Objectives for Test Ten: Chapter 31 (31.2-31.4), 37, 38, 39, 52

Nervous system, Senses, Muscle System, Animal Behavior and Plant Responses

You should be able to:

1. Identify several differences in the nervous system of humans and that of other animals. (From your reading)
2. Distinguish between reception of a stimulus and perception of that stimulus.
3. List the sequence of neurons and the pathway in a typical reflex.
4. Describe how the neuron pathway differs between conscious thought and a reflex.
5. Label a diagram of a typical neuron (include dendrite, axon, cell body, axon hillock, synaptic terminal, Schwann cell, myelin sheath, Nodes of Ranvier).
6. Describe how a neuron maintains its resting potential.
7. Describe how a resting potential changes to an action potential.
8. Distinguish between depolarization, hyperpolarization, and repolarization.
9. Explain the role played by the following in resting and action potentials:
   a. Sodium-Potassium pump
   b. Chemically sensitive (ligand gated) ion channels
   c. Voltage sensitive (voltage gated) ion channels
10. List the sequence of changes that occur during an action potential; identify these changes on a graph of an action potential.
11. Explain the role threshold plays in an action potential.
12. Explain how an impulse travels across a chemical synapse; by what mechanisms can a neurotransmitter removed from a synapse?
13. Explain how a neurotransmitter can have an inhibitory effect on a neuron.
14. Explain the role of neurotransmitters and name several examples along with their main functions. (**These are neurotransmitters we have emphasized in class.)
   a. Acetylcholine
   b. Epinephrine
   c. Serotonin
   d. Dopamine
   e. GABA
15. Using dopamine and the reward pathway as an example, explain how various drugs (heroin, cocaine, meth) or diseases (like Parkinson’s) disrupt the normal levels of dopamine in the synapses. How does repeated use of these drugs lead to down-regulation? How was the reward pathway discovered in rats?
16. How does Botox work to decrease wrinkles?
17. Explain how treatments like deep-brain stimulation and stem cell therapy may help Parkinson’s patients.
18. Explain the role of the myelin sheath.
19. Explain a neuron’s threshold potential. How can having neurons with different threshold provide one with more information?
20. If an action potential is an “all-or-nothing” spike, how are variations in stimulus intensity communicated?
21. Explain this statement: Whether or not a neuron will fire depends on synaptic integration.
22. Explain how a post-synaptic neuron does temporal summation and spatial summation. Distinguish between an EPSP and an IPSP.
23. A neurotransmitter can bind to a receptor that is an ion channel or it can bind to a metabotropic receptor that activates a signal transduction pathway. Describe the steps occurring during such a signal transduction pathway. Compare the speed and duration of these two mechanisms.
24. Distinguish between a nerve and a neuron.
25. Identify the functional differences between the somatic, the sympathetic and the parasympathetic divisions of the human nervous system (from your reading; we did not discuss this in class.)
26. Describe the general structure of the brain and spinal cord of vertebrates. Identify the function of the following brain regions:
   a. Medulla oblongata
   b. Pons
   c. Cerebellum
   d. Cerebrum, pre-frontal cortex
   e. Thalamus
   f. Hypothalamus
   g. Corpus callosum
   h. Limbic system
27. Describe the Limbic system and how it is related to Phineas Gage; describe the importance of the corpus callosum and how cutting it in patients with epilepsy demonstrated its function.
28. Explain how brain stimulation can provide information about the functioning of the brain.
29. Identify the types of sensory receptors with examples and the type of stimulus energy each detects.
   a. Mechanical
   b. Chemoreceptor
   c. Electromagnetic receptor
   d. Thermoreceptor
   e. Pain receptor
30. Describe the basic structure and function of the vertebrate eye. Label a diagram.
31. Describe how an eye focuses on an object and how the shape of the eyeball affects that focusing.
32. Compare the function and location of rods and cones.
33. Compare eyes (especially the size of the cornea and the appearance of the choroid coat) of nocturnal
   (night) and diurnal (day) animals.
34. Label a diagram of the ear and use it to explain the function of each part.
35. Explain how the ear turns sound waves into a signal the brain can perceive.
36. Explain how the ear aids the body in assessing position and balance.
37. Explain the relationship between the amount of pressure and the frequency of firing of a touch receptor.
38. Lab Activity on Vision: Explain what is happening with:
   a. Blind spot
   b. Accommodation
   c. Pupillary Reflex
   d. Night vision
   e. Stereoscopic (3D) vision
   f. Near- and Far-sightedness
   g. After image
   h. Optical illusions
39. Explain the relationship between taste and smell.
40. Identify several antagonistic muscle groups and their actions. Explain why skeletal muscles need to come
    in antagonistic pairs.
41. There are three different types (skeletal, smooth and cardiac) of muscle tissue. Identify their locations.
42. Distinguish between muscle, muscle fiber, myofibril, sarcomere, thick and thin filaments (myosin and
    actin).
43. Label a diagram of a sarcomere (Actin, myosin, myosin heads, Z lines).
44. Sketch a sarcomere when a muscle is contracted and one when a muscle is relaxed.
45. Explain how a muscle contracts according to the sliding filament model.
46. Explain how a motor neuron stimulates a muscle to contract (Acetylcholine, t-tubule, sarcoplasmic
    reticulum, ATP, Calcium, troponin, tropomyosin).
47. Identify how a muscle can exert more or less force (motor units).
48. Distinguish between oxidative & glycolytic fibers and fast twitch & slow twitch muscle fibers (See your
    text page 1111). Why would successful sprinters have a higher percentage of glycolytic (white) fibers and
    marathoners have oxidative (red) fibers?
49. Explain where, in the cycle of muscle contraction, the ATP molecules are spent. Why does a dead body
    enter a phase called rigor mortis?
50. LAB: Muscle Grip and Fatigue Rates: Design an experiment to answer questions about muscle grip
    strength and muscle fatigue rates.
51. Provide examples of organisms interact at various levels:
    a. Cells: Biofilms
    b. Organisms: predators and prey
    c. Community: Food web
52. Distinguish between proximate (how) and ultimate (evolutionary) explanations for why organisms
    behave the way they do.
53. Explain the concept: timing and coordination are regulated by various mechanisms are important in
    natural selection. Consider:
    a. Innate behaviors that are inherited
    b. Learning occurs through interactions with environment and other organisms.
    c. In phototropism in plants, changes in the light source lead to differential growth, resulting in
       maximum exposure of leaves to light for photosynthesis.
    d. In photoperiodism in plants, changes in the length of night regulate flowering and preparation
       for winter. (reproduction, courtship, hibernation)
    e. Behaviors in animals are triggered by environmental cues and are vital to reproduction, natural
       selection and survival.
54. Compare innate and learned behavior — provide examples of each.
55. Give examples of how animals use visual, audible, tactile, electrical and chemical signals to indicate dominance, find food, establish territory and ensure reproductive success.
   a. Bird courtship dances
   b. Predator warning in Belding's Squirrel
   c. Coloration (warning)

