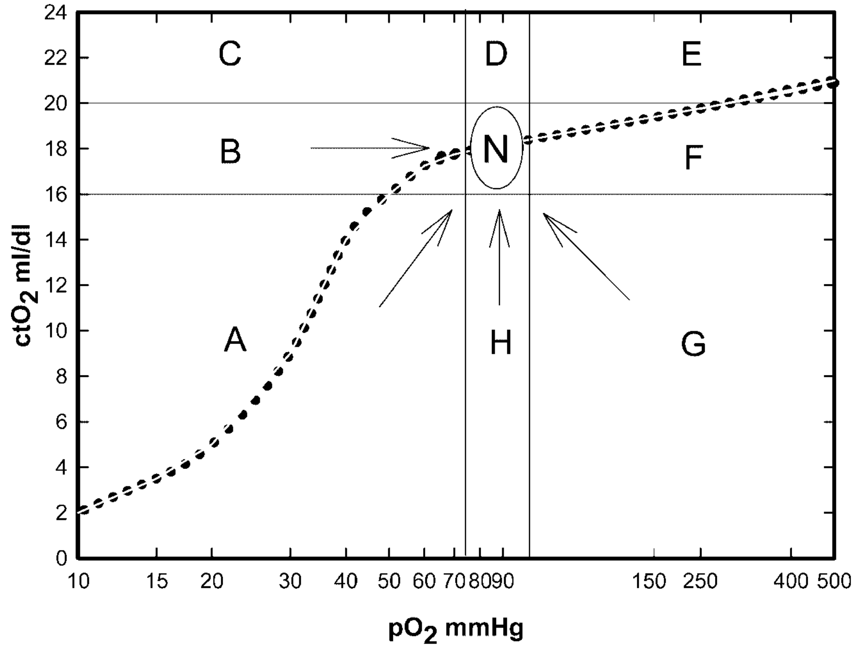
SUBMITTING ILLUMINATIONS FOR REVIEW

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 submissions is quite simple: a succinct description of about one or two double-spaced pages (less title and authorship) of something you have used for the classroom, teaching, lab, conference room, etc. You may include one or two simple figures or references. Submit ideas for inclusion in *Illuminations* directly to the Associate Editor in charge, Stephen DiCarlo (sdicarlo@med.wayne.edu).

Two-Dimensional Oxygen Map for Graphic Representation of Different Hypoxic Conditions

The simultaneous measurement of oxygen partial pressure, oxygen saturation, and hemoglobin content are important for diagnosing pulmonary complications (1, 2). The differentiation between hypoxia (a decrease in oxygen partial pressure, P_{O_2}) and hypoxemia (a decrease in oxygen content, CT_{O_2}) is fundamental to an understanding of hypoxic conditions as well as for the diagnosis and optimal management of critically ill patients. The differentiation between hypoxia and hypoxemia helps specify the pathophysiological mechanism of the impaired oxygen balance and indicates whether oxygen therapy, additional ventilation, and/or active hemoglobin are required (2). The different combinations that could occur from the relationship between P_{O_2} and CT_{O_2} (9 in number) and the bulky terminology (e.g., hypoxic normoxemia) are difficult for many students to understand. Therefore, we present a two-dimensional oxygen map that can be used for a graphic representation and straightforward understanding of different hypoxic conditions (Fig. 1). In our department, we have used this map as an effective aid for teaching oxygen disturbances for more than 10 years. The oxygen map was designed by dividing the area around the oxygen dissociation curve into nine zones. Of the nine zones, *A, B, D,* and *H* are those that are clinically important in subjects breathing atmospheric air. *Zones A* and *B* include patients with respiratory insufficiency and *zones D* and *H* those having abnormal hemoglobin values. *Zones E, F,* and *G* are of significance in patients on normo- or hyperbaric oxygen therapy. Finally, *zone N* is normoxic normoxemia. As an illustration of the assessment capabilities of the diagram we show some typical cases.

