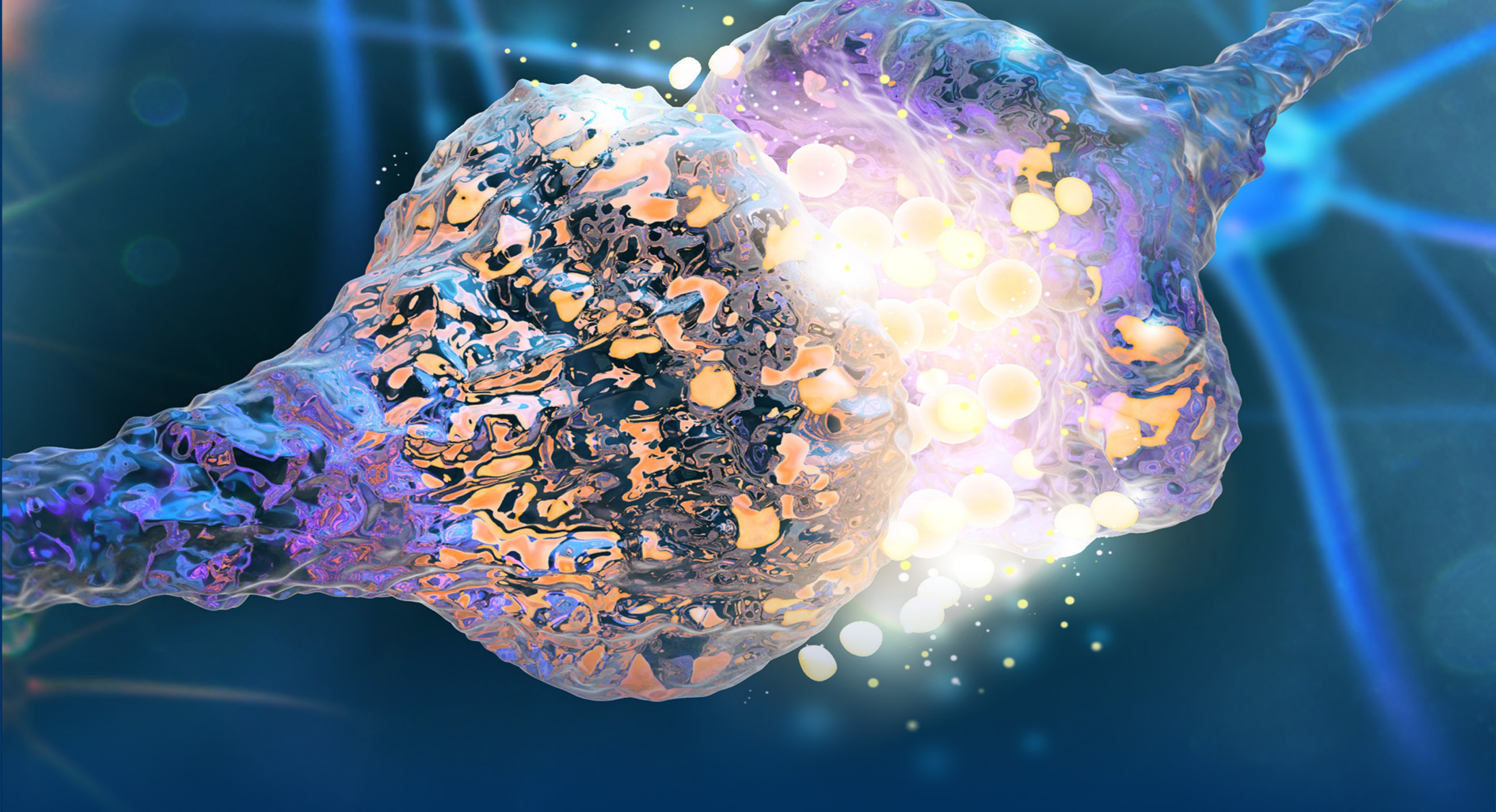


# Logic and Physiology: The Case for Revised Pedagogy

## The Problem

Students have, and probably always will, drift toward what they perceive to be the easiest (and, most likely, least effective) ways of mastering what they think we want them to know. For many, rote memorization is their primary tool, reinforced by years of "succeeding" with just that in secondary education and even some college level courses. Physiology is the study of complex systems in motion. While aspects of key mechanisms do require some memorization (e.g., angiotensin II vasoconstricts), their logical implementation within adaptive responses to change is critically important. Lacking an understanding of the framework, the "why" of physiology, students are left only to memorize the "what". Even the "how" is not well-learned without a basis for understanding the causative "links" between sequential actions. This is a critical concern because nobody can possibly master the expanse of knowledge that currently exists in this field, let alone deal with the explosion of information that's surely coming in the future. Memorizing details for the purpose of earning a grade is pointless. No skills are gained and little meaningful knowledge is retained. Maybe even more distressing is the thought that we as instructors are simply stirring the air in the room when our lectures are content focused and lack conveyance of the essential "why?".

*(Continue)*

## The Solution

The keys to imparting useful skills depend largely on the proficiency of the instructor and how well course content tools, often a single textbook, deliver the rationale of functional systems. Explanation of the "adaptive logic" of physiology is critical to student comprehension, both by the instructor and the textbook. Textbooks in human physiology are historically encyclopedic in breadth, yet tend to lack explanations given at a level required for true understanding of the underlying logic. Consequently, the outcome becomes an exercise in term recognition and memorization, as opposed to **comprehension**, **integration** and **predictive ability**. Content in many textbooks, and the courses that follow them, seem to be driven more so by the need to be comprehensive, rather than by an effort to fully develop ideas that follow a narrative and display the logic and adaptive nature of function. Rather than simply conveying the content and sequence