56. Explain how natural selection can result in the evolution of cooperative behaviors that increase either the fitness of the individual or the survival of the population at the expense of the fitness of the individual (e.g. altruistic behavior). A couple of examples:
   a. Belding's squirrel and warning calls
   b. Bee society -- genetic relatedness
   c. Naked mole rats

57. Describe several experiments involving young oat seedlings that led to our understanding of phototropism.

58. Describe the affects of several hormones on plant growth and development:
   a. auxins (tropisms)
   b. gibberellins (growth & seed germination)
   c. abscisic acid – ABA - (stomates)
   d. ethylene (fruit ripening)

59. Identify the effect and advantage to the plant of photo-, gravi- and thigmo- tropism on plant growth.

60. Explain the mechanism for how phototropism work.

61. Compare short day plants and long day plants. Explain why "short-day plant" is really a misnomer.

62. Describe experiments that discovered photoperiodism is controlled mainly by the length of the night rather than the length of the day.

63. Explain the role of phytochrome as a "timer switch" for phototropism. Predict whether a short day plant will flower based on the sequence of Red/Far Red flashes of light during the dark period.

64. Explain turgor movements in plants such as that exhibited by sensitive plants.

65. Use the Venus fly trap as an example of growth movements (How is a trap triggered to close? How does a trap close?) and relate carnivorous plants to nutrient supply (nitrogen) in their soils.

66. Each chapter has some multiple choice questions and a few other additional questions at its end. Give these a try. You might see them again!

Any of the above objectives could be turned into a short free response question.

