HEARTS, LUNGS, AND CHILDREN: A PHYSIOLOGIST RETURNS TO KINDERGARTEN

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Scientific illiteracy is a prevalent problem: between kindergarten and high school, most children progressively lose their inherent affinity for science exploration. The correction of this deficiency requires vigorous participation by the scientific community. This paper details my experiences introducing kindergartners to the basics of cardiorespiratory physiology: pulmonary ventilation and circulatory transport of oxygen. More important, my presentation gives children an opportunity to participate in the process of scientific inquiry and to discover and explore the mystique of real hearts and lungs. The children and their teachers truly enjoy the demonstration. In particular, my use of animal organs meets with phenomenal success: the children are enchanted by my inflation and their exploration of pig lungs, and one teacher told me weeks afterward that her students were still "bragging of how they touched a real heart and lung." Young children delight in science exploration and marvel at the wonder inherent to physiology. Armed with an intriguing hands-on presentation and a spirit of adventure and fun, any scientist can return to kindergarten. The rewards are likely to be profound.

Key words: cardiorespiratory physiology; education; elementary school; scientific literacy

Preschool children learn through exploration and experimentation: in short, they act like scientists. But between kindergarten and high school, most of these children progressively lose interest and proficiency in science (see Ref. 12); this scientific illiteracy alarms educators and scientists alike (5, 7, 10, 12). To mitigate societal ignorance about science, the educational and scientific communities are instituting fundamental reform in kindergarten through 12th grade science education (6, 11, 12); requisite to the success of these efforts is interested participation by practicing scientists (5, 6, 11, 12, 15). I believe we can contribute most effectively in early elementary grades: even young children are capable of sophisticated scientific thought, and early childhood discoveries in science have persistent benefits (9).

In this paper, I report my experiences introducing kindergartners to the basics of cardiorespiratory physiology: in essence, to the mystique of real hearts and lungs. Although my demonstration may promote scientific literacy of the children, I really visit kindergarten because the children and I have great fun; in the process, they discover the wonder in science and physiology.

THE DEMONSTRATION

Preparation. In the days preceding my visit, the children learn about lungs and oxygen and the heart...
TABLE 1  
Physiological concepts and their in-class illustrations

<table>
<thead>
<tr>
<th>Concept</th>
<th>Illustration</th>
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<tbody>
<tr>
<td>Requirement for O₂</td>
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<td>O₂ transport: air → blood</td>
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<td>Mechanics of breathing</td>
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<td>Pulmonary ventilation</td>
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and blood; in some classes, the children make realistic models of the lung and discuss components and functions of blood (16). In my presentation, I exploit these experiences: I integrate my explanations and questions with the children's knowledge and hands-on activities.

My preparation for the demonstration is quite modest. The previous day, a local meat-processing plant supplies the heart and lungs from a pig; I rinse them with normal saline and then tie a length of stiff tubing into the trachea. After I complete an unrelated rabbit study, I remove and rinse the heart and lungs and then cover them with saline-moistened gauze sponges. Just before the demonstration, I fill two 20-ml syringes with 100% N₂ and 100% O₂ and give two 1-ml samples of venous blood; last, I suspend the rabbit heart and lungs in a bell jar analogue.¹

The demonstration itself. This presentation illustrates some sophisticated concepts involved in pulmonary ventilation and convective oxygen transport (Table 1). My goals for the children, however, are quite basic: I want them to participate in the process of scientific inquiry, I want them to discover and explore the wonder of actual hearts and lungs, and I want them to have fun. In the following outline, I have identified experiments and listed questions that I incorporate into the demonstration.

I begin by introducing myself as a parent, a scientist and finally, a physiologist who is fascinated by hearts, lungs, and oxygen. After previewing the demonstration, I describe the correspondence between the human body and a burning candle. I demonstrate the importance of oxygen by enclosing a burning candle with a jar (Expt 1).

