What we talk about when we talk with medical students

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Joyner MJ, Charkoudian N, Curry TB, Eisenach JH, Wehrwein EA. What we talk about when we talk with medical students. Adv Physiol Educ 35: 16–21, 2011; doi:10.1152/advan.00058.2010.—In this article, we review how we interact with medical students in our efforts to teach blood pressure regulation and systemic cardiovascular control along with related elements of respiratory and exercise physiology. Rather than provide a detailed lecture with key facts, we attempted to outline our approach to teaching integrative cardiovascular physiology to medical students, which includes five major themes. First, focus on questions versus answers and facts. We believe that this offers both the learner and teacher a number of advantages. Second, avoid teaching dogma in the name of clarity (i.e., heavy focus on teaching “facts” that have not yet been fully investigated). This is especially important because of the way knowledge evolves over time. Third, include laboratory-based experiences in human integrative physiology. Fourth, provide students with intellectual frameworks versus a list of “facts” to serve as a platform for question generation and deeper understanding. We want to educate versus train medical students. To do so, we focus on questions versus rote memorization, and we avoid heavy focus on “answers and facts” because of the way that knowledge evolves over time. Our perspective is also informed by our belief as physiologists and anesthesiologists that laboratory experience in physiology is critical for the future physician. Finally, it is essential to focus on the role of integration and regulatory redundancy in physiology, so this is built into our discussions.

The Problem of “Information Smoothies” and Academic Hurdling

“Basic science” is usually taught to medical students by basic scientists. These individuals are, for the most part, interested in the deep intellectual exploration of a specific set of problems, topics, ideas, and questions. In contrast, the undergraduate education experience leading up to medical school, the admissions process, and success in the didactic portions of medical school can be seen as a collection of reasonably well-defined hurdles that have to be overcome by the student so that the next hurdle or hurdles can be addressed. So, to the basic scientists participating in the education of medical students, it seems as if they are doing no more than creating an “information smoothie.” This can be described as filling the brains of the students with a collection of facts, stirring the facts, and sampling the outcome via some sort of standardized testing procedure. This general approach also leads to terribly frustrating questions, such as:

- “Can you post the answers to the quiz on the web?”
- “Can you post the slides on the web?”
- “Will this be on the test?”
- “Why do we have to know X when my clinical preceptor tells me it’s not relevant to medical practice?”

So, there is a clash of cognitive style that, at some level, requires deeply curious individuals to present oversimplified material (and lots of it) to obviously intelligent people who are too busy to get deeply involved in the material. Frustration abounds, for different reasons, on both sides.

Our Unique Environment Facilitates Our Approach to Teaching

In contrast to the situation described above, our diverse team of authors is lucky because we have varied backgrounds and perspectives that allow us to understand both sides of the frustrations described above. We have backgrounds in basic science, clinical investigation, medicine, and integrative physiology. Additionally, the clinical investigators among us (all anesthesiologists) are willing to make definitive and concrete statements to students about the relevance of integrative physiology and research to
医疗实践。事实证明，我们是研究合作者，我们的工作也传递了强有力的信息。

我们也很幸运，因为我们的学校很小，有一门“必修”课程在第三年在梅奥医学学校。此外，我们有学生在夏季轮转，没有上述的轮转，以及我们临床和转化科学活动（CTSA）计划负责招募、鼓励，并资助医学学生在暑假期间进行一年的“在实验室”研究。（作为对一年“在实验室”投资。）这意味着，即使我们做一些不寻常的事情并真正推动学生思考，我们也有一些方法来达到我们的目标。最后，每一个水平的组织都是与临床和转化科学家的强强联合。

“金星综合征”是你的朋友

如上所述，医学学校被学术挑战所充斥。有一种强烈的关注“正确答案”和一个似乎无休止的追求金星（尽管对某些人来说，似乎是在学前教育）的每堂课或每项任务。在令人沮丧的地方，它也是生活的一部分，是可以被模拟能在大流行病学名称中提供的信息。情况是怎样的？有时候，情景被转换为问题形式，然后是生成问题或找到整合答案，它们是有关黄金星综合征的。在这个设置中，我们发现学生是相当有动力和热情地寻求信息、提问和讨论答案。通过将20个问题的作业转换为学习型格式，黄金星综合征实际上被强化。

将焦点从问题到答案而非答案

第一种要求是摆脱信息倾销游戏，改变范式。这意味教师避免用简化的讲座形式以一种在论述中以事实数据集形式呈现的信息。第二步是将焦点从问题转移到问题，授予学生信息收集和学习的主动权。在这个过程中，我们生成了一系列的20个问题，这些问题与呼吸系统和运动生理学有关，用于鼓励一种强烈的关于信息的“吸收”行为。图1显示了这些情况的示例。

这些20个问题是为学生或小组学生分配的。他们需要使用任何必要的资源来生成答案，然后答案是被重新审视和讨论在小班的领导下的导师。这种方法支持主动学习，允许学生以不同的学习风格积极参与学习。这也转换了从讲座形式，这有利于听觉学习者，向学生传递一个强有力的信号，即教师和小组教师需要以不同的方式对待。