of actions in physiological systems, instructional resources should provide the logic of how and why systems operate as they do. This is true from the perspective of entire organ systems, down to the molecular mechanisms they employ. When these elements are in place, and combined with a motivated student, physiology can be studied in the best possible way – from the standpoint of functional logic. That's infinitely better than relying mainly on factual recall!

**"True scholarship consists in knowing not what things exist, but what they mean; it is not memory but judgment."**
James Russell Lowell *(1819-1891)*

Because many books are improperly focused, novice instructors are often similarly misaligned with what true teaching achieves…the conveyance of understanding. Lacking breadth of knowledge and depth of experience, they become effective at sequenced content dispersal, as this is what many books provide – they become proficient at telling, not explaining. This focus on content leaves students in many courses feeling as though physiology is, and should be, "learned" as simply a series of self-contained phenomena and, thus, respond by treating its study as merely a strenuous exercise in memorization. Often, even if instructors seek to convey understanding, they initially lack the skills or tools required to be effective. Teaching the "why" requires deeper thinking and understanding of the discipline, often acquired over decades. By focusing on why things happen in physiology, one can see real consistency in the fundamentals of many mechanisms. What they do, and when they do it becomes almost intuitive when one acquires a wider perspective. Very importantly, successful students then become better at application of knowledge, the holy grail of learning! This ability is essential to thinking critically about novel situations; the best possible outcome for students heading toward careers in clinical medicine or other professions where an analytical mind is key. This style of teaching and learning will make students better prepared for virtually any intellectual endeavor, be that endocrinologist or auto mechanic!

Ultimately, teaching is infinitely more fulfilling when we are effective. When you've provided a solid framework for true understanding (a logical and interest-piquing "story"), and students are able to apply their newly gained knowledge, you'll know you've altered their life skills and career trajectories.

