Learning the function of cranial nerves is a challenge for most students. My coverage of this concept has changed since I first began teaching anatomy and physiology over 15 years ago. Initially, I spent only time in lecture (1 ¼ hour lecture) on the cranial nerves and their functions. I came to realize that my saying it just was not enough. Later I added an optional exercise, “Application of Cranial Nerve Function” that students could complete outside of class (attached). Students could access this on Blackboard™.

In 2006 I made a significant change and added a lab exercise on cranial nerves (½ of a lab period, [1 ½ hours]) and decreased the time I spent in lecture to approximately ½ hour. Students spent time with models of structures innervated by cranial nerves while answering questions about each cranial nerve. Although I had no objective evidence to support this change, when questions were posed during lecture concerning cranial nerves, students appeared to have a better understanding of their functions.

In 2007 I changed the lab to be an interactive exercise in which students test the functions of cranial nerves. I divided the cranial nerves into the 1st set of six cranial nerves and the 2nd set of six cranial nerves. Students answered questions after completing the 1st six and then after completing the 2nd set of six. I also added a flowchart on the cranial nerves, “Cranial Nerve Flowchart”, that visually shows the relationship of the 1st six cranial nerves and the 2nd six cranial nerves (attached). The completing of this flowchart was an optional exercise that students could complete outside of class by accessing it on Blackboard™.

Beginning in 2008 the two optional exercises – “Application of Cranial Nerve Function” and the “Cranial Nerve Flowchart” – will be required assignments. These will be included as the culminating activities of the lab on cranial nerves.

To determine if there were any improvements in student learning, I included the same questions on cranial nerves on the exam this year (attached). The results are shown below for Fall 2006 and Fall 2007. Unfortunately, I do not have results for prior years. I was relieved to see that there was some improvement in Fall 2007. However, students are still confused on several areas (as reflected in the percentage of students who missed the question related to that concept). The most notable areas where a large percentage of students performed poorly include the concepts related to autonomic effectors (question 9) and the three cranial nerves involved with the sense of taste (question 10). Perhaps with the addition of more directed questions in the lab report related to these areas, I can help a larger percentage of students develop a better understanding.

Table 1: Results of Exam (After completing an item analysis on the 10 questions)

<table>
<thead>
<tr>
<th>Item on Exam</th>
<th>Fall 2006 (Percentage)</th>
<th>Fall 2007 (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question 1</td>
<td>59</td>
<td>65</td>
</tr>
<tr>
<td>Question 2</td>
<td>90</td>
<td>91</td>
</tr>
<tr>
<td>Question 3</td>
<td>83</td>
<td>84</td>
</tr>
<tr>
<td>Question 4</td>
<td>90</td>
<td>97</td>
</tr>
<tr>
<td>Question 5</td>
<td>69</td>
<td>76</td>
</tr>
<tr>
<td>Question 6</td>
<td>88</td>
<td>98</td>
</tr>
<tr>
<td>Question 7</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Question 8</td>
<td>71</td>
<td>74</td>
</tr>
<tr>
<td>Question 9</td>
<td>39</td>
<td>34</td>
</tr>
<tr>
<td>Question 10</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>All 10 Cranial Nerve Questions</td>
<td>73.8 (n=59)</td>
<td>76.8 (n=58)</td>
</tr>
<tr>
<td>All 88 Exam Questions</td>
<td>71</td>
<td>72.9</td>
</tr>
</tbody>
</table>
Ten Questions on Cranial Nerves

1. Which of the following most ACCURATELY describes the Accessory Nerve?
   a. motor, cranial, and autonomic
   b. motor, cranial, and somatic
   c. motor, cranial, and autonomic and somatic
   d. sensory, cranial, and somatic
   e. motor, spinal and autonomic and somatic

2. Choose the CORRECTLY matched pair.
   a. optic nerve...sense of smell to parietal lobe.
   b. vestibulocochlear nerve...vision to occipital lobe
   c. vagus...major nerve extends down into the thoracic and abdominopelvic cavities.
   d. oculomotor...sensory visual information to occipital lobe
   e. abducens...controls the skeletal muscle of the tongue

3. Choose the cranial nerve CORRECTLY matched with its function.
   a. olfactory – vision
   b. optic – controlling the extrinsic muscles of the eye
   c. hypoglossal – movement of the tongue
   d. facial – movement of the neck and shoulders
   e. abducens – smell

4. To control all the extrinsic eye muscles requires:
   a. optic nerve only
   b. optic nerve and the oculomotor nerve
   c. oculomotor nerve only
   d. oculomotor nerve, trochlear nerve, and abducens nerve
   e. oculomotor nerve, trigeminal nerve, and abducens nerve