这种方法发送了一个有力的信息，即问题比答案更重要。这不仅适用于学生，而且在学习和保持方面也是如此。因此，最后几个问题中的20个问题系列也代表一个努力，以一种关于太多焦点和未经过滤的简化主义。

- **问题 18**（图1）考虑一个由红细胞内红细胞内2,3-二磷酸甘油酸（2,3-DPG），它控制氧从血红蛋白的释放。正常水平下，2,3-DPG导致氧从血红蛋白释放的增加。而在海拔高处，当pH升高时，2,3-DPG导致氧从血红蛋白释放的右移。为什么在海拔高处，氧从血红蛋白的释放会增加？2,3-DPG在分子水平上是如何表现出右移的？在血液中，2,3-diphosphoglycerate (2,3-DPG) 的作用是什么？

- **问题 20**（图1）关于鸟类肺部的使用，以提醒鸟类肺部的一个事实，氧气和运动生理学自基本科学以来就在从事分子和整合生理学。这实际上也是一个关于如何2,3-DPG在生物化学水平上的作用的水平；然而，当人类向高处移动时，氧-血红蛋白曲线被移动到左。为什么会有这种变化？2,3-DPG在分子水平上是否实际上会增加氧-血红蛋白 dissociation curve on a cold high mountain when pH is elevated is considered a taboo for patients with heart failure; and now they are considered standard therapy. Similar stories can be told about the management of mechanical ventilation and the use of exercise and physical activity versus bedrest in the treatment of heart disease.

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**为什么问题更重要？**

它已经估计至少50%的教科书在临床医学中的教学是“错误”的，但是在用信息作为教义的形式，这限制了新思想的采纳。高级作者的团队可以清楚地记得当时β阻滞剂被认为是禁忌症，因为患者有心脏失败。相似的故事可以被讲述出来关于机械通气的管理以及运动和生理活动与卧床休息在治疗心脏病方面。

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**问题**

#1 什么是Fick方程？
#4 Avogadro可以解释为什么每g的Hgb可以 bond~1.35 mls of O2?
#17 Is the main cause of increased lactic acid production during exercise hypoxia in the exercising muscles?
#18 2,3-DPG causes a right shift in the O2-Hb dissociation curve. Why then is the curve shifted to the left at extreme altitude?
#19 You are 70% saturated while mountain climbing in the Himalayas. Why are you becoming apneic at night?
#20 What feature of the Avian Lung permits birds to fly over Mt. Everest?

Fig. 1. Six of the twenty questions we ask medical students to consider before a discussion/lecture on issues related to oxygen transport, respiratory physiology, and exercise. Hgb, hemoglobin; 2,3-DPG, 2,3-diphosphoglycerate.
also a unique physiological challenge encountered by high altitude-dwelling natives and adventure travelers that can lead to dire consequences; in contrast, many other species, such as bar-headed geese and bats, are remarkably tolerant to hypoxia and altitude (6). Could mechanistic knowledge of how this hypoxic tolerance is achieved lead to novel drugs or other therapies? The avian hypoxia tolerance discussion is useful for many reasons: 1) it brings to light the clinical relevance of integrative and comparative physiology; 2) there are studies on most organ systems of hypoxia-tolerant animals, so this discussion can span several organ systems for teaching or can serve as a stand-alone integrative physiology discussion; and 3) when appropriate, original research articles can be woven into class reading and discussion to promote physiological research and its relevance to clinical studies.

The Internet Is Your Friend

Another advantage of using the question-driven approach is that it turns the internet and other forms of electronic media into your friend. Depending on the age of the teacher, a detailed understanding of how young people use the electronic environment to gain information is more or less clear. Figure 2 is a slide taken from a drug company talk available on the internet that presents a “Readers Digest” version of the kidney and blood pressure control. It can be used to reinforce simple thinking or to ask what is wrong with this schematic. Certainly, unfiltered use of the electronic environment can contribute to the information smoothie problem, but by carefully framing the questions, the educator encourages the learners to take a more targeted and integrated approach to finding the information and putting it in some sort of intellectual context. Again, this approach encourages learners to take charge of their own education and discourages rote performances on both sides of the lectern.

Give Students Freeways and Let Them Make the Off Ramps

As noted above via the example of β-blockers and heart failure, at least 50% of what students learn today will be seen as outdated or “wrong” in the coming years. If this material is presented “too well” or overemphatically as “right,” it makes it even harder to “fix” things later. Therefore, it seems reasonable to advocate that the key principles and main regulatory influences be outlined as intellectual “freeways,” with the discussion questions serving to let students build their own mental on and off ramps.