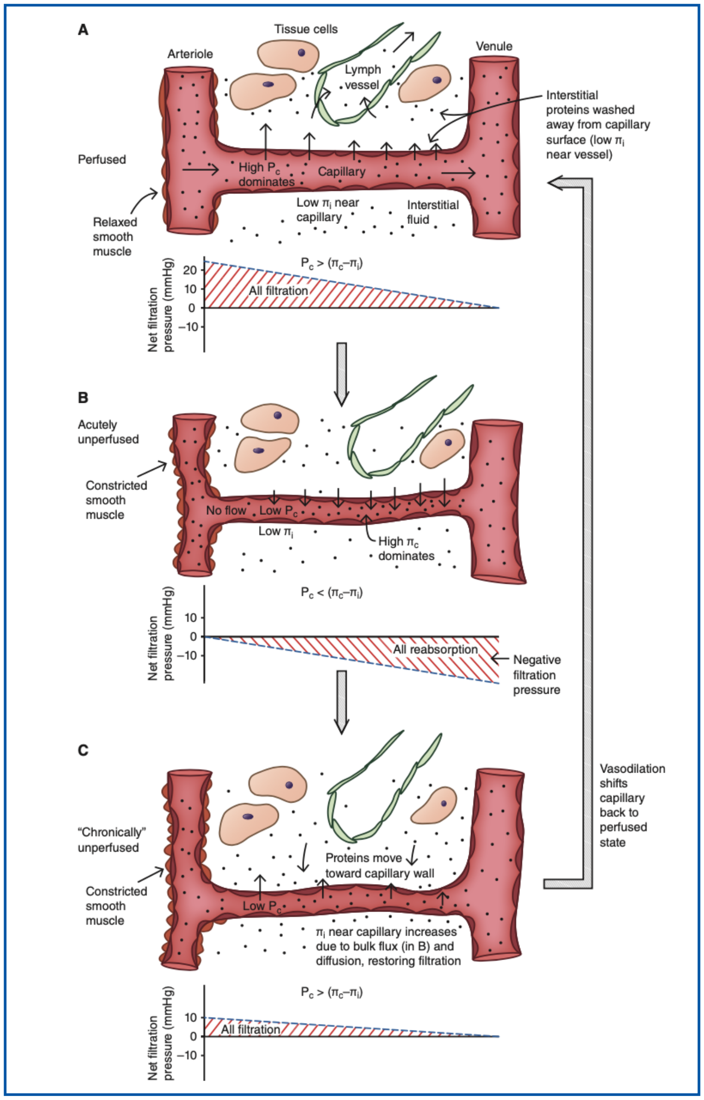
# Pedagogical Applications to Enhance Learning

## Regular Use Of Unifying Principles

One example of a key unifying principle would be the concept of diffusion as explained by Fick's laws. While Fick's law (usually his first) may be presented and defined by many, it is often done in an overly simplified manner that can be detrimental to real understanding of how important mechanisms work. Diffusion is essential to capillary exchange at vascularized tissues and the movement of many substances across cell membranes. Accordingly, it should be reiterated, in context, throughout the course. Many inappropriately describe diffusion and the factors that affect it. Some use the example of cologne permeating a room. While not untrue, diffusion within the body occurs largely within aqueous solutions, not air. Water has a 1000-fold higher density and is 60 times more viscous than air, making diffusion through air spectacularly faster than through water. Certainly, this example isn't providing the proper perspective to students trying to understand physiological diffusion. In a related example, descriptions of rising temperature-enhancing diffusion due to increased molecular motion (kinetic energy) are used. This is again misleading. The rise in diffusive flux with increased thermal energy has much more to do with a fall in solvent viscosity, a factor rarely mentioned. Certainly, none of us are perfect, however, we must strive to provide the most accurate and up to date information possible. Doing so involves continuously seeking new knowledge and greater explanation in order to more effectively convey understanding to our students.