5. A reflex to slow the heart would involve which cranial nerve?
   a. accessory
   b. hypoglossal
   c. facial
   d. trigeminal
   e. vagus

6. This nerve transmits sensory impulses involving equilibrium.
   a. olfactory nerve
   b. vestibulocochlear nerve
   c. facial nerve
   d. ophthalmic nerve
   e. glossopharyngeal nerve

7. This nerve transmits sensations of touch of the face and motor impulses for controlling the muscles of chewing.
   a. trigeminal nerve
   b. facial nerve
   c. hypoglossal nerve
   d. accessorius nerve

8. This cranial nerve is a mixed nerve.
   a. accessory
   b. hypoglossal
   c. glossopharyngeal
   d. oculomotor
   e. abducens

9. All of the following cranial nerves extend to autonomic effectors EXCEPT:
   a. oculomotor
   b. vagus
   c. facial
   d. glossopharyngeal
   e. trigeminal

10. The sense of taste is transmitted to the brain along which three cranial nerves:
    a. 1, 2, 3
    b. 1, 3, 5
    c. 2, 3, 5
    d. 1, 4, 5
    e. 3, 4, 5

You are welcome to use the 10 questions on the cranial nerves for a quiz or an exam to see how your students would do.
Cranial Nerve Flowchart

Directions: Fill in the blank with the name of the cranial nerve.

First Six Cranial Nerves

Sensory

1 ___________ 2 _________ 3 ____________________

Motor

Extrinsic Eye Muscles (spell OAT)

4 ____________________

5 ____________________

6 ____________________

*also intrinsic eye muscles

Second Six Cranial Nerves

Sensory

7 ____________________ 8 ____________________

Motor

Neck and Shoulder Muscles

11 ____________________ 12 ______________

Taste and Swallowing Muscles and Parotid Salivary Gland

9 ____________________

Taste and Swallowing Muscles and Smooth Muscle and Glands of Viscera of Thoracic & Abdominal Cavities

10 ____________________

Sensory

Somatic Motor

Autonomic Motor

Key:
1 – olfactory, 2 – optic, 3 – trigeminal, 4 – oculomotor, 5,6 – abducens or trochlear
7 – vestibulocochlear, 8 – facial, 9 – glossopharyngeal, 10 – vagus, 11 - accessory, 12 – hypoglossal

You are welcome to copy the flowchart and use it in your course.
Directions: Using your diagrams, notes and textbooks, determine the spinal nerve or cranial nerve that is damaged based on the symptoms of the individual.

a. olfactory nerve (I)
b. optic nerve (II)
c. oculomotor nerve (III)
d. trochlear nerve (IV)
e. trigeminal nerve (V)
f. abducens (VI)
g. facial (VII)
h. vestibulocochlear nerve (VIII)
i. glossopharyngeal nerve (IX)
j. vagus nerve (X)
k. accessory nerve (XI)
l. hypoglossal nerve (XII)

1. The patient is deaf.
2. The pupil in one eye is dilated due to decreased tone of the constrictor muscles of the iris.
3. An individual has taken a hard blow to the face (e.g. as a result of falling on concrete) and has lost some sense of smell.

The ANS is a dynamic, responsive system that maintains homeostasis through reflex adjustment to changing conditions - but it is not an intuitive topic for students, and its antique terminology does not help. This article offers a “housekeeping” metaphor to introduce the ANS in everyday language, and short class activities with questions that enable students to answer, “Just how much can I control my own body?” and “What would happen if the ANS failed?”

Housekeeping: the biological function of the ANS

Housekeeping in a complex building (i.e., a hotel) means sending fresh supplies to the right location, maintaining a comfortable temperature, etc. and hotel guests are free to plan their own activities since the building seems to run itself. Similarly “housekeeping” by the ANS adjusts cardiorespiratory control, temperature control, etc. so that the conscious brain is free to think while the body’s routine functions operate automatically. In a hotel or in the body, housekeeping management also provides automatic, rapid responses that protect against internal or external threats or disturbances (see Table 1).

4. An individual has diabetes and blood vessels in the retina are damaged, what nerve would be sending less sensory impulses?
5. Due to surgical error, the patient has lost most sensory perception on one side of the face and difficulty chewing.
6. Individual cannot move most muscles of the face.
7. Paralysis of the superior oblique muscle results due to damage of this nerve. The individual’s one eye rotates outward.
8. The patient complains of decreased sense of taste (3 cranial nerves).
9. The individual cannot abduct (move the eye laterally to see something to the side) one eye due to damage to this nerve.
10. Stimulation of this nerve in the region of the neck decreases heart rate.
11. One shoulder droops.
12. The patient has Bell’s palsy.