Fig. 2. Example of a schematic of the renal-centric view of blood pressure regulation. It was downloaded via Google images from Merck. It represents both the quality of the graphical material that is available online as well as a typical “Readers Digest” explanation of physiological principles that can appeal to medical students. Depending on how this material is presented, it can serve as either a “fact” crutch or an intellectual framework. ACE, angiotensin-converting enzyme. [Modified from Ref. 12a.]
pathways in blood pressure control, the discussion questions that might flow from this include outlining how commonly used antihypertensive medications influence various elements of the diagram and what compensatory mechanisms might occur in response to various drug therapies. Are the redundant regulatory pathways the reason why so many patients fail monotherapy for hypertension, and why there is so much “resistant” hypertension that is nonresponsive to conventional therapy? Blood pressure is clearly important in anesthesiology and critical care, and hypertension is one of three or four conditions that dominate the office practice of internal medicine and family practice. Therefore, a discussion of the system as a whole along with thought-provoking questions about system responses to perturbations will reinforce the key pathways, feedback loops, and redundant mechanisms by way of “thinking” about rather than “listening” to a lecture. This type of active thinking and learning is an important exercise to generate the conceptual freeway that allows students to develop questions rather than memorize facts.

The Gore diagram (Fig. 4), in conjunction with the examples shown in Fig. 3 and the observation that many patients fail monotherapy for hypertension, is also interesting in the context of emerging new device therapies for “resistant” hypertension. These include renal denervation as well as electrical stimulation of the carotid baroreflexes (9, 13). Figures 5 and 6 show data from clinical trials using these physiologically based approaches as a therapy for hypertension (9, 13). The Gore diagram and these observations provide a clear way to question about these therapies and also about the clinical relevance of physiology as a whole. The value of using current research in teaching is that students can keep up with the constantly evolving knowledge and therapies in a particular area and see the immediate clinical relevance of research.

The Retrospectoscope Should Be Required Reading

In the opening parts of this article, we highlighted the role of questions, incomplete information presented as facts, and the need to provide the students with intellectual highways versus fixed ideas. Many of these ideas flow from the work of Prof. Marlys Witte (also from the University of Arizona) on “medical ignorance” (15, 16). They also highlight the nonlinear nature of medical progress and “cures” or novel therapeutic approaches. In this context, in the 1970s, Comroe and Dripps (2) published an intellectual autopsy of the discoveries needed to make open heart surgery at first possible and then routine. They concluded that much, or even most, of the key information was generated by people working or thinking about very different things. Comroe called such exercises looking through a “retrospectoscope.”

The Comroe and Dripps (2) article should be required reading for medical students in an effort to combat fixed thinking and a focus on the right answer. One only has to remember that Viagra and VEGF inhibitors are effective against the “wrong” diseases: originally developed for the treatment of angina, phosphodiesterase type 5 (PDE5) inhibi-
Physiology (and Learning) Is a Process and Not an Event

There is a narrative quality to medical progress based on physiology. The dramatic decrease in deaths from heart disease is multifactorial but, in large part, reflects very basic ideas about the relationship between oxygen supply and demand in the heart, and almost every successful treatment for heart disease does something in the short or long term to alter this balance in a favorable way. In contrast, one could also argue that progress against cancer has been slowed by a lack of an integrated understanding of what goes wrong and how redundant regulatory systems either reinforce the problem or can be modulated to correct it. The value of research and teaching of integrative physiology is that we are able to focus on the big picture, and this provides a valuable thought tool for students to consider systems. In contrast, the fact-driven lecture is passive to students, and this format tends to treat physiology as an “event” or set of facts, not a “process.” The question-based approach to learning and emphasizing that we need to engage in constant learning as new information becomes available is a valuable tool. By presenting a list of facts in a well-polished lecture, we do a disservice to ourselves and the students by eliminating the active component of the learning process in the “event” of the lecture.

Fig. 4. A “Gore” diagram. This diagram demonstrates the vast majority of the key local, organ, and systemic interactions that regulate blood pressure. In addition to providing useful key principles and pathways in blood pressure control, the discussion questions that might flow from this include outlining how commonly used antihypertensive medications influence various elements of the diagram and what compensatory mechanisms might occur in response to various drug therapies. Educators can use this diagram not only as a factual diagram but, more importantly, as a question generator and discussion builder in conjunction with Figs. 5 and 6. EDV, end-diastolic volume; ESV, end-systolic volume; TPR, total peripheral resistance; CO, cardiac output.

Fig. 5. Effects of renal denervation on systolic and diastolic blood pressure in patients with resistant hypertension. Renal denervation reduces both systolic and diastolic pressure in patients with resistant hypertension. Data such as this, in combination with the Gore diagram (Fig. 4), help students think about therapy for hypertension and why it fails so often. [From Ref. 13.]

Fig. 6. Effects of carotid sinus nerve stimulation on a patient with resistant hypertension. Bilateral carotid sinus stimulation can be used to reduce blood pressure in patients. As is the case with Fig. 5, this graph, in conjunction with the Gore diagram (Fig. 4), can help students think about the pathophysiology of hypertension and why therapy fails so often. [From Ref. 9.]
Summary: This Lecture Has Been Different

We avoided the temptation in this article and also the lecture associated with it to give a detailed and scripted example of a polished “factual” lecture on a topic like blood pressure regulation. From an intellectual perspective, we have strongly challenged the renal-centric view of blood pressure regulation and argued that the role of the sympathetic nervous system has been underappreciated (8). From a philosophical perspective, we believe questions and not answers are where the action is for both research and education.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

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