INTRODUCTION
Students, clinicians and anatomists all agree that the study of anatomy is integral to medical education and the practice of medicine. However, incoming residents’ knowledge of anatomy has been rated as inadequate for future practice by both clinicians and students themselves. This might be explained by large-scale changes made to medical curricula over the past 20 years. Namely, medical students may find their anatomy curriculum is fast-paced with little time to reflect on concepts. They may also find difficulty in accessing faculty members for guidance, and resources, such as a dissection laboratory, may not be readily available. Thus, students must take an active role in guiding their own learning to ensure their understanding facilitates transition into their future practice. This review discusses effective strategies for learning anatomy and creating a strong foundation of knowledge that can be built upon throughout medical training.

LEARNING STRATEGIES
The primary purpose of learning anatomy is to recognize the body’s normal structure and function so that when structures are altered by defect, trauma, or disease, knowledge of these deviations can be utilized in making clinical decisions. Anatomy also serves as the language of medicine through which we describe and assess human structure. Naturally, anatomy is an area of lifelong development where understanding is shaped by clerkship rotations, residencies, and destined specialties.

The strategies presented here offer useful considerations for a student’s self-directed approach to learning anatomy in conjunction with a formal curriculum. A student’s anatomy course and medical program provide a roadmap for learning, outlining the material to be learned, the order in which it should be covered, the depth of coverage and measures for evaluating performance. Active learners must follow this curriculum while supplementing it with information learned using self-directed study strategies. The three strategies highlighted are: deep learning, visualization, and application of knowledge.

Deep Learning
The learning process may be traditionally described through Marton & Saljo’s concepts of surface and deep level learning. Surface learning involves a reproduction of factual knowledge. Conversely, a deep approach is motivated by the vocational relevance of the material, with a focus on the meaning of content rather than just the content itself. For example, the aorta is described as the largest artery in the body with thick, elastic walls, which allow for expansion as blood is forcefully expelled from the heart. In this example, surface learning is the knowledge that there is a blood vessel called “the aorta”, whereas deep learners use a broader knowledge of the aortic wall structure to appreciate what the
walls of other arteries might be like. Making generalizations about structures, and then establishing a rationale for how and why they are similar or different, allows for the understanding of one concept to aid the understanding of another.

Following the steps presented in Figure 1 puts deep learning to practice. Rather than using memorization for learning, it is important to focus on the meaning of learned content and to make connections between concepts. This may involve brainstorming explanations for the design of a particular structure. Further, understanding the function of a particular structure may help explain other parts of the body. Finally, previously consolidated knowledge is useful for extrapolation and problem solving. Overall, adopting strategies that help form a deeper understanding of anatomical material will facilitate long-term retention and understanding.19

**Visualization**

Visualization, in the context of anatomy, can be defined as creating a mental picture of anatomical structures that is easily recalled. It is a powerful tool in learning anatomy since the complex spatial organization of the body across three dimensions is best represented visually.20

Two strategies that aid in visualizing anatomical concepts are highlighted (Table 1). First, studying from various sources offers different perspectives on a particular topic leading to a more complete mental picture of the area. Sources of information range from textbooks and electronic resources to cadaveric specimens that demonstrate different orientations and anatomical variances. Second, complex imagery is easier to understand if the visual stimulus is reduced to simple patterns.21 For example, the details of the internal thoracic artery—forming off of the subclavian artery and branching into the anterior intercostal, musculophrenic and superior epigastric arteries—can be represented as a line diagram (Figure 2). This simplified example can then be built upon by putting it in context of surrounding structures such as the ribs, intercostals muscles, and mediastinum.

**Table 1. Strategies for Visualizing Anatomy**

<table>
<thead>
<tr>
<th>Study from a Range of Sources</th>
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<tbody>
<tr>
<td>• Course lectures/notes</td>
</tr>
<tr>
<td>• Textbook text</td>
</tr>
<tr>
<td>• Textbook diagrams</td>
</tr>
<tr>
<td>• Atlases</td>
</tr>
<tr>
<td>• Cadaveric specimens</td>
</tr>
<tr>
<td>• Artificial models</td>
</tr>
<tr>
<td>• Online modules</td>
</tr>
<tr>
<td>• Online public health information, i.e. Heart and Stroke Foundation</td>
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<table>
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<tr>
<th>Work from the Basic to the Complicated</th>
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<tr>
<td>• Reduce complex anatomical design to simple drawings/depictions</td>
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<tr>
<td>• Master one concept then build upon it, i.e. understand arterial pathways first then place arteries in relation to other structures</td>
</tr>
<tr>
<td>• Take individual organs, become familiar with their design, then place them in context of the body cavity in which they reside, observing their relationship to other structures</td>
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**Focus attention away from memorization strategies**

