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Advan Physiol Educ 265:32-34, 1993.

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A SIMPLE ANALOGUE OF LUNG MECHANICS

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A model of the chest and lungs can be easily constructed from a bottle of water, a balloon, a syringe, a rubber stopper, glass and rubber tubing, and clamps. The model is a more exact analogue of the body than the classic apparatus of Hering in two respects: 1) the pleurae and intrapleural fluid are represented by water rather than air, and 2) the subatmospheric "intrapleural" pressure is created by the elasticity of the "lung" (balloon) rather than by a vacuum pump. With this model, students can readily see how the lung is inflated and deflated by movements of the "diaphragm and chest" (syringe plunger) and how intrapleural pressures change as this is accomplished.

AM. J. PHYSIOL. 265 (ADV. PHYSIOL. EDUC. 10): S32-S34, 1993.

lung model; mechanics of breathing; physiology teaching

Many students of physiology have been introduced to the mechanics of breathing with the aid of the "bell jar and balloons" model, more often perhaps by a drawing in a textbook or on a lantern slide than by the actual glassware in the laboratory. The model shows how the balloons (lungs) can be made to inflate and deflate as changes in the bell jar (intrathoracic) pressure are caused by movement of a rubber diaphragm. The model is depicted by Harris et al. (2), who attribute it to Ewald Hering (of the Hering-Breuer reflex); a beautiful modern improvement has been described by Chinot (1). All such models were anticipated by John Mayow (3), who described in 1674 an elegantly simple model consisting of an animal bladder mounted inside a bellows (with a glass window in the bellows so that the inflation and deflation of the bladder could be observed).

The bell jar model has, however, one alarming feature that confuses the discussion of lung mechanics: the thorax is full of air instead of aqueous fluid or tissue. A student tends to be left with the impression that our chest would work like the bell jar if only there were some air between the pleurae. Moreover, to expand the lungs (balloons) to a reasonable resting extent and achieve a subatmospheric intrathoracic pressure (before inspiration created by the diaphragm), the bell jar must be

partially evacuated by a vacuum pump. This does not seem very helpful in understanding how the subatmospheric pressure is generated in the mammalian body.

A more exact analogue can be made without a vacuum pump by working, as the body does, with water instead of air. Blow up a small balloon in a bottle full of water, letting water escape from the bottle as air is blown into the balloon. Clamp off the water exit, and release the balloon. What happens? The balloon, open to the atmosphere, remains inflated and will remain so indefinitely, held in place by a negative (subatmospheric) water pressure created by the balloon's attempt at elastic recoil. If a large syringe is connected to the bottle, the balloon can be made to inspire and expire by movements of the plunger. The negative "intrathoracic" pressure is felt resisting the plunger during inspiration and is seen in the tendency of the plunger to recoil spontaneously during expiration. A U-tube manometer can be inserted to measure the subatmospheric pressure in the thorax (bottle) and the changes in that pressure with inspiration and expiration.

By means of this easily constructed model, students seem quickly to grasp the basic mechanics of breathing and to see how the elasticity of the lung

generates a subatmospheric pressure in the thorax. The model has the added benefit of displaying a property of water (and other liquids) that students have little experience with but that is of considerable physiological significance: that water can have negative as well as positive pressures and can, in effect, move solid objects by pulling as well as pushing.

PROCEDURAL NOTES

The model can be built in many forms and sizes, but one wants the syringe (or other such device) to have a volume that is an appreciable fraction of that of the inflated balloon so that the tidal volume of the "breathing" will be easy to see. A 500-ml bottle with a 50-ml syringe works well, with a balloon 8–10 cm long and 2–5 cm wide. There can be as few as two tubes into the bottle: one for mounting the balloon, the other for letting water escape and attaching the syringe and manometer. A bottle with an outlet at its bottom allows the syringe to occupy a position suggestive of that of the diaphragm. A manometer attached to the top of the bottle works well, with an air space in the connecting tube allowing the water levels in the two limbs of the U-tube to be compared. It may be desirable (depending on the shape of the balloon) to extend this tube down into the bottle (as shown in Fig. 1), so that the balloon cannot obstruct its entrance.

The tension in the walls of the inflated balloon, and the pressure difference generated by it, will depend on the balloon's initial dimensions, its shape, the elastic characteristics of its rubber, and the degree of inflation, but the negative pressures generated by the balloon will usually be greater than those of the lung. If the manometer comes into the top of the bottle, it will measure the greatest negative pressure in the system, so a fairly long manometer may be needed. One model having a small, stiff balloon displayed a negative pressure of $-36 \text{ cmH}_2\text{O}$ at "exhalation," which increased to $-42 \text{ cmH}_2\text{O}$ dur-

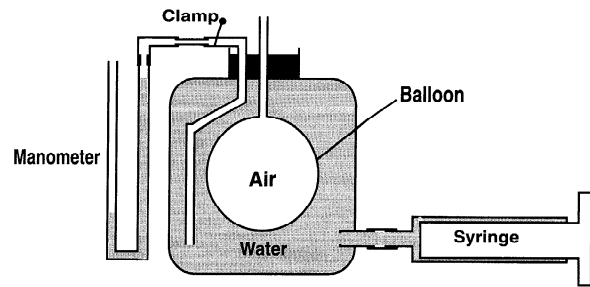


FIG. 1.

Apparatus for simulating the breathing lung. Water in bottle is under tension due to elastic recoil of balloon, which is held open by water tension. The water directly pulls or pushes (pulls less) on the balloon in response to movements of syringe. Changes in negative pressure in water can be read with a manometer.

ing a 50-ml "inhalation." A 50-cm manometer was therefore adequate.

To mount the balloon, it should be teased through a hole in a rubber stopper so that the body of the balloon lies below the stopper but the lip rests on its top side. (Make the hole in the stopper adequate to this operation, or twist the balloon to get it through.) A glass tube can then be inserted into the balloon, which will be tightly held between the glass tube and the rubber stopper.

The only significant difficulty in putting the apparatus together is in believing that it will work. It will.

Received 30 November 1992; accepted in final form 16 June 1993.

References

1. Chinet, A. E. Chest-lung statics: a realistic analog for student laboratory. *Am. J. Physiol.* 257 (*Adv. Physiol. Educ.* 2): S9–S10, 1989.
2. Harris, D. T., H. P. Gilding, and W. A. M. Smart. *Experimental Physiology for Medical Students* (6th ed.). London: Churchill, 1956, p. 103.
3. Mayow, John. *Medico-Physical Works* (A translation of *Tractatus Quinque Medico-Physici*, Oxford, 1674). Edinburgh: Livingston, 1957, p. 186–187 and Fig. 6 of Table 2. (Alembic Club Reprints No. 17).

Teachers and their students may find the following articles from *News in Physiological Sciences* useful when exploring the physiology of the preceding paper:

Decramer, M. Respiratory muscle interaction. *NIPS* 8: 121–124, 1993.

Macklem, P. T. The act of breathing. *NIPS* 5: 233–237, 1990.

Miserochi, G., and D. Negrini. Pleural lymphatics as regulators of pleural fluid dynamics. *NIPS* 6: 153–158, 1991.

Sant’Ambrogio, G., and O. P. Mathew. Control of upper airway muscles. *NIPS* 3: 167–172, 1988.

Schmidt-Nielson, K. Hopping and breathing. In *NIPS* (News and Notes) 2: 237, 1987.

Weibel, E. R., and H. Bachofen. How to stabilize the pulmonary alveoli: surfactant or fibers? *NIPS* 2: 72–75, 1987.