinokinesis
4. positive taxis
5. negative taxis

Read and analyze the code carefully… it is purposefully written in a way that makes you think.

(Indicate your answer by writing the appropriate response in the box next to the question #.)

<p>| | |</p>
<table>
<thead>
<tr>
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</thead>
</table>
| 14. | var a = 0.1;  
|     | var b = random(0.5);  
|     | var c = snsL + snsR;  
|     | var d = snsL - snsR;  
|     | this.speed = b;  
|     | this.heading += a * d; |
| 15. | var a = random(0.2);  
|     | var b = 0.1;  
|     | var c = snsL + snsR;  
|     | var d = snsL - snsR;  
|     | if (c < this.previous_val) {  
|     |     this.heading += a - b;  
|     | } else {  
|     |     this.heading += random(0.2) - 0.1;  
|     | }  
|     | this.speed = c;  
|     | this.previous_val = c; |
16. A threshold-logic unit has three inputs $A$, $B$ and $C$, which can have values of 0 or 1. The weight values are: $w_A = +2$, $w_B = +1$, $w_C = -2$ and the threshold value is $\theta = +0.5$ For how many of the 8 possible states does this unit have an output value of 1? Recall that the output of a threshold logic unit is either 0 or 1. (If needed, you can use the logic table below to help you answer the question.)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>out</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

17. In *C. elegans* area-restricted search behavior, neuromodulation influences the probability for high-angle turns over what characteristic time scale?

1. milliseconds
2. seconds
3. minutes
4. hours
5. days
18. Below is a graph showing high-angled turns per millimeter of path length ($\#$ turns/mm) for *C. elegans* in a standard area-restricted search (ARS) experiment after the worm has been transferred to an observation plate. Which of the following statements is TRUE?

![Graph showing high-angled turns per millimeter of path length for C. elegans.](image)

① The worm covers more total distance (mm) in the 0-5 observation period than in the 30-35 period.
② Dopamine levels are higher during the 0-5 observation period than during the 30-35 period.
③ The worm was exposed to food just before the 30-35 observation period.
④ Mechanosensory dopamine neurons receive more sensory stimulation during the 0-5 observation period than during the 30-35 period.
⑤ Chemosensory neurons receive more sensory stimulation during the 30-35 period.
19. The diagram to the right is a proposed neural model for control of area-restricted search behavior. In this model the dopamine-releasing cell is a

① sensory neuron
② interneuron
③ motor neuron

20. In Beer’s artificial insect model, a pacemaker neuron associated with the right middle leg sends inhibitory connections to how many other pacemaker neurons?

① 1
② 2
③ 3
④ 4
⑤ 5
⑥ 6
21. In the leg-control circuit shown above, the forward angle sensor (FAS) is activated when the leg contacts the forward sensory hairs (indicated by dashed line). The FAS neuron would be expected to make EXCITATORY connections with which of the following neurons?

1. FS
2. FT
3. BS
4. both FS and FT
5. both FT and BS
6. none of the above
22. In Beer’s model of action selection shown to the right, filled circles are inhibitory and open triangles are excitatory. What behavior would likely be selected if the agent had a low energy level, chemical and tactile input from mouth sensors, and chemical input from antenna sensors?

① consummatory  
② appetitive  
③ edge-following  
④ wandering

23. In the generalized diagram of the vertebrate brain shown above, the structures labeled a, b, c correspond to which brain regions, respectively:

① cerebellum, tectum, thalamus  
② cerebellum, thalamus, striatum  
③ cerebellum, tegmentum, amygdala  
④ tectum, hypothalamus, amygdala  
⑤ tectum, thalamus, striatum  
⑥ thalamus, tectum, striatum
24. The output structures of the basal ganglia primarily exert an excitatory influence on motor output areas.

① TRUE  ② FALSE

25. While reaching in to get a pizza out of the oven, you touch the hot metal rack. Your withdrawal reflex is primarily mediated by circuitry in the

① amygdala  ② basal ganglia  ③ cerebral cortex  ④ hindbrain  ⑤ midbrain  ⑥ spinal cord  ⑦ thalamus

26. Individuals with obsessive-compulsive disorder (OCD) often repeat behaviors multiple times. If this reflects a problem with action selection circuitry, a reasonable hypothesis would be that OCD might involve the

① amygdala  ② basal ganglia  ③ cerebral cortex  ④ hindbrain  ⑤ midbrain  ⑥ spinal cord  ⑦ thalamus
27. On the graph to the right, which curves best represent the behavioral response of a toad to a SQUARE stimulus BEFORE and AFTER lesioning of the thalamo-tectal pathway?

<table>
<thead>
<tr>
<th></th>
<th>BEFORE</th>
<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(a)</td>
<td>(a)</td>
</tr>
<tr>
<td>2</td>
<td>(a)</td>
<td>(b)</td>
</tr>
<tr>
<td>3</td>
<td>(a)</td>
<td>(c)</td>
</tr>
<tr>
<td>4</td>
<td>(b)</td>
<td>(a)</td>
</tr>
<tr>
<td>5</td>
<td>(b)</td>
<td>(b)</td>
</tr>
<tr>
<td>6</td>
<td>(b)</td>
<td>(c)</td>
</tr>
<tr>
<td>7</td>
<td>(c)</td>
<td>(a)</td>
</tr>
<tr>
<td>8</td>
<td>(c)</td>
<td>(b)</td>
</tr>
<tr>
<td>9</td>
<td>(c)</td>
<td>(c)</td>
</tr>
</tbody>
</table>
Consider the following code for a “house robot” that can detect fire, detect humans, recognize family members (who are also humans), vacuum the carpet, and recharge its own batteries. The programming team has produced two questionable versions of the action selection code. Assume that ‘action’ is a string and doTask(action) executes that action.

