SUBMITTING ILLUMINATIONS FOR REVIEW

As educators we are continually designing new methods and procedures to enhance learning. During this process good ideas are frequently generated and tested, but the extent of such activities may not be adequate for a full manuscript. Nonetheless, the ideas may be quite beneficial in improving the teaching and learning of physiology. Illuminations is a column designed to facilitate the sharing of these ideas (illuminations). The format of the column is quite simple: a succinct description of about one double-spaced page (less title and authorship), without figures or references, of something you have worked up for the classroom, teaching lab, conference room, etc. Submit your column entry directly to Daniel Richardson, Illuminations Column Editor, Department of Physiology, University of Kentucky, College of Medicine, Lexington, KY 40536-0298.

Using demonstrations to uncover student misconceptions: the Law of LaPlace

A simple demonstration with balloons has been used in physiology teaching to illustrate the Law of LaPlace (see below). For the past several years I have used this demonstration in my pre-med physiology class after discussing the law of LaPlace and alveoli. However, this past semester I decided to make it a discovery activity. On the first day of the respiration section, before even the most compulsive students had read about alveoli and elastance, I told the class what we would do in the demonstration and asked them to predict what would happen to the balloons. The students knew about pressure and flow from the cardiovascular system, which we had just completed. Almost all of them had completed two semesters of physics and chemistry through organic, so I was very intrigued when I saw the written responses they turned in before we did the demonstration. Of the 124 students in the room, only 7 (5.6%) made the correct prediction, and none of the 6 engineering students in the class was correct. The majority of the class (82 students, 66%) said that the balloons would become equal in volume, with 19 (15%) of that group specifically stating that higher pressure air in the large balloon would flow into the lower pressure small balloon. Of the remaining 35 students, 8 (6.5%) said correctly that air would flow from higher pressure to lower pressure but did not answer the question about what would happen to the balloons. Five students (4%) said the balloons would fly off the ends, with explanations such as "pressure forces them off" or "pressure builds up inside the tube." Fourteen students (11.3%) wrote that both balloons would decrease in size because "they would lose air to the tube," "the pressure was lower in the tube," or "because there was no resistance left." Five students (4%) said the balloons would stay the same size, whereas the final three answers were unable to be categorized ("They will equilibrate"). This simple discovery exercise revealed the prevalence of incorrect mental models, held by nearly 95% of the class, and also uncovered some faulty models that were so unusual that I could never have predicted them. It would be interesting for faculty who are using other demonstrations to try them as discovery learning activities to see what other misconceptions our students are holding and to share their findings.

For those not familiar with the LaPlace demonstration, a description of the principles involved can be found in the International Union of Physiological Sciences (IUPS) handbook, A Source Book of Practical Experiments in Physiology Requiring Minimal Equipment (World Scientific Publishers, 1990, p. 24). We construct this demonstration using two 9-in. balloons and an 18-in. piece of rigid Plexiglas tube (inner diameter about 3 mm). Around the outside ends of the Plexiglas tube, I glue a ¼-in. piece of rubber tubing. This creates a ridge to tie the balloons behind so that they will not slide off the tube. I get four student volunteers to help: two to blow up the balloons and hold the necks shut.
while they are being tied onto the tube, and two to do the tying. We use a fine silk thread, wrap it tightly around the balloons and tubing to prevent leaks, and then knot it off. I hold the tube in the middle during the procedure. One balloon is blown up fairly large (but not near the limit of its elasticity), whereas the other balloon is markedly smaller. When the holders let go of the balloon necks, the two balloons and the tube form a continuous system. Barring leaks, it behaves according to the Law of Laplace and the smaller balloon collapses into the larger one.

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Teaching about disinhibition

Disinhibition is a concept that is useful for explaining many functions of the nervous system and also other systems of the human body. In psychology it describes bizarre behaviors of patients who are unable to inhibit their impulses. Students may hear a definition of disinhibition but do not realize what a broad concept it is. Disinhibition is the release of inhibition, a double negative, which results in increased activity. A good example of disinhibition happens in exercise, when normal vagal tone that slows heart rate is withdrawn, thereby increasing heart rate. Sympathetic activity to the heart also increases with exercise, which raises heart rate directly. A good analogy to use in explaining disinhibition to students is to consider an automobile at the top of a hill. Releasing the brake and allowing the car to roll down the hill is disinhibition.

Disinhibition explains many phenomena in the nervous system. For example, the only output from the cerebellar cortex onto subcortical nuclei is from Purkinje cells that are inhibitory. When Purkinje cells are inhibited by Basket cells, their inhibitory effect on the subcortical neurons is reduced (disinhibition), so the subcortical neurons fire faster. This contributes to sequences of inhibition and disinhibition that the cerebellum uses to coordinate body movements. Injuries to motor control systems in humans are often associated with excessive activity rather than to lack of activity, because many pathological conditions damage neurons involved in normal inhibition. Patients with Parkinson's disease, Huntington's disease, or cerebral palsy have particularly exaggerated movements that are due to disinhibition. The spastic paralysis (too much activity of antagonistic muscles at rest) of patients with strokes or spinal injuries is due to the loss of tonic inhibition from the brain to the spinal cord, causing hypertonia and hyperreflexia. The role of disinhibition in spasticity is well illustrated by an example from insect physiology. When praying mantises mate, the smaller male mounts the back of the female. During copulatory thrusting, the front of the male may slip and his head may be eaten off by the female. If this happens, the copulatory movements become more vigorous, because tonic inhibitory activity from the head ganglion no longer suppresses neurons in the thoracic ganglion. Students always remember this example.

Disinhibition is also useful to describe the operation of negative feedback control systems, which maintain the levels of ions, nutrients, and hormones in the body relatively constant. For example, secretion of trophic hormones from the anterior pituitary stimulates production of hormones from endocrine glands elsewhere in the body. When the peripheral endocrine gland produces too little hormone, then there is less negative feedback to the anterior pituitary (and hypothalamus), so more trophic hormone is produced to try to stimulate the original target endocrine gland. The increased blood level of trophic hormone is the result of disinhibition.

Homeostatic control with opposing forces to increase or decrease blood levels of various chemicals can be likened to a damped oscillation. In our bodies plenty of excitation is opposed by some inhibition, and then this inhibition is partly opposed by disinhibition. The balance of opposing forces maintains a controlled midlevel range of normal operation. Excess activity often results from too much disinhibition rather than from too much facilitation. The final outcome may appear similar, but understanding the physiology provides more logical explanations of how the result is achieved.

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