- Hypoxic hypoxemia (*zone A*) can be found in patients with acute or exacerbated chronic respiratory insufficiency who need intensive care (common condition).
- Treatment principles: adequate ventilation and supplemental oxygen.
- Hypoxic normoxemia (*zone B*) is most often found in patients with stable chronic respiratory insufficiency and compensatory polyglobulia, e.g., patients with chronic obstructive pulmonary disease (common condition);
- Adequate treatment of respiratory insufficiency and oxygen therapy.
- Normoxic hyperoxemia (*zone D*) is characteristic of patients with polyglobulia (rare condition).
- The therapeutic target is reduction of the polyglobulia.
- Normoxic hypoxia (*zone H*) is found in patients with various types of anemias and dyshemoglobinopathies (common condition).
- Blood (erythrocytes) transfusion is usually needed.
- Hyperoxic hypoxemia (*zone G*) can be found in patients with hematoxic hypoxemia on oxygen therapy (rare condition).



N: Normoxic normoxemia
A: Hypoxic hypoxemia
B: Hypoxic normoxemia
C: Hypoxic hyperoxemia
D: Normoxic hyperoxemia
E: Hyperoxic hyperoxemia
F: Hyperoxic normoxemia
G: Hyperoxic hypoxemia
H: Normoxic hypoxemia

FIG. 1.
Two-dimensional oxygen map with respective zones.

- Removal of the noxious agent is often the only treatment needed. In severe cases with methemoglobinemia (Mhgb levels >30%), methylene blue may be utilized; in case of severe carboxihemoglobinemia, continuous oxygen therapy.

For the purpose of more accurate blood gas analysis, the conditions of hypoxia and hypoxemia are graded as mild, moderate, severe, and extreme. We believe that these diagnostic zones not only illustrate the types of arterial blood oxygen disturbance but also suggest the therapeutic approach with respect to the need of oxygen, ventilation, or active hemoglobin and their optimal combination in the course of the treatment. In addition, the oxygen map shows the effect of correction (arrows in Fig. 1).

In conclusion, the two-dimensional oxygen map can be used successfully for a straightforward understanding of different hypoxic conditions. The visualization of the relationships between oxygen P_{O_2} and oxygen concentration is quite beneficial in improving teaching and learning in the field of respiratory pathophysiology.

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Simple, Inexpensive Classroom Experiments for Understanding Basic Gas Laws and Properties of Gases

Because respiration deals with gases, a thorough understanding of the physical principles relating to the behavior of gases is important for understanding respiratory physiology. However, the concepts and physiological significance of the gas laws and properties of gases are often difficult for students to grasp. To help students understand these concepts, simple experiments are often utilized, because *"[a]pretty experiment is in itself often more valuable than twenty formulae extracted from our minds. . ."* [Albert Einstein]. Students examine the force of ambient pressure, observe the concept of pressure gradients, experience the force of compressed air with three simple, inexpensive classroom experiments that are conducted during the lecture: "*The Collapsing Can,*" "*The Balloon Inside the Bottle,*" and "*The Compressed Air*" experiments. For the Collapsing Can experiment, we place 15 ml of water into an empty soft-drink can and boil the water on a hot plate for approximately 1 min. As the water boils, a cloud of condensed vapor escapes from the opening in the can. At this point, and using tongs, we grasp the can, invert it, and dip it into a beaker of water. The can collapses immediately with an impressive crush! The explanation for the collapsing can is that the vapor from the boiling water forced the air out of the can. Cooling the can by dipping it into a beaker of water condensed the water vapor, leaving the can empty. When the can was empty, the ambient pressure (pressure outside the can) crushed it (pressure outside greater than pressure inside).

For the Balloon Inside the Bottle experiment, we place 15 ml of water into an empty Pyrex bottle and boil the water on a hot plate until the water is almost gone. At this point, we remove the bottle from the heat and stretch the opening of a balloon over the opening of the bottle. As the bottle cools, the balloon is pushed into the bottle and inflates to fill the entire inside of the bottle. Again, the vapor from the boiling water forced the air out of the bottle. The balloon blocked the entrance to the bottle, and as the bottle cooled the water condensed, leaving the bottle empty. When the bottle was empty, the ambient pressure (pressure outside the bottle) rushed in (pressure outside greater than pressure inside), inflating the balloon.