<table>
<thead>
<tr>
<th>VERSION A</th>
<th>VERSION B</th>
</tr>
</thead>
<tbody>
<tr>
<td>action = &quot;chase-cat&quot;;</td>
<td>if(batteryIsDead)</td>
</tr>
<tr>
<td>if(detectFire)                                                               {action = &quot;taxis_to_fire&quot;;}</td>
<td>{action = &quot;annoying_beep&quot;;}</td>
</tr>
<tr>
<td>if(nearFire)                                                                  {action = &quot;extinguish_fire&quot;;}</td>
<td>else if (atCharger)</td>
</tr>
<tr>
<td>{action = &quot;taxis_to_fire&quot;;}</td>
<td>{action = &quot;recharge_battery&quot;;}</td>
</tr>
<tr>
<td>if(detectFamilyMember)                                                        {action = &quot;say_hello&quot;;}</td>
<td>else if (batteryIsLow)</td>
</tr>
<tr>
<td>{action = &quot;use_stunGun&quot;;}</td>
<td>{action = &quot;taxis_to_charger&quot;;}</td>
</tr>
<tr>
<td>if(detectHuman)                                                               {action = &quot;use_stunGun&quot;;}</td>
<td>else if (detectHuman)</td>
</tr>
<tr>
<td>{action = &quot;clean_carpet&quot;;}</td>
<td>{action = &quot;use_stunGun&quot;;}</td>
</tr>
<tr>
<td>if(batteryIsLow)                                                              {action = &quot;taxis_to_charger&quot;;}</td>
<td>else if (detectFamilyMember)</td>
</tr>
<tr>
<td>{action = &quot;recharge_battery&quot;;}</td>
<td>{action = &quot;say_hello&quot;;}</td>
</tr>
<tr>
<td>if(atCharger)                                                                                 {action = &quot;recharge_battery&quot;;}</td>
<td></td>
</tr>
<tr>
<td>{action = &quot;chase_cat&quot;;}</td>
<td>else if (detectFire)</td>
</tr>
<tr>
<td>if(batteryIsDead)                                                             {action = &quot;annoying_beep&quot;;}</td>
<td></td>
</tr>
<tr>
<td>{action = &quot;taxis_to_fire&quot;;}</td>
<td>else if (detectDirt)</td>
</tr>
<tr>
<td>{action = &quot;clean_carpet&quot;;}</td>
<td>{action = &quot;chase_cat&quot;;}</td>
</tr>
<tr>
<td>else if (detectFamilyMember)</td>
<td>else</td>
</tr>
<tr>
<td>{action = &quot;say_hello&quot;;}</td>
<td>{action = &quot;clean_carpet&quot;;}</td>
</tr>
<tr>
<td>if(batteryIsLow)                                                              {action = &quot;taxis_to_fire&quot;;}</td>
<td></td>
</tr>
<tr>
<td>{action = &quot;extinguish_fire&quot;;}</td>
<td>else if (detectFire)</td>
</tr>
<tr>
<td>if(batteryIsDead)                                                             {action = &quot;annoying_beep&quot;;}</td>
<td></td>
</tr>
<tr>
<td>{action = &quot;taxis_to_fire&quot;;}</td>
<td>else</td>
</tr>
<tr>
<td>{action = &quot;taxis_to_fire&quot;;}</td>
<td>{action = &quot;chase_cat&quot;;}</td>
</tr>
<tr>
<td>else</td>
<td>else</td>
</tr>
<tr>
<td>{action = &quot;chase_cat&quot;;}</td>
<td>{action = &quot;annoying_beep&quot;;}</td>
</tr>
</tbody>
</table>

28. Which version will ignore fires if the carpet is still dirty?
   ① A  
   ② B  
   ③ both A and B  
   ④ neither

29. Which version will recharge the battery whenever it is at the charger, even if the battery isn’t low?
   ① A  
   ② B  
   ③ both A and B  
   ④ neither
Questions 30-32 refer to the *computational model* of visually guided locomotion in the lamprey published by Kamali-Sarvestani et al. (2012).

30. Consider a perfect integrate-and-fire neuron subjected to constant current injection. Assume a resting voltage of 0 mV and a threshold voltage of 20 mV. If the injected current causes the membrane voltage to rise linearly at a rate of 1 V/s, what is the firing rate of the neuron in spikes/s?

- ① 1
- ② 2
- ③ 5
- ④ 10
- ⑤ 20
- ⑥ 50
- ⑦ 100
- ⑧ 200

31. Consider the block of code below specifying the connectivity between two layers of neurons. How many lines are printed out when the code is executed?

```javascript
for (var i = 0; i < 4; i++) {
  for (var j = 0; j < 4; j++) {
    if abs(i - j) <= 1 {
      console.log(i + " -> " + j);
    }
  }
}
```

- ① 4
- ② 6
- ③ 8
- ④ 10
- ⑤ 12
- ⑥ 14
- ⑦ 16
32. When a lamprey is confronted with two prey objects at different locations, what computational
mechanism and brain region helps the lamprey select and approach just one of the two targets, rather
than swimming midway between them?

① contrast enhancement, retina
② contrast enhancement, tectum
③ lateral inhibition, basal ganglia
④ lateral inhibition, retina
⑤ winner-take-all, basal ganglia
⑥ winner-take-all, tectum
⑦ sensory adaptation, retina
⑧ reciprocal inhibition, spinal cord

END OF EXAM