Constructing a Dynamic Lung and Breathing Model

Gerald C. Llewellyn
Virginia Commonwealth University
901 West Franklin Street
Richmond, Virginia 23284

A simple mechanical model can be used to demonstrate ventilation of the lungs by diaphragmatic negative-pressure breathing and how the sensitive pressure balance can be upset by minor injuries to the thorax or by chest puncture wounds. Because the lung can collapse without being punctured, students often do not consider the potential for damage by mechanical accident. The adverse effects of smoking, air pollution, and other irritants may be illustrated with the model, which also provides information for discussions of chest (or (thoracic) breathing and other aspects of respiratory physiology.

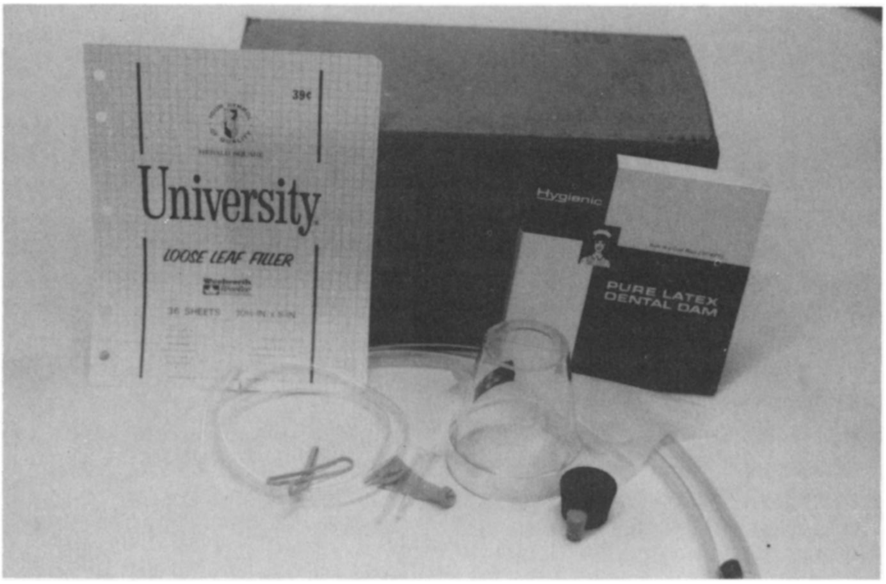

FIGURE 1. Materials needed to construct the model.

The Mechanism of Breathing

The lungs act as a respiratory pump (Kao 1972). The forces that act to operate the pump are the muscles, inspiratory and expiratory, and the lungs, which serve as the bellows. Differences in pressure cause the air to flow from an area of higher pressure to an area of lower pressure. Hence, negative pressure breathing occurs naturally. When the volume of air in the thorax is increased, the negative or subatmospheric pressure in the alveoli causes the air to flow into the lungs.

Gordon (1972) describes the diaphragm as a domelike sheet of muscles separating the thoracic cavity from the abdominal cavity. When these muscles contract, the medial portion of the diaphragm moves downward acting as a piston. This downward movement enlarges the thoracic cavity; and the lungs, which are attached to the sides of the cavity like a wet suction cup that adheres to a smooth surface, expand because of their own natural elasticity as the cavity grows. The energy for expiration comes from the energy stored within the lungs and the thorax wall. The elastic recoil is the motive force for expiration causing the glottis to open and the inspiratory muscles to relax.

The flow of air during breathing is due to three different pressures: (1) Atmospheric pressure, or the air that surrounds us that we breathe. Its pressure at sea level is equal to 760 mm Hg; this pressure decreases with altitude. (2) Intrapulmonary pressure, or the pressure within the respiratory space of the lungs (bronchi and alveoli). (3) Intrapleural pressure, or that found within the pleural space between the lungs and the walls of the thoracic cage (Raynor 1977).

In discussing intrapleural pressure, Raynor (1977) defines negative pressure as less than atmospheric pressure. Intrapleural pressure at rest is 756 mm Hg. This is not negative, but it is still less than 760. Therefore, -4 is used to indicate the pressure.

The force that expands the lungs comes from a pressure difference between the larger intrapulmonary pressure and the intrapleural pressure. Between breaths, this pressure difference pushing out on the lungs merely balances the elastic force tending to collapse the lungs.

Immediately after birth, an extremely powerful contraction of the diaphragm generates the negative intrathoracic pressure. This pressure stretches the lungs, and the elastic tissue they contain never again returns to its original length (Montcastle 1974). The force with which the lung attempts to collapse accounts for the subatmospheric pressure that normally exists between the inner surfaces of the thorax and the outer surfaces of the lungs.