I don't find any calculation type problems for this unit.

ESSAYS:
I have listed several essays that correspond to this unit because any one part of these essays would make a good and reasonable short free response questions. You will write one essay during the test. Parts of these essays would make good short free response questions. You will not know which essay before the test.

Likely Essays: 149 (sarcomere, nephron, neuron), 122, 89, 44, 164c (parts), 130, 114(b), 60, 158 (part), 146 (d,e), 59

Essays regarding behavior and plant response need to be identified.
The Neuron's Impulse: The Action Potential

1. Repolarization of the membrane.
2. Sodium is rushing (diffusing) into the neuron.
3. An action potential is triggered.
4. Some chemically sodium channels are open.
5. Voltage sensitive Na+ channels are wide open.
6. Depolarization of the membrane is occurring.
7. The membrane is at about +35 mV.
8. The voltage sensitive K+ channels are wide open.
9. K+ is rushing (Diffusing) out of the neuron.
10. The Na+ / K+ pump maintains -70 mV before a stimulus.
11. K+ channels close.
12. The neuron is has returned to its resting membrane potential.
13. Threshold is reached.
15. The time of stimulation.
16. The neuron is maximally depolarized.
17. The neuron is maximally hyperpolarized.
18. Neuron is at it's initial resting membrane potential.
AP Bio: Nervous Systems & Sensation Diagrams

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AP Bio: Nervous Systems & Sensation Diagrams

Central nervous system (CNS)
- Brain
- Spinal cord

Peripheral nervous system (PNS)
- Cranial nerves
- Ganglia outside CNS
- Spinal nerves

Parasympathetic division
- Action on target organs:
  - Constricts pupil of eye
  - Stimulates salivary gland secretion
  - Constricts bronchi in lungs
  - Slows heart
  - Stimulates activity of stomach and intestines
  - Stimulates activity of pancreas
  - Stimulates gallbladder
  - Promotes emptying of bladder
  - Promotes erection of genitals

Sympathetic division
- Action on target organs:
  - Dilates pupil of eye
  - Inhibits salivary gland secretion
  - Relaxes bronchi in lungs
  - Accelerates heart
  - Inhibits activity of stomach and intestines
  - Inhibits activity of pancreas
  - Stimulates glucose release from liver; inhibits gallbladder
  - Stimulates adrenal medulla
  - Inhibits emptying of bladder
  - Promotes ejaculation and vaginal contractions

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AP Bio LAB: Brain Anatomy

1. Attached you will find a diagram of the human brain. Using the brain parts from the table below, label the diagram. Associate each brain part with the function from the list below. Find each part on the preserved sheep brain specimen.

<table>
<thead>
<tr>
<th>Brain Anatomy</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spinal Cord</td>
<td></td>
</tr>
<tr>
<td>Medulla Oblongata</td>
<td></td>
</tr>
<tr>
<td>Pons</td>
<td></td>
</tr>
<tr>
<td>Cerebellum</td>
<td></td>
</tr>
<tr>
<td>Midbrain (Superior and Inferior Colliculi)</td>
<td></td>
</tr>
<tr>
<td>Optic Chiasmata</td>
<td></td>
</tr>
<tr>
<td>Thalamus (Reticular Formation)</td>
<td></td>
</tr>
<tr>
<td>Hypothalamus</td>
<td></td>
</tr>
<tr>
<td>Basal Ganglia</td>
<td></td>
</tr>
<tr>
<td>Cerebral Cortex</td>
<td></td>
</tr>
<tr>
<td>Corpus Callosum</td>
<td></td>
</tr>
</tbody>
</table>

Match each statement to a brain part:

A. Works with the medulla to regulate homeostatic activities; coordinate large scale body movement; conduct info. from the higher brain functions
B. Projection center that maps sensory info. to specific brain parts
C. Important area for hypothalamus (releasing factors, thermostat, hunger, thirst, sexual response and others)
D. Integrate simple responses (reflexes) and relay info. to the brain.
E. Unconscious coordination of movement and balance (e.g. eye-hand coordination)
F. Homeostatic functions (breathing, heartbeat, swallowing)
G. Relays info. to the cerebral cortex
H. Allows communication between the two hemispheres of the cortex
I. Higher brain function: speech; reading; vision; hearing
J. Motor coordination; sends impulses to the muscles; dopamine is the neurotransmitter and is lacking is Parkinson’s disease
K. The point where the optic nerves cross
AP Bio: Nervous Systems & Sensation Diagrams
2. Eyeball Anatomy: Dissect a sheep's eyeball by removing the fatty layers around the sclerotic coat. Find the optic nerve. Puncture the sclerotic coat and continue to cut the eyeball in half. Identify:

- cornea
- pupil
- lens
- choroid
- retinal
- vitreous humor
- aqueous humor
- ciliary body
- suspensory ligament
- sclera
- iris
- optic disk
- optic nerve

Label the diagram of the eyeball.

3. Vision Activities that help demonstrate function.
   a. Snellen test of visual acuity.
   b. Astigmatism chart.
   c. Color vision.
   d. Near point. Correlate your near point with the projected for your age.
   e. Consensual Light Reflex.
   f. Afterimages (positive and negative)
   g. Blind spot
   h. Dominant eye determination
   i. Stereoscopic vision
   j. Role of vision in balance
   k. Retinal inhibition
   l. Optical illusions
AP Bio: Nervous Systems & Sensation Diagrams
LAB: Grip Strength and Muscle Fatigue

Background Information
Skeletal muscle is composed of bundles of individual muscle fibers (see Figure 1) and has unique properties which allow it to respond to stimuli by contracting. Individual muscle fibers respond to a stimulus (e.g., nerve impulse) with an all or none response, meaning the muscle fiber contracts to its maximum potential or not at all. Once a muscle has contracted, relaxation must occur before it can contract again. There are three basic types of muscle fibers: slow fibers, fast fibers, and intermediate fibers. Fast fibers contract quickly but for a relatively short duration. Slow fibers respond less rapidly, but are capable of a more sustained contraction. The strength of contraction of a whole muscle is dependent on the number of muscle fibers involved.

![Diagram of skeletal muscle fibers](image)

Muscle fatigue occurs with prolonged or repetitive use of a muscle group, and is familiar to anyone who has ever carried a heavy suitcase or walked up a long flight of stairs. With fatigue, there is a sense of weakness and even discomfort, which eventually leads one to discontinue the activity that is causing it. The mechanism of fatigue is multifactorial and not fully understood, but is felt to involve the central nervous system, peripheral nervous system, muscle units and individual muscle fibers. At the level of muscle cells, depletion of energy stores may be important.

Regular exercise improves muscular function and delays the onset of fatigue, thus increasing the amount and duration of work that can be performed. Exercise is important for optimal athletic performance, prevention of injury in athletes and non-athletes, and the maintenance of good general health.

In this experiment, you will examine the effect of fatigue on muscle action by performing sustained and repetitive isometric contractions of muscles of the arm and hand using a Vernier Hand Dynamometer.

**Important:** Do not attempt this experiment if you have arthritis, or other conditions of the hand, wrist, forearm, or elbow. Inform your instructor of any possible health problems that might be exacerbated if you participate in this exercise.

**OBJECTIVES**
In this experiment, you will
- Obtain graphical representation of the force exerted by your hand while gripping.
- Observe the change in hand strength during a continuous grip over time.
- Observe the change in hand strength during rapid, repetitive gripping.

**MATERIALS**
- computer
- Vernier computer interface
- Logger Pro
- Vernier Hand Dynamometer
PROCEDURE – Learning what the Hand Dynamometer can do
Part I Muscle Strength with Continuous Grip

1. Connect the Hand Dynamometer to the Vernier computer interface. Open the file “17a Grip Strength Fatigue” from the Human Physiology with Vernier folder.

2. Zero the readings for the Hand Dynamometer.
   a. Hold the Hand Dynamometer along the sides, in an upright position (see Figure 2). Do not put any force on the pads of the Hand Dynamometer.
   b. Click the Zero button.
   c. Experiment Set-up: 100 seconds and 2 samples/sec

3. Have the subject sit with his/her back straight and feet flat on the floor. The Hand Dynamometer should be held in the dominant hand. The elbow should be at a 90° angle, with the arm unsupported (see Figure 3).

4. Have the subject close his/her eyes, or avert them from the screen.

5. Instruct the subject to grip the sensor with full strength and click to begin data collection. The subject should exert maximum effort with each grip throughout the duration of the experiment.