- Don’t be overwhelmed by all the labels
- Ask yourself why this anatomical structure or concept is important to you
- Establish a reason for why a structure is named the way it is
- Explain to yourself why structures are the way they are i.e. the aorta lies to the left of the body’s midline because it comes off of the left ventricle where oxygenated blood is pumped from

**Focus on meaning of content and make connections**

- Pay attention to patterns in organization, where they are similar and dissimilar
- Become familiar with cell types; the function of different cells based on design, make connections between similar cell types belonging to different organs/areas
- Pay attention to consistency, feel and appearance of different tissues and relate this knowledge to function

**Extrapolate what you know about one area to another**

- Estimate the design of an anatomical structure based on “what makes the most sense” for the desired function
- Logically deduce the name of a structure based on location, function, related organ, etc.
Application of Knowledge

The application of anatomical knowledge to a variety of situations and problems is an effective method for establishing a deeper understanding of anatomy.22,23 Woods et al. argue that students who learn basic science in a clinically relevant manner are better able to remember clinical conditions after a delay period.23

Since its introduction in the 1960s, problem-based learning (PBL) methods developed at McMaster University have been adopted by many institutions worldwide to encourage the application of biomedical knowledge to real-world problems and situations.24-26 Drawing on the theoretical foundations of Schmidt’s seven-step process for working through problem-based cases, Table 2 demonstrates how problem-based activities can be approached with a focus on related anatomy.27 With each case, specific questions can help identify clear learning goals, clarify clinical significance of related anatomy, and establish how material might be communicated and solidified though group-based discussion.

Beyond problem-based activities, there are many other ways students can apply their knowledge of anatomy (Table 3). For example, relating new concepts to personal or family experiences and designing individual clinical cases are two ways in which anatomy knowledge can be actively applied.

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Table 2. Relevant Problem-based Case Questions that Focus on Developing Anatomical Knowledge

<table>
<thead>
<tr>
<th>Schmidt’s 7 Step Process26</th>
<th>Relevant Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Clarify terms and concepts not readily comprehensible</td>
<td>What anatomical terms and concepts must our group clarify? Does my understanding of related anatomical concepts differ from that of my peers?</td>
</tr>
<tr>
<td>2. Define the problem</td>
<td>What anatomical concepts and other interrelated phenomena should be explained/explored in relation to this case?</td>
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<tr>
<td>3. Analyze the problem and develop a hypothesis</td>
<td>Utilizing the knowledge developed in steps 1 and 2, what hypotheses can we brainstorm about the case?</td>
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<tr>
<td>4. Organize a systematic inventory of the explanations inferred from step 3 - discussing, evaluating and arranging possible explanations</td>
<td>How can we summarize and structure our case-analysis?</td>
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<tr>
<td>5. Formulate learning objectives</td>
<td>What are our learning objectives?</td>
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<tr>
<td>6. Collect additional information outside the group</td>
<td>Where do I find the appropriate resources to answer these questions?</td>
</tr>
<tr>
<td>7. Report back to the next tutorial, synthesizing and testing the newly acquired information</td>
<td>How can I explain my newly-formed anatomy knowledge to my peers in a way that will aid the group in understanding the case further?</td>
</tr>
</tbody>
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Table 3. Creative Ways of Applying Anatomy Knowledge

- Approach problem-based cases with anatomy-specific questions (Table 2)
- Learn from personal, friend and family experiences
- Relate knowledge to observations through clinical rotations
- Relate knowledge to pop-culture, world events, and interesting clinical cases
- Try writing your own clinical cases
CONCLUSIONS

Overall, these three strategies aim to encourage an exploration of anatomy for today's medical student. While there are no definitive guidelines for optimal learning, it is evident that active learning is essential in building a strong foundation of knowledge for transition into future practice. Being an active learner involves going beyond surface approaches, visualizing anatomy as a three-dimensional mental picture, and applying knowledge in a broad context. Anatomy is more than memorization and encounters with cadavers. It is a living tool that can bolster and improve clinical reasoning practices. It is up to students to decide for themselves if they will learn with the fervor necessary to achieve such goals.

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REFERENCES


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