A lung collapses after a wound when the pleural membrane is ruptured either from the outside or the inside (Raynor 1977). The outside air rushes into the intrapleural space when the intrapleural pressure becomes equal to the atmospheric pressure. The needed pressure difference no longer exists, and there is no way for the lungs to expand. The original elasticity produced by that first inhalation is now unopposed, and the lung collapses. However, the separation of the pleural membrane protects the safety of the other lung.

Asimov (1963) describes lung collapse as necessary in the healing process of a lung after surgery or some disease. The continual rubbing of a lung against the rib cage would be harmful; therefore, air is introduced between the ribs and the lung. This air collapses the lung. Breathing can continue with the other lung until the collapsed lung resumes its natural size and becomes functional.

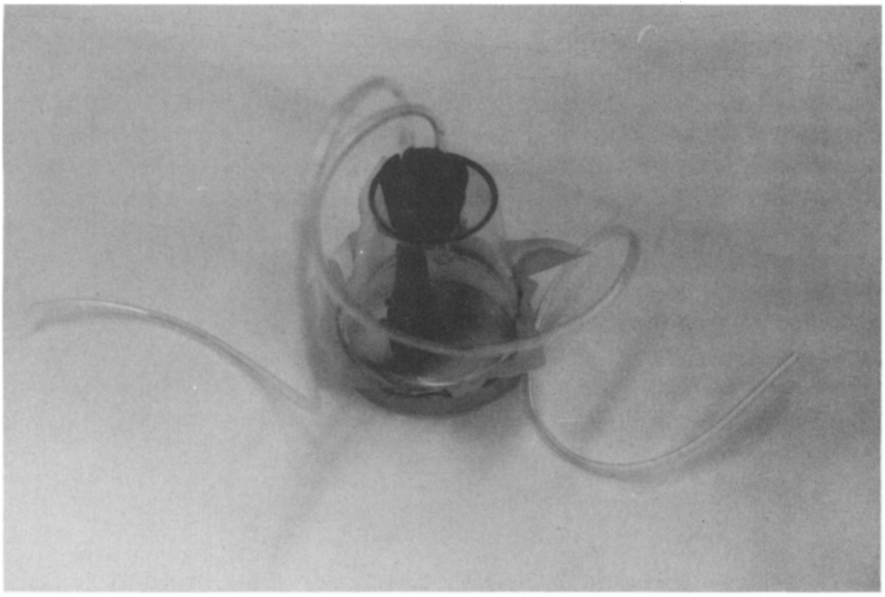

FIGURE 2. Insertion of rubber-stopper apparatus into flower pot assembly.

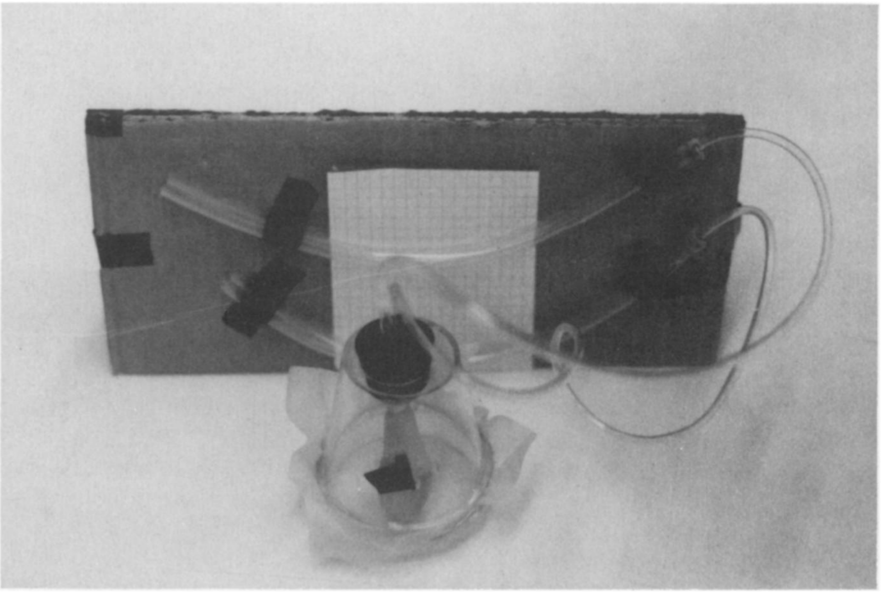

FIGURE 3. Model completely assembled. It can be used for manometric measurements. The curved tube contains colored water to illustrate pressure changes as the diaphragm is moved.