6. At 90 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

7. Determine the maximum force exerted during different time intervals.
   a. Position the cursor at 0 s and click and drag to highlight 0–10 s on the graph.
   b. Click the Statistics button, , to see the Statistics box.
   c. Record the maximum force during the interval in Table 1, rounding to the nearest 0.1 N.
   d. Move the brackets to highlight the 20–30 s period on the graph. As you move the brackets, the statistics in the Statistics box will be updated based on the data between the brackets.
   e. Record the maximum force during this interval in Table 1, rounding to the nearest 0.1 N.
   f. Repeat this process for the time intervals: 40–50 s, 60–70 s, and 80–90 s.
   g. Close the Statistics box by clicking the — in the corner of the box.

8. Calculate the difference between each maximum value and the next and record these values in Table 1.

9. Position the cursor at 0 s. Click and drag to highlight 0–90 s on the graph. Click the Linear fit button, and record the slope (round to the nearest 0.01) in Table 3.

Part II Muscle Strength with Repetitive Grip

1. Use the same set up as you did in Part 1 of this experiment.

2. Have the subject sit with his/her back straight and feet flat on the floor. The Hand Dynamometer should be held in the dominant hand. The elbow should be at a 90° angle, with the arm unsupported (see Figure 2).

3. Have the subject close his/her eyes, or avert them from the screen.

4. Zero the readings for the Hand Dynamometer.
   a. Hold the Hand Dynamometer along the sides, in an upright position. Do not put any force on the gray pads of the Hand Dynamometer.
   b. Click the Zero button.
5. Instruct the subject to rapidly grip and relax his/her grip on the sensor (approximately twice per second). Click to begin data collection. The subject should exert maximum effort throughout the duration of the experiment.

6. At 90 s, the lab partner(s) should encourage the subject to grip even harder. Data will be collected for 100 s.

7. Determine the maximum force exerted during different time intervals.
   a. Position the cursor at 0 s and click and drag to highlight 0–10 s on the graph.
   b. Click the Statistics button, , and record the maximum force during that interval in Table 2, rounding to the nearest 0.1 N.
   c. Move the brackets to highlight the 20–30 s period on the graph. As you move the brackets, the statistics in the Statistics box will be updated based on the data between the brackets.
   d. Record the maximum force during this interval in Table 1, rounding to the nearest 0.1 N.
   e. Repeat this process for the time intervals: 40–50 s, 60–70 s, and 80–90 s and then close the Statistics box by clicking the “—” in the corner of the box.

8. Calculate the difference between each maximum value and the next and record these values in Table 2.

9. Position the cursor at 0 s. Click and drag to highlight 0–90 s on the graph. Click the Linear fit button, and record the slope in Table 3.

DATA ANALYSIS
1. Examine your graph and the data in Table 1. What conclusion can you draw about the number of individual muscle fibers that are firing in the last 10 s compared with the first 10 s?

2. Is the change in number of muscle fibers that contract occurring at a constant rate? Use data to justify your answer.

3. Use your knowledge of fast, slow, and intermediate skeletal muscle fibers to hypothesize which fibers are contracting in the first, third, and final 10 s intervals.

4. How might you explain the subject’s response to coaching? This should be evident in the last 10 s of data for Parts I and II of the exercise. Discuss the possible involvement of the central nervous system, in addition to the muscle fibers.
5. Compare the slopes recorded in Table 3. Give a possible explanation for the difference, if any, in musclefatigue rates seen in continuous versus repetitive gripping.

<table>
<thead>
<tr>
<th>Time interval</th>
<th>Maximum force (N)</th>
<th>Δ Maximum force (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–10 s</td>
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<td>20–30 s</td>
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<td>40–50 s</td>
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<td>60–70 s</td>
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<tr>
<td>80–90 s</td>
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</tbody>
</table>

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<td>60–70 s</td>
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<tr>
<td>80–90 s</td>
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</table>

### Table 3

<table>
<thead>
<tr>
<th></th>
<th>Slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part I—Continuous gripping</td>
<td></td>
</tr>
<tr>
<td>Part II—Repetitive gripping</td>
<td></td>
</tr>
</tbody>
</table>