Key: 1-h; 2-c; 3-a; 4-b; 5-e; 6-g; 7-d; 8-g, i, j; 9-f; 10-j; 11-k; 12-g

Activity 1: Extensive, protective homeostatic functions of the ANS

Guess how many reflexes are known. A search of the Internet, textbooks, and the Merck manual produces definitions like “rapid, automatic, stereotyped response to stimuli”, and lists of scores of reflexes – far more than anyone guesses. Working in groups to sort the reflexes, students set aside descriptive terms such as spinal/cranial or monosynaptic/polysynaptic and proper names such as Babinski for later research. Are there more autonomic or somatic reflexes? By sorting the reflexes according to body parts involved, it becomes clear that the autonomic group, controlling the imperceptible “housekeeping” functions of glands or smooth muscle in viscera such as heart, iris, stomach, blood vessels, etc., is much larger than the somatic group of reflexes that act in posture and withdrawal. Students may think they control their own bodies, but realize the only organ under conscious control is skeletal muscle!

How does each ANS reflex act to maintain homeostasis and/or provide some kind of protection? For example, chemoreceptor...
reflexes maintain blood gases and therefore pH, and gastric and enteric reflexes maintain food propulsion at the right rate for digestion and absorption. Cough and gag reflexes protect directly, and the diving and bladder emptying reflexes protect indirectly.

<table>
<thead>
<tr>
<th>What is the ANS?</th>
<th>Efferent signals in the ANS cause smooth muscle contraction, gland secretion, and/or regulate cardiac action; all of the uncontrollable bodily activities result from one or more of these actions.</th>
</tr>
</thead>
</table>

**Activity 2: Efferent limb**

*What bodily activities cannot be consciously controlled?* Students offer goose bumps, stomach gurgling, sweating, fainting, heart thumping, blushing, and so on. After a few hints they add pupillary, bladder, bowel, and sexual functions. These autonomic effects are mediated by efferent (motor) signals from the central nervous system (CNS). Students should note that the dual sympathetic and parasympathetic nerves to viscera shown in textbook illustrations are both efferent – the ANS is predominantly efferent. These nerves are the housekeeping staff that perform the work.

<table>
<thead>
<tr>
<th>Table 1. Comparison of housekeeping in a complex building and in the body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Who/what does the work?</td>
</tr>
<tr>
<td>When is work done?</td>
</tr>
<tr>
<td>What jobs are done?</td>
</tr>
<tr>
<td>What are job descriptions?</td>
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<td></td>
</tr>
<tr>
<td>What happens when there is no oversight?</td>
</tr>
</tbody>
</table>

**Activity 3: Afferent limb**

*What work does the ANS perform?* Efferent signals in the ANS cause smooth muscle contraction, gland secretion, and/or regulate cardiac action; all of the uncontrollable bodily activities result from one or more of these actions.

*Does something stimulate the CNS to cause the efferent effects (above), or are these random?* Physiology is anything but random, so we need to consider what the “work orders” are that cause housekeeping nerves to perform some type of job.

*How does it feel to have an X-ray, and what happens?* There is no feeling and nothing happens because the body cannot sense X-rays. It must be able to detect, through some kind of sensory receptor, what is going on in and around itself, and report that work order (afferent limb of the reflex) to a housekeeping office (integration center of the reflex) before appropriate motor work can be done (efferent limb of the reflex).

*What are some work orders for autonomic action?* Students already know that heat causes sweating, embarrassment causes blushing, hunger causes stomach gurgles, etc. Other work orders are unfamiliar, such as baroreceptor afferents that report details of blood pressure, but everyone has felt dizzy on standing up suddenly. The baroreceptor reflex must catch up in its work of “autofocusing” the blood pressure after blood sinks into the legs by gravity.

When enough afferent impulses (work orders) have been identified, students sort them into two categories: *Which are triggered by sensation such as pain, fullness of the stomach, or light shining in the eyes? Which are triggered by memories, thoughts, or emotions such as anxiety, hatred, or sexual attraction?* This establishes that the afferent limb of the ANS reflex can be any type of peripheral sensation, or can be central input from the cerebral hemispheres. Autonomic afferent nerves are few (relaying visceral sensation, and baroreceptor and chemoreceptor input), and somatic nerves provide the afferent limb (or even efferent limb, but if both limbs are somatic, it is a somatic reflex) in some autonomic reflexes (see Table 2).