Finally, for the Compressed Air experiment, we place a balloon into an empty bottle and stretch the opening of the balloon over the opening of the bottle. Students try to inflate the balloon in the bottle. No student has ever been able to inflate the balloon in the bottle, because the bottle is full of air. When the students blow into the balloon, the air in the bottle is compressed. The compressed air exerts more pressure on the balloon than even the largest student can blow into it.

Students' eyes light up when these concepts are illustrated by simple experiments.

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Pressure-Volume Curve and Compliance of a Balloon: a Simulation

Compliance is a term that is being used in physiology of the respiratory and cardiovascular systems. From our experience, although compliance has rather a simple physical (mathematical) definition, the physiological concept is not so simple and is not intuitively understood by students.

The balloon model is often used in the literature to explain lung (or blood vessels) compliance (1, 2, 3). During their physiology studies, biology undergraduate students do not have the opportunity to measure real lung or blood vessel compliance. Measuring the compliance of a balloon instead may help students to understand the concept better.

Because the Open University is a long-distance learning university, we have prepared a simulation that enables the students to perform the experiment on their home PCs.

Study Goals

After the exercise students should be able to

- draw a pressure-volume curve of the balloon on the basis of the data they collect.

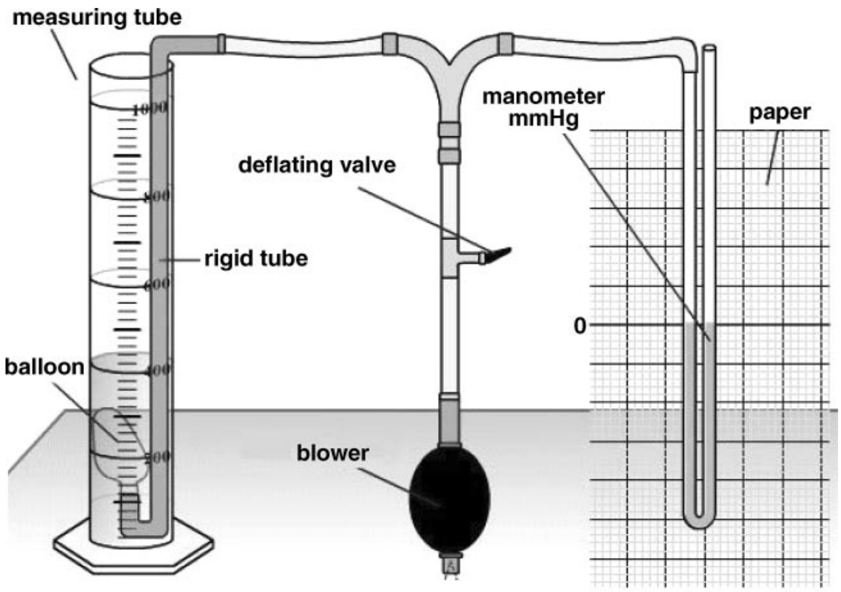

FIG. 1.
The simulation.

- calculate the compliance of the balloon from the pressure-volume curve.
- suggest a way to measure compliance of lungs.
- explain the difference between the balloon model and the lung/chest.
- suggest methods to measure compliance of blood vessels.

Experiment and Simulation

The simulation is based on a "real" experiment that was performed at the Open University students' laboratory with simple equipment: a mercury manometer and a device for measuring the volume of a balloon. To measure the balloon's volume, the balloon was immersed in a measuring tube filled with water. The volume change was calculated from the water's height (Archimedes Law). From the data, the volume-pressure curves for inflating and for deflating the balloon were plotted. With a few assumptions, (neglecting the water pressure on the balloon) the balloon's compliance can be calculated from the curve. The simulation was prepared by the multimedia team of SHOHAM, The Open University Center for Information Technology in Distance Education.

The simulation can be performed on-line on the course home page, or it can be downloaded to PCs in the student's home. On the simulation (Fig. 1), the students are required to inflate and deflate a virtual balloon and collect the volume and pressure data onto an Excell worksheet. They are asked to draw the pressure-volume curve of the balloon and calculate the compliance.

The simulation is accompanied by a guide and an online multiple-choice preparatory questionnaire. The guide includes theoretical background, instructions for performing the experiment/simulation, and instructions for calculations and lab report. At the end, they have to submit a lab report.

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