**INQUIRY:** As a class, you will brainstorm a set of questions that can be answered using this technique. You can ask questions regarding gender, size, arm circumference, repetition, dominant – nondominant hand, finder type, etc. You will design the experiment and determine what data you need to gather from each set of students. As follow-up, you will do a complete analysis (data table, graph, written conclusion) regarding your question.
AP Biology: Muscle System Diagrams

(a) Skeletal muscle
(b) Cardiac muscle
(c) Smooth muscle

(d) Z-line
(e) Z-line

(f) Thick filament
(g) Thin filament

Myosin head
Myosin molecule

Portion of a sarcomere showing the overlap of thick and thin filaments
AP Biology: Muscle System Diagrams
AP Biology: Muscle System Diagrams

(a)

(b)

Fig. 5 Thin filament

- Actin molecules
- Troponin
- Cross bridge binding sites
- Myosin binding sites
- Ca$^{2+}$ binding sites
- Troponin complex

(a) Myosin binding sites blocked; muscle cannot contract

(b) Myosin binding sites exposed; muscle can contract

binding site

myosin head

thin filament (actin)

ADP

thick filament (myosin)

release cross bridge

form cross bridge

shorten sarcomere

Z line

Sarcoplasmic reticulum

Sarcolemma

Nucleus

Transverse tubules (T tubules)

Mitochondrion

Myofibril
AP Biology: Muscle System Diagrams
AP Biology: Plant Responses: Tropisms

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**AP Biology: Plant Responses: Photoperiodism**

(a) Short-day (long-night) plant

(b) Long-day (short-night) plant

Responses:
- At high levels, photoperiodic responses are
  - Seed germination
  - Control of flowering

Red light

$P_r \rightleftharpoons P_{fr}$

Far-red light

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Part I—Hypothesis Development

Belding's ground squirrels (*Spermophilus beldingi*) are diurnal rodents. They live in sub-alpine meadows in the far Western United States. Due to the extreme weather, the squirrels hibernate for seven or eight months of the year. The squirrels must enter hibernation with sufficient fat stores to survive this long hibernation. They spend their short active period by initially mating, then eating large quantities of food. They are primarily herbivorous, eating mostly seeds, flowers, and vegetation.

Adult females mate shortly after they emerge from hibernation. After mating, some males disperse to new groups and the others often return to hibernation before the young are born. The females establish territories within the social group and have between three and six pups. The pups emerge from their burrows when three to six weeks old and the juvenile males disperse (leave to join new groups) shortly after. The females typically remain in their natal (birth) group for life.

Paul Sherman (1977) studied Belding's ground squirrel behavior. The squirrels are subject to many dangers. Predators include coyotes, weasels, and raptors. Often, if a squirrel spots a predator, they will stand up on their hind feet and call out an alarm. When others hear the alarm, they quickly retreat to their burrows. Not all squirrels are equally likely to call.

**Question**

1. Generate some hypotheses to explain why the squirrels call.
What predictions do you have about the frequency of alarm calling for the hypotheses you generated in Part I?

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Predictions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do the squirrels call?</td>
<td>Who benefits?</td>
</tr>
<tr>
<td></td>
<td>When do they benefit?</td>
</tr>
<tr>
<td>Should all individuals call?</td>
<td>Group/predator response to call?</td>
</tr>
<tr>
<td></td>
<td>Immediate effect on caller?</td>
</tr>
</tbody>
</table>

**Question**

1. How can we discriminate between these competing hypotheses?
Not all squirrels call equally. See the following figures.

**Figure 1**
*First Callers to a Predatory Mammal*

**Figure 2**
*All Callers to a Predatory Mammal*

"G" Statistic: 88.5
P > .001

"G" Statistic: 73.5
P > .001

*Figures represent expected vs. observed frequencies of alarm calls across classes of Belding's ground squirrels drawn from 102 interactions with predators. Adapted from Sherman 1977.*

**Question**

1. What conclusions can you draw from these data?
Females call disproportionately more often than predicted by their abundance. Adult females call more often than one-years or juveniles. Males call disproportionately less than predicted by their abundance.

Questions

1. Why might this be?

2. Advanced Questions:
   1. How do these data compare to your predictions?
   2. Why would females call more than males?
   3. How should the proximity of relatives influence whether it is cost-effective to call?