<table>
<thead>
<tr>
<th>Table 2. Components of visceral and somatic reflexes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Afferent limb autonomic</td>
</tr>
<tr>
<td>-----------------------------</td>
</tr>
<tr>
<td>Efferent limb autonomic</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Efferent limb somatic</td>
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<td></td>
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</tbody>
</table>

When there is no further supervision, housekeeping...
Teaching Tips - continued from page 16

Activity 4: Integrating center.
Where are the housekeeping offices that receive reports through the afferent limb? Students can identify the centers of autonomic regulation from these questions: Is the conscious brain involved? Yes, feelings and thoughts cause autonomic effects. Is the limbic system involved? Yes, it is involved in “gut feelings” and moods that cause autonomic effects. Is the brainstem involved? Yes, chemoreceptors and baroreceptors ‘report’ there, and the cranial nerves that serve cough and gag reflexes originate there. Is it likely that the hypothalamus, a center controlling homeostatic functions such as food and fluid intake, should also control autonomic functions through the sympathetic and parasympathetic divisions? Yes, it seems likely.

The hypothalamus is the headquarters or housekeeping main office, but also some branch offices are under hypothalamic control: the spinal cord that integrates autonomic reflexes such as urination, defecation, erection, and ejaculation; and the brainstem that integrates cardiovascular, respiratory, and swallowing functions. Other branch offices are the limbic system, especially the amygdala that responds to gut feelings and olfactory input, the thalamus that integrates sensory input, and even the cerebral cortex with its conscious thoughts.

If the conscious brain is involved, does that make it a reaction like those used in playing video games, and not a true automatic reflex? Blushes and sweaty palms are not voluntary and cannot be directly stopped, so they are autonomic reflexes even though the afferent is conscious thought. In biofeedback, conscious thought can be used to indirectly control ANS reflexes to some extent – focusing on calming topics can slow the heart rate.

Activity 5: Dynamic balance between sympathetic and parasympathetic divisions
Students are familiar with the extremes of autonomic response – fight or flight, rest and restoration – but what happens between extremes? What happens if anxiety causes sympathetic outflow to accelerate the heart, but lying down to rest causes parasympathetic outflow to slow the heart? Which division “wins”? What if low blood sugar causes the need for parasympathetic stimulation of digestion, but fear dries the mouth and slows the intestines through sympathetic outflow?

Homeostasis in non-extreme conditions is maintained by a dynamic balance between the two divisions. Neither ANS division would win – the heart rate would be somewhere between usual rate for ‘at rest’ and a higher rate for ‘anxious’, the food would be eaten with less appetite and digested more slowly than usual.

Activity 6: Easily demonstrated ANS effects
Digital blood vessels undergo sympathetic vasoconstriction in ice water, and reduced blood flow causes pallor and even cyanosis as tissue extraction of oxygen from the sluggish blood continues. On re-warming, sympathetic vasoconstriction is inhibited and skin vasodilation causes redness and tingling. (Google Images show dramatic exaggeration of this in Raynaud’s disease).

The parasympathetic salivation reflex is stimulated by substances such as lemon juice, gum, or clean pebbles in the mouth. Baseline production of saliva is measured over 3-5 minutes in a small graduated cylinder, and the measurement is repeated after exposure to lemon juice, etc.

Normal ventilation is controlled by the brainstem to maintain homeostasis of blood gases. Deliberate alteration of the normal pattern of ventilation in rate and depth for one-half minute alters the pCO₂ and pH of the blood, after which chemoreceptor reflexes cause an opposite pattern of abnormal ventilation until homeostasis is restored. Subjects should be unaware of observation during recovery.

Pupillary responses to light are easy to observe, but even easier is the pupillary response to near and far accommodation.

Everyone can demonstrate cardiac changes on exercise – but can everyone explain the parts of the reflex arc?

Activity 7: ANS topics for research
Shy-Drager syndrome (multi-system atrophy) is a condition in which extensive autonomic failure is prominent. What symptoms of this illness illustrate how essential autonomic control is to the body?

Ondine’s curse is a genetic condition with inadequate ventilation especially during sleep. How would it be to need to stay awake to consciously control breathing? What part of the chemoreceptor reflex is impaired in this condition? Who was Ondine? (Hint: she inspired ‘The Little Mermaid’.)

The polygraph (lie detector) test works by measuring autonomic responses to emotion, such as alteration in electrical impedance of the skin with nervous sweating. The test is not infallible, and its use in a court of law is controversial. What could happen with hardened liars, or nervous individuals? What prescription drugs would act on the ANS to reduce responses?

Extreme fear in victims of torture acts through the limbic system and hypothalamus to cause a massive sympathetic response. What are the bodily effects of this? Hypoxia of the brain from hanging or strangling has similar effects.

Contradictory signals from the vestibular system, the visual system, and/or the proprioceptive system stimulate the vomiting center in the brainstem. Parasympathetic (vagal) signals reverse the transit in the gastrointestinal system, and coordinated action of respiratory and abdominal muscles force out gastric content. What conditions does this describe?

* Galen described structures of the ANS in the 2nd century and thought they allowed “sympathy” or coordination of organs. Ackerknecht EH. The history of the discovery of the vegetative (autonomic) nervous system. Med Hist, 1974;18(1):1-8