Science is fundamental: the role of biomedical knowledge in clinical reasoning

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CONTEXT Although training in basic science is generally considered a critical aspect of medical education, there is little consensus regarding its precise role in clinical reasoning. Whereas some reports suggest that biomedical knowledge is rarely used in routine diagnosis, other research has found that biomedical knowledge can become an integral part of the expert knowledge base.

OBJECTIVE The purpose of the current paper is to present evidence in support of different views regarding the role of biomedical knowledge, including the two-world hypothesis, encapsulation theory and recent work on the role of biomedical knowledge in novice diagnosticians. The implications of these models for clinical teaching will be examined.

DISCUSSION Recent work suggests that biomedical knowledge can help novices develop a coherent and stable mental representation of disease categories. As a result, learners are able to retain clinical knowledge over time and maintain diagnostic accuracy when faced with clinical challenges. This suggests that clinical teachers should attempt to make explicit connections between biomedical knowledge and clinical facts during training.

KEYWORDS *clinical competence; *decision making; *diagnosis; biological sciences/*education; education, medical, undergraduate/*methods; teaching/*methods.

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INTRODUCTION

Clinical reasoning depends on a careful balance of several different types of knowledge, including knowledge of the clinical features of disease, of case-based exemplars and of the biomedical mechanisms that govern the functioning of the human body. Although few would argue the importance of clinical knowledge or that novices should be exposed to a variety of cases, clinical teachers continue to debate the role of biomedical knowledge in routine clinical reasoning. Whereas basic scientists may tout the importance of their discipline, some clinicians see the biomedical sciences as only peripherally relevant to daily practice.

At first glance it is easy to understand both sides. Even a layperson would agree that a trained health professional should have some understanding of anatomy, physiology, genetics, biochemistry and biology. Patients imagine that their doctors routinely consider these fundamental principles. Most people would find something unsettling about the notion that these disciplines might have little impact on everyday medical decisions. By contrast, we are all familiar with situations in which information that is important in theory becomes less so in practice. Much like the content of a high school physics class, the basic science training received in medical school might be quickly forgotten with time and practical experience. According value to basic science in routine clinical reasoning may represent a naïve perception that is not reflective of daily experience. Proponents of such an argument can find ample support in the clinical reasoning literature, citing numerous examples of expert reasoning that is seemingly independent of basic science knowledge. Pattern recognition and other forms of non-analytic reasoning can lead to accurate clinical decisions with little-to-no biomedical knowledge. A clinician...
Overview

What is already known on this subject

There are conflicting views on the role of biomedical knowledge. It may play a limited role in clinical reasoning or be embedded into the knowledge structure of the expert clinician and activated during diagnosis.

What this study adds

This paper presents an indirect role for biomedical knowledge in diagnosis by novices. It outlines the value of biomedical knowledge in memory and diagnosis under challenging conditions.

Suggestions for further research

Future research examining these effects in the classroom and other aspects of clinical reasoning is needed.

simply does not need to recall the specific mechanism of a disease in order to recognise the similarities between 2 patients, suggesting that there is little need for basic science knowledge to play a substantial role in any model of the nature of medical expertise.

Patel and colleagues once championed such a model in which basic science concepts and clinical knowledge form 2 entirely separate mental representations, with clinical knowledge providing the basis for most expert reasoning and biomedical knowledge serving predominantly as a communication tool.3 Patel et al. sought to support this model through the most direct means possible: a series of studies that simply asked clinicians to think aloud while working through a clinical case. A qualitative analysis of the verbal reports revealed little mention of biomedical concepts.3,4 Instead, most doctors focused on the analysis and interpretation of clinical features. Only when confronted with a diagnostic challenge did experienced clinicians begin to explicitly rely on biomedical principles.5

Combine the empirical findings of Patel et al. with the anecdotal reports of practising clinicians and it is tempting to conclude that basic science is of little value to the experienced clinician. However, the doctors in these think-aloud studies and the practising clinician who believes he does not use his basic science knowledge may simply be expressing a type of meta-cognitive bias that we all display. They simply do not recognise (and therefore cannot verbalise) how their knowledge of physiology, biochemistry and the other sciences shapes the way they view, organise and interpret clinical information. This is neither a novel concept nor unique to doctors. As human beings, we are often unaware of cues, assumptions and background knowledge that impact our decisions.6 However, lack of awareness of the impact of basic science knowledge does not diminish its actual significance. Although the clinical sciences may have the most obvious impact on expert reasoning, basic science may still play a subtle, yet important, role.