3. Consider the following additional information: females call more readily when they are close to other related individuals. Does this provide further support for the kin selection hypothesis?
The kin selection hypothesis requires that individuals can recognize kin. Sherman’s data demonstrate that females are more likely to call when there are kin nearby.

Questions

1. How might individuals recognize kin?

2. Can you provide some ways of testing whether a particular modality (call, smell, taste, etc.) is important in kin recognition?

Image Credit: Photo by Dr. Gwen Bachman, School of Biological Sciences, University of Nebraska-Lincoln. Used with permission. To learn more about Dr. Bachman’s research with Belding’s ground squirrels, see http://bsweb.unl.edu/emb/bachman/index.html.
There is another species of ground squirrel whose males behave differently (Dunford 1977). In this species (*Spermophilus tereticaudus*), males are more likely to alarm call before they leave their natal site, but remain silent after they disperse.

**Questions**

1. Do these data support your current hypotheses about calling?
2. What predictions would you make if females dispersed and males remained in natal groups?
3. What predictions would you make if neither sex dispersed?
4. Why is it that one sex disperses from each of these groups?
"My Brother’s Keeper" by Kari Benson

Part VII—Economics of Kin Selection

Hamilton (1964) proposed a mathematical means of interpreting whether individuals should help kin. The economic analysis incorporates several aspects of the situation.

First, the decision requires that you can recognize (in some way) who is related to you, and (ideally) by how much. In this case, Hamilton measures the percent of DNA that you would share with someone by common descent, which he calls relatedness \( r \). For example, you would share half of your genes with a parent by common descent. Thus, you would have a relatedness of 0.5 with either parent or with a full sibling; you would have a relatedness of 0.25 with a half sibling or a grandchild; and you would have a relatedness of 0.125 with a cousin. (This is why the biologist J. B. S. Haldane purportedly stated that he would die for two of his brothers or eight of his cousins.)

You will need to know the relatedness between the donor and the recipient \( r_{\text{recipient}} \) and the relatedness between the donor and their offspring \( r_{\text{offspring}} \). Note that \( r_{\text{offspring}} = 0.5 \) in typical diploid organisms.

Second, you have to know what it will cost you to help. For simplicity, Hamilton measured cost as the number of offspring (corrected for the relatedness) that you won’t have because you helped someone else. This is the cost of helping \( c \).

Third, you have to know how many more offspring your kin can have because you helped; this is the benefit of helping \( b \).

It is adaptive to help if:

\[
\frac{B}{c} > \frac{r_{\text{offspring}}}{r_{\text{recipient}}}
\]

Thus, you can determine for a number of circumstances whether you should help your relative or not.

Example

You share a relatedness of 0.5 with your offspring and the same \( r_{\text{offspring}} = 0.5 \) with a full sibling (one with whom you share a father and mother). If you can help some nephews, then \( r_{\text{recipient}} = 0.25 \). The benefit in the form of nephews must be greater than twice the cost to your own offspring to be adaptive. That is, for every offspring you cannot have due to helping (this is the cost or \( c \)), anything more than an additional two nephews (this is the benefit or \( B \)) would satisfy the inequality. For example, this condition would be satisfied if \( B = 2.5 \) and \( c = 1 \).
Example continued

Written mathematically, this would look like the following:

\[
\frac{2.5}{1} > \frac{0.5}{0.25}
\]

This expression is correct. The left hand part of the equation equals 2.5. The right hand part of the equation equals 2. The left exceeds the right, so helping is adaptive through kin selection.

Questions

1. Suppose there were a car wreck and you could only save one person, your best friend or your sibling. Whom would you save?

2. How many siblings would you have to save if helping forced you to give up one child?

3. How many nephews or nieces would you have to help if helping forced you to give up three children?
Many recent articles demonstrate that decreased parental attention and increased child abuse are more common in step-children than for offspring that are genetically related to both caregivers (Tobby and Cosmides 1989, Emlen 1997, and Hofferth and Anderson 2001).

Question

1. How does kin selection explain these data?
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References and Additional Reading


  http://www.psc.isr.umich.edu/pubs/papers/rr01-471.pdf


- Human Behavior and Evolution Society (HBES) website.
  http://www.hbes.com/


- Belding’s Ground Squirrel (*Spermophilus Beldingi*)—Juveniles and Adults—Photos and Quick Facts http://www.scarysquirrel.org/current/belding/

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