Next, I frame convective oxygen transport as a two-part problem: 1) pulmonary ventilation (“How do we get oxygen inside our bodies?”) and 2) circulatory transport (“How does blood get to every part of our bodies?”). I sketch a thorax that includes chest wall, trachea, main bronchi, lungs, and diaphragm (“If we were oxygen, where would we go?”); in my overview of pulmonary anatomy, I use the analogies of an upside-down tree for airway branching and a bunch of grapes for alveolar structure. I mention in general terms the roles arteries and veins play in the circulatory transport of oxygen. So the children can see that blood does carry oxygen, I mix venous blood with either N₂ or O₂ (Expt 2).²

To show “real lungs in action,” I first illustrate mechanics of breathing using pig lungs. I invite the children to touch the atelectatic lungs.³ Then, using the classic analogy of a balloon, an object most children are familiar with, I allude to the concepts of functional residual capacity and elastic recoil. Before I inflate the lungs, I ask for and mark the children’s guesses⁴ about the size of the soon-to-be-expanded lungs (Expt 3). The children are so enthralled by the lung distension that they eagerly reach to touch the lungs and then enthusiastically request several encore inflations.

After the curtain calls, I demonstrate pulmonary ventilation (“What happens to our lungs when we breathe?”) using rabbit lungs in an analogue th-
I show the effects on ventilation of increased breathing frequency and tracheal obstruction (Expt 4).

At the end of the demonstration, I cut the pig lungs into chunks and allow time for each child to explore his/her own piece; the children readily find airways and blood vessels. I open the pig heart and talk briefly about its chambers and valves. Finally, I recapitulate for the children what they saw during the demonstration. Before I leave the classroom, I present to the children detailed anatomical charts and a plastinated horse heart so they can continue to discover and explore after my visit.

Performance aspects of the demonstration. In any presentation, execution is as important as content and organization; execution is particularly crucial if the presentation involves young children. During this demonstration, I am animated and theatrical, and I continually solicit and encourage active participation of the children. In a conducive atmosphere, young children quickly become eager participants; the challenge can be managing their lively contributions in order to finish the demonstration within a practical length of time (~45 min).

The following abbreviated version of Expt 1, in which I illustrate the requirement for oxygen, exemplifies my use of questions and conveys the tone of my demonstration:

What would you say if I told you this candle is a lot like our bodies? (Usually, the children look puzzled and glance among themselves. I put on my best bewildered expression.) You might say, "Dr. Doug, are you cub-ra-zy?" (If I have succeeded in connecting with the children, they giggle; some ask if I am crazy.)

(After lighting the candle and discussing oxygen, I continue.) One way to see how important oxygen is, is to see what happens when we take it away. Now, we can't do that with our bodies, but we can use this candle. What will happen when I cover the candle with this jar? (Most children answer that the candle will go out.) Why did the candle go out? (Some children say that the candle used up the oxygen in the jar.)

Theatrics and active involvement of the children are integral and essential elements of my demonstration; they help convey excitement and a sense of fun and ultimately contribute to the children's educational experience.

Reactions to the demonstration. The children and their teachers have enjoyed the demonstration; several parents, out of their own curiosity, attended one presentation. At the end of another visit, one girl asked excitedly, "Can I tell everybody?"; one boy asked that I stay the rest of the day; some of their classmates pleaded that I return with other body parts—ears, noses, eyes, and brains were just some they requested.

During the demonstration, the children are sometimes reluctant, usually exuberant, always spontaneous; they enjoy "surprising" me with insightful answers to my questions, and they are amazed that the blood in Expt 2 came from me. But without doubt, they are most captivated by my inflation and their exploration of the pig lungs. Some children do hesitate initially to touch the atelectatic lungs; the incredible pulmonary transformation caused by inflation nearly always overcomes their reluctance.

DISCUSSION

I attribute the children's enthusiastic reception of this demonstration primarily to three factors: 1) the animal hearts and lungs, 2) the children themselves,

5 In my opinion, the recent characterization of an air-filled intrapleural space as "alarmong" (13) is too harsh. By definition, a model approximates an actual system; when deficiencies in the model exist, and they usually do, it is often because the model emphasizes other aspects of the true system. For example, although a fluid-filled intrapleural space has clear advantages in any model of the thorax (see Ref. 13), obvious limitations remain: 1) the thickness of the intrapleural space, a potential space only, is exaggerated, and 2) a syringe, regardless of its position on the apparatus, is a poor representation of the diaphragm.