It is precisely this type of indirect role for basic science knowledge that forms the basis of Schmidt’s encapsulation theory.7 According to Schmidt, biomedical knowledge and clinical facts becoming increasingly integrated as the clinician gains experience. For the medical expert, basic science concepts become encapsulated under clinical facts in the mental representation of a disease. With time, clinicians can seamlessly recognise a group of clinical facts linked by biomedical knowledge, without needing to overtly describe the underlying pathophysiology. This encapsulation of biomedical knowledge explains why there is little mention of basic science principles or mechanism in explicit recall or reasoning measures. Instead, the impact of biomedical knowledge will be revealed only through indirect means. Using a ‘priming’ paradigm, a recent series of studies by Rikers found that, unlike medical students, practising clinicians were able to quickly identify biomedical words and phrases related to the correct diagnosis of a previously presented clinical case.7–9 This suggests that as the clinician worked through the clinical case, both clinical and biomedical knowledge were activated, enabling quick identification of biomedical target words shortly afterward. Critically, this occurred regardless of the doctor’s explicit awareness.

It is important to note that, considered in isolation, encapsulation theory tells us that expert mental representation of any disease can include biomedical knowledge embedded in clinical knowledge. Encapsulation theory does not explain whether encapsulated biomedical knowledge is a causal factor in expert performance or simply the by-product of years of clinical experience. Just because biomedical knowledge can be encapsulated under clinical knowledge does not mean it must be in order for expert clinical performance to be attained. Perhaps

clinicians would perform equally well without these types of knowledge structure.

This is a critical question for clinical teachers. It has been assumed since Flexner that basic science education is a critical part of medical training. Yet there is little basis for this assumption. Perhaps the instructional and mental resources devoted to the basic sciences could be better spent by having students gain additional clinical exposure or learn alternate reasoning strategies. For example, there have been several demonstrations that diagnostic accuracy can be improved by helping students consider the alternatives and think about the features of disease in terms of statistical probabilities. In fact, students who learn using quantitative aids have been found to show greater accuracy than those who learn the same material with the benefit of verbal descriptors. This would seem to suggest that mathematical probabilities may in fact be a valuable learning tool for the novice diagnostician.

However, recent research has tested the learning efficacy of a type of quantitative aid against that of a biomedical description. Although the 2 learning methods led to equal levels of success immediately after learning, the basic science framework led to greater diagnostic accuracy after a 1-week delay. This suggests that the novice diagnostician can benefit from understanding biomedical knowledge even without a wealth of additional case-based knowledge and that biomedical knowledge can be the basis of a useful learning tool for even rank novices, although the added value may not manifest until it is used long after the original learning.

One possible explanation for this finding comes from cognitive psychology and research into categorisation. In order to categorise something, we must have intimate knowledge of the features of the category as well as some theory regarding the relationship between those features. Critically, the features of any category are rarely random. Instead, they go together for a reason – perhaps an underlying biological or mechanical process. In medicine, each diagnostic category includes a set of key clinical features. For the participants in this study, the basic science text explained the relationship between those features, allowing the students to understand that features of each disease go together for a reason. Once the diagnostic category becomes more than a random assortment of signs and symptoms, students can develop a more coherent mental representation that is easier to retain in the longer term. Hence the biomedical knowledge served as a mnemonic device for learners.

Additional research suggests that training students with the underlying mechanisms does more than just help them remember the material. In another study, undergraduate psychology students were asked to learn a series of artificial diseases. For 1 group of participants, the learning materials included the clinical features as well as simple explanations for how the features were connected. The other group learned the clinical features without the explanations. In a later speeded decision-making task, participants were asked to diagnose a set of cases as quickly as possible. They were then asked to diagnose another set of cases, taking as much time as they needed. The results showed that although students who only learned the features showed a typical, standard speed–accuracy trade-off (they were more error prone on the speeded version of the diagnostic task), students who learned the causal mechanisms did not. In fact, the students trained with causal mechanisms were more accurate when asked to move quickly than when told to take their time. This counter-intuitive pattern of performance is similar to a pattern demonstrated in experts performing a well learned skill. This suggests that the causal mechanisms allowed the novices in this study to function more like experts. In another study, participants trained with either isolated features or features with causal explanations were presented with difficult cases that included novel terminology. Despite having the same amount of practice, students with knowledge of underlying mechanisms were better able to make the translation from their learning material to the novel terminology and arrive at the correct response, compared with those who had only studied the clinical features. Like the experts in the encapsulation studies, students with the causal knowledge structure were also able to quickly recognise ‘encapsulated’ terms presented after studying a related clinical case. Although causal knowledge was not explicitly required to complete the tasks assigned in any of these studies, learners were able to use their additional understanding to their advantage.