Model Practicality

The model presented is easy to construct with inexpensive and accessible materials. The difficult concept of pressure differences seems elementary to students as they pull the "diaphragm" and observe the lesser or greater amount of lung expansion. In addition, lung collapse is clearly demonstrated by removing the side tape covering holes previously made in the model. The model is fun to make and encourages students to learn.

Assembling the Model

Obtain a clear, plastic flower pot with a wall thickness of about 3 mm. A clear plastic pot will enable you to see lung movements. In the bottom of the pot, drill a hole large enough to accommodate a size 6 to 7 one- or two-hole rubber stopper. Also, drill a small hole in the side wall of the pot. Seal this latter hole with airtight tape. Fit the glass portion of a bulbless eyedropper into each hole in the rubber stopper, allowing the narrow ends to point toward the top of the stopper.

A rubber balloon should be secured tightly to the bulb-end of each eyedropper. The eyedropper lip will help hold the balloon in place. Invert the flower pot and carefully place the rubber stopper in the large hole drilled earlier. With assistance, if necessary, place a rubber (dental) dam over the mouth of the flower pot. Secure the dam in place, drawing it taut with a series of strong rubber bands.

One-balloon, one-eyedropper models, two-balloon, two-eyedropper models, and two-balloon, one-inverted-Y-tube models all work adequately; however, the model described above is, perhaps, more realistic for an assembled lung model.

Classroom Use

Identify the eyedropper (or inverted Y-tube) as the trachea and bronchi, the balloons as the lungs, the rubber dam as the diaphragm, and the flower pot as the thoracic cage. Illustrate diaphragmatic breathing simply by pulling down on the "diaphragm" with the "trachea" open. Observe the "lungs" filling, exemplifying inspiration, and while the "diaphragm" is being released, the "lung" empty, or expire. Actually, the diaphragm is curved upward at rest and taut at contraction.

This model may be used to illustrate the effects of occluding the trachea and respiratory opening. It also illustrates lung collapse resulting from a pneumothoracical wound. To do so, pull off the sealing tape covering the sidewall holes and operate the "diaphragm." Also, the "lungs" and/or the "diaphragm" may be punctured to allow observation of the ensuing results.

The simple model may serve as a demonstration for elucidating diaphragmatic and negative-pressure breathing. Discussions can be encouraged concerning chest (or thoracic) breathing as well as other areas of respiratory studies. Students may build or assemble prefabricated parts for individual laboratory studies. Clear tubes filled with colored water, and attached to the "trachea" may serve as manometers to illustrate the resultant pressure changes.

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A Laboratory Exercise on Photoperiodic Changes in the Testes of the Mongolian Gerbil

David F. Treagust
Michigan State University
East Lansing 48824

Abbie B. Moos
G. Edgar Folk, Jr.
The University of Iowa
Iowa City 52242

Fisher and Llewellyn (1978) report on the suitability of the Mongolian gerbil (*Meriones unguiculatus*) as a laboratory animal in the science classroom. Recent legislation in many states has, however, greatly restricted the use of vertebrates in science laboratory experiments (Animal Welfare Institute 1978). The National Science Teachers Association (1978) has also recently provided guidelines for teachers and their students in using vertebrate animals for experimentation. Furthermore, the works of Ryder (1975) and Singer (1975) dealing with the abuse of vertebrates by humans are becoming more popular. Similar recent publications focusing on the ethical issues underlying human treatment of animals by Regan and Singer (1976), Clark (1977), and Morris and Fox (1978) attempt to address more carefully, and with increased rationality, the moral status of animals and the effects of this status on our use of animals in laboratory experiments.

Almost nothing is known about the normal ecology of the gerbil, a native of Eastern Mongolia, Northeast China, and Western Manchuria, except that it is a burrowing animal living in arid regions. The gerbil is reported to be both day and night active (Walker 1964), and maintains body temperature within narrow limits (Robinson 1959); whether this animal is a hibernator is subject to debate (Theissen and Yahr 1977). It is likely, however, that during adverse winter conditions gerbils spend much of their time in lightless underground burrows; it might also be expected that under these conditions the gonads regress (Reiter 1974). This suggestion is supported by the observation that most litters are born between April and September following a gestation period of 25-29 days (Walker 1964).

An investigation was performed by Moos, Treagust, and Folk (1979) to examine the photoperiodic response of testicular development of the Mongolian gerbil and to determine the role that light might play in the animal's reproductive life. This investigation lends itself to adaptation for a secondary biology laboratory exercise and at the same time retains and