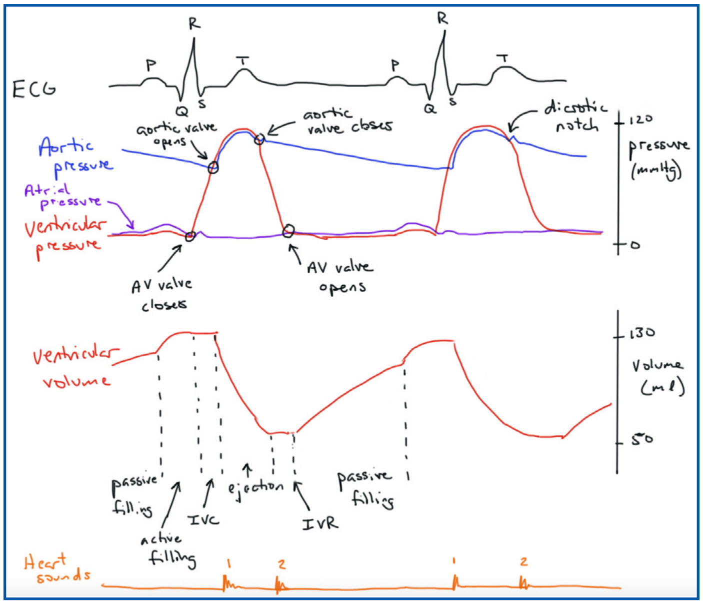
## Addressing Historical Errors

There is quite a bit of "historical inertia" in some academic texts and teaching. In other words, content is often slowly updated to match the current state of understanding by the research community. A great example of that is the ubiquitous capillary bulk flux that occurs in all vascular tissues and provides for essential lymph flow. In the "old" model, generally still presented, capillaries filter out fluid and small solutes at their arterial ends and tend to reabsorb the majority of that content at their venous ends. The difference between them producing lymph. Researchers in this field have for years been outwardly annoyed that the academic publishing community has not caught on to the new model of capillary exchange presented below. Note that it is reliant on alternating perfusion and stagnation in capillaries caused by arteriolar vasomotion. This is a topic rarely even mentioned, yet absolutely essential given the fact that we don't have enough blood to perfuse 60,000,000 meters of capillaries at once!

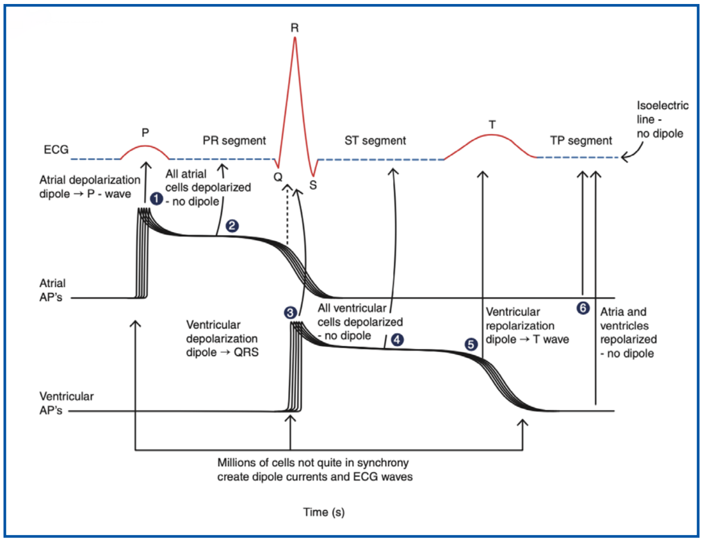


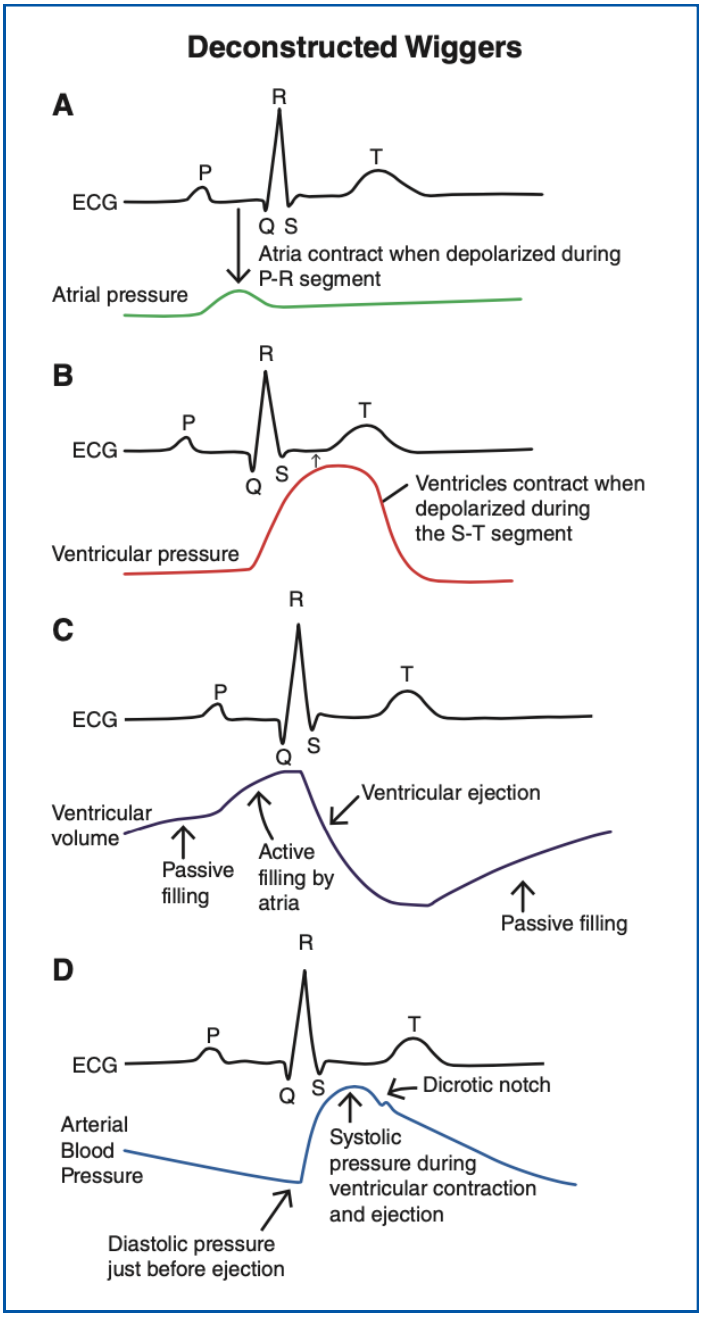
## Content Deconstruction

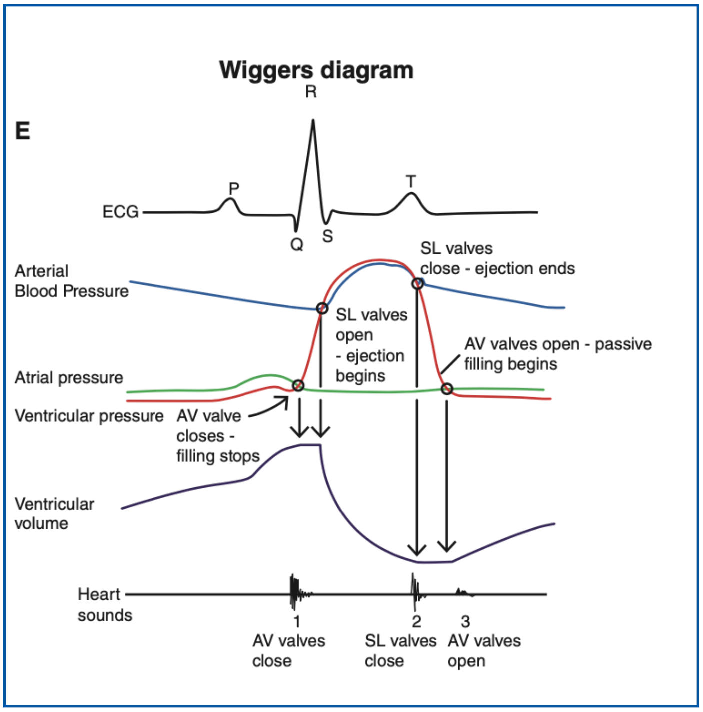
Deconstructing complex topics into portions manageable for student comprehension is an essential task of the instructor. Reconstructing those pieces into functioning units might be even more so. One topic students often struggle with is comprehension of the cardiac cycle and its summary within the Wiggers diagram. Here is an example of where employing deconstructed content might be useful. Some representation of this figure is found in almost every textbook. Here's a particularly thorough one:




If you know any students who can truly decipher this figure without help, send them straight to graduate or medical school! When illustrations contain this much integrated information, it is essential they be broken down into digestible "chunks" for presentation and comprehension. Ultimately, the pieces need to be reassembled and viewed as a whole, but that really isn't possible without taking one step at a time and applying logic! Instead of the version above, one might dissect the figure into individual panels that each relate back to the unifying ECG trace, as shown here;



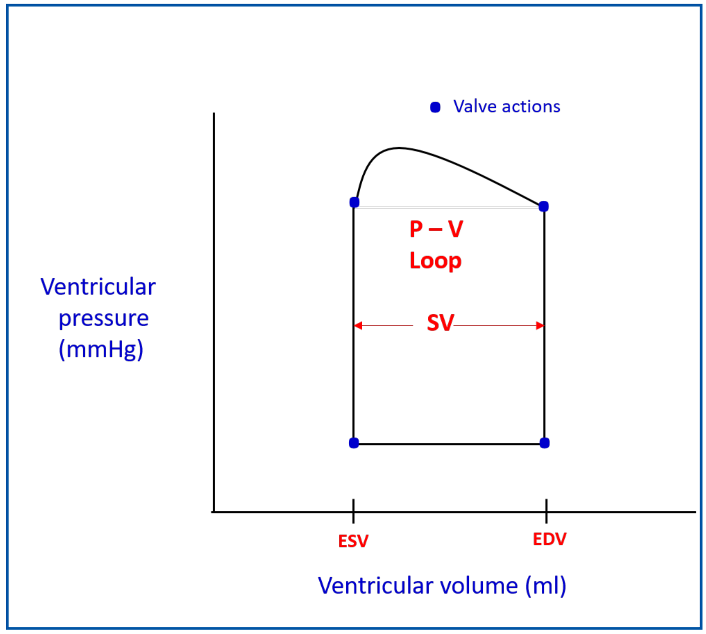





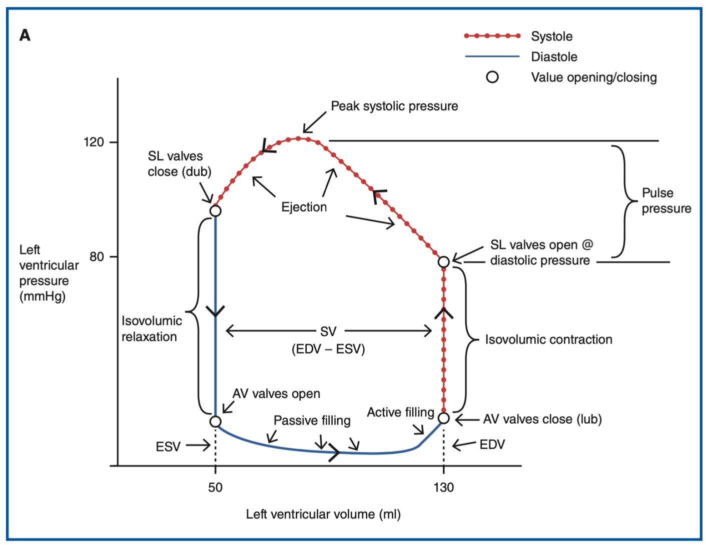

This sequence provides greater explanation in a linear progression, as well as providing labels, arrows and descriptors that allow students to "connect the dots" between ordered electrical and mechanical events; the entire point of including the figure in the first place! Additionally, it is essential to see how the ECG is derived from action potentials of individual cells (top panel). Without understanding this, the true origin of the ECG trace, and how it relates to cycles of systole and diastole remains a mystery, the details of which can only be memorized. Some will argue this is too much detail, yet if true comprehension is the goal, then not presenting this information is unacceptable.

## Adding Tools That "Chunk" Information Effectively

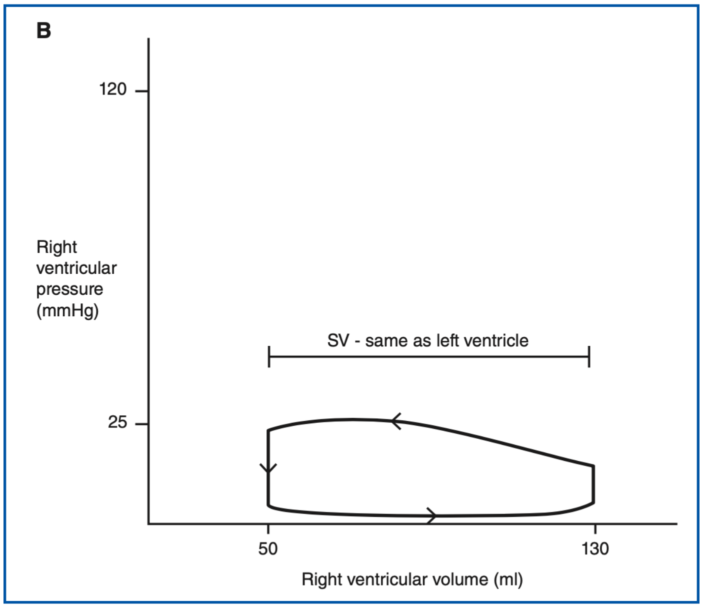
Some elements seem to be presented because they have become "standard". However, doing so without full explanation will leave students floundering. A good example of this is the ventricular pressure-volume loop used to assess the cardiac cycle and ventricular performance. Below is an example followed by questions posed by that author that many students would be ill-equipped to answer due to the lack of understanding that there is a sequential pattern (counter-clockwise movement through time) associated with this figure.




Do you understand ventricular performance and how it relates to the cardiac cycle after reviewing this figure? What if, instead, it looked like this;