Taken together, these findings suggest that understanding the underlying mechanism of disease can create valuable coherence among the clinical features. Immediately after learning, or with very simple cases, students can use their knowledge of clinical features to arrive at the correct diagnosis. However, such a strategy will become less effective as memory
decays over time or cases increase in difficulty. As a result, students trained using just clinical features have difficulty diagnosing cases after a time delay or when presented with novel terminology. Providing students with the appropriate theoretical knowledge gives them the means to create a coherent picture of a case when the clinical features become disorganised. This ability to rely on what makes sense rather than a step-by-step analysis of clinical information also seems to move a novice further along the road to expertise.

In order to translate the findings of these laboratory studies into effective educational practice, we must first answer a question that could have begun this entire discussion: what is basic science? The term ‘basic science’ probably evokes many responses in different people. It may be that a single answer to this question is not possible or even desirable. Clearly, there are many different types of information that can be used to link and explain clinical features. In psychiatry, for example, a complete biological description of a disease may simply not be possible. However, under some circumstances, the nature of the links, the depth of the scientific explanation and even the accuracy of the information seems to have little impact on the value of biomedical knowledge in helping novices retain and use clinical information to diagnose a case. Studies using artificial materials, simple causal chains and incomplete explanations suggest that what matters most is that the links provided are clear, plausible and stable. A study using undergraduate medical students, for example, demonstrated that providing simple biochemical and pathophysiological explanations for clinical findings was sufficient to provide a stable performance in diagnosis of neurological and rheumatologic diseases. The basic science explanations did not help students understand the science in great depth, but they did give them some understanding of why a particular sign or symptom occurred in a specific disease. It is this type of simple relational knowledge that seems to enhance memory, to improve the ability to diagnose challenging cases and, potentially, to act as a precursor to the encapsulated representation that is considered a hallmark of expertise.

Given these findings, perhaps the most important aspect of the issue at hand concerns how we make sure that students do in fact learn the links and mechanisms that will be of greatest value. The structure of the traditional medical curriculum in which basic sciences courses are taught first, and are followed by clinical training, may simply not be conducive to this type of learning. Unlike the laboratory studies in which participants learned the biomedical and clinical information in an integrated package, the traditional 2-stage model of undergraduate education requires that students first learn the basic science and then spontaneously recognise its relationship to the clinical information they learn 2 years later. However, it has been demonstrated that this type of accurate transfer of biomedical concepts to clinical problems is unlikely to occur, even when the biomedical information is provided only minutes prior to the clinical information. If experienced clinicians do not explicitly and overtly express basic science concepts in their work-up of clinical cases, it seems highly unlikely that clinical clerks or even junior residents will be able to spontaneously see the connections and apply their knowledge correctly. Thus, medical training must be structured so that the relationship between biomedical concepts and clinical facts is made explicit, concise and clear. To this end, a key goal throughout the early stages of medical training should be to integrate clinical information and the supporting biomedical concepts into a coherent package.

Although the studies presented focused on text-based cases in a few medical domains, clinical teachers from many disciplines may be able to use these findings as a simple model for effective educational practice. The success of laboratory studies using very simple materials suggests that causal connections and explanatory links infused into clinical instruction can enhance student learning even when the basic science concepts are not covered in great detail. Rather than requiring elaborate explanations, it seems that students can benefit from a basic understanding of the links between clinical features and the pathways that lead to specific presentations. This could potentially be accomplished by clinical teachers choosing to infuse basic science concepts into traditional lectures or by having basic scientists and clinicians work together to create clinical curricula.

Further study is needed in order to determine how to best achieve this balance without the careful controls of laboratory studies. In the classroom and on the ward, it is likely to be very difficult to ensure that students pay attention to the biomedical knowledge that will support their success. With further research we will probably find that an understanding of biomedical knowledge can drastically change the way a student perceives and interprets clinical data. This may even occur in visual domains, such as dermatology or radiology. The correct application of these findings to the curriculum will also require addressing the role of
biomedical knowledge outside of diagnosis. Thus far, we have focused on the impact of basic science during the processing of a clinical case. However, it is likely that biomedical knowledge impacts on other decisions regarding the treatment and management of a case.

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