6 The anatomical charts are from the Johns Hopkins Human Anatomy Series (The Lungs and Blood Vessels and The Heart). I loan the set of charts and the plastinated heart for 1–2 wk.

7 My inflation of the lungs has prompted cries of "Awesome!". And the now-predictable curtain calls are every performer's dream.
and the atmosphere of collaboration and fun that I establish. Because young children are egocentric, the animal hearts and lungs are intrinsically appealing. But children are inherently curious about most things, so nearly any science demonstration is likely to be well received as long as it actively involves the children and creates excitement. I foster a collaborative spirit by respecting the children’s intellectual abilities: for example, I use full-fledged anatomical terms accompanied, of course, by age-appropriate explanations.

Animal organs. In all honesty, it is the lungs that form the cornerstone of my demonstration. It was around a sense that children would find fascinating the ventilation of real lungs that I wove a richer story of oxygen transport. When I introduce the pig lungs, I matter-of-factly say that they came from a company that prepares meat for grocery stores: “Instead of sending the lungs to the grocery store, this place gave them to me so I could show them to you.” Only once has a child asked my source of the rabbit lungs; my prepared answer “From a rabbit that helped me do experiments” satisfied the child. I answer any questions about the organs openly and directly; and, I answer only the question I am asked.

My use of animal organs has met with phenomenal success. Several weeks afterward, one teacher told me that her students were still “bragging of how they touched a real heart and lung” (M. Radigan, personal communication). One of my most enduring memories will be of Derek, described by his teacher as a rebellious child who had difficulty staying on task (C. Roybal, personal communication). For 10 min after his classmates—my son included—had vanished outside, Derek, disheveled gloves clinging to his hands, sat inside exploring the pig heart, poking his fingers through valves, playing with papillary muscle, squeezing ventricular walls, saying again and again, “This is cool!” For an educator, experiences like these are powerful stuff.

Early science discovery. The benefits of childhood exploration and discovery in science are clear; they have both short-term and long-lived impact. For weeks and months afterward, science discoveries provide vivid reference for class activities: one kindergarten eventually discussed diet and health; its teacher could ask, “Remember when we saw the heart?” (C. Roybal, personal communication). The children did.

More important, hands-on discovery in early elementary school can provide a framework for valid understanding of science concepts studied through high school (9). Nearly 30 years ago, Ausubel (2) anticipated this effect.

If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows.

What the learner already knows may be wrong. Existing misconceptions stubbornly resist revision and, by influencing the acquisition of new concepts, impede meaningful learning (8, 9, 12). Early learning in science helps eradicate those misconceptions (9).

Elementary science education resources. Recent curriculum guidelines and programs (3, 4, 11, 14, 16, 17) stress and suggest hands-on activities to promote science concept learning. The American Medical Association and the Massachusetts Society for Medical Research have produced a guide (1) to encourage and facilitate clinical and research community contributions to elementary science education. Likewise, the American Physiological Society is compiling science education guidelines and activities for eventual release (M. L. Matyas, personal communication). These resources may facilitate the development of an early elementary school presentation.

Conclusions. Young children are eager, able learners; they delight in science exploration and marvel

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8 When I discuss pulmonary anatomy, I introduce and then use the words trachea and airways rather than windpipe and tubes. The children genuinely enjoy knowing and using proper scientific terms.

9 With one exception, parental reactions have been highly favorable; the lone exception was when a parent, concerned about fixatives, asked the teacher if the children would wear gloves during the demonstration (C. Roybal, personal communication).
at the wonder inherent to physiology. Armed with an intriguing hands-on presentation and a spirit of adventure and fun, any scientist can return to kindergarten. The rewards are likely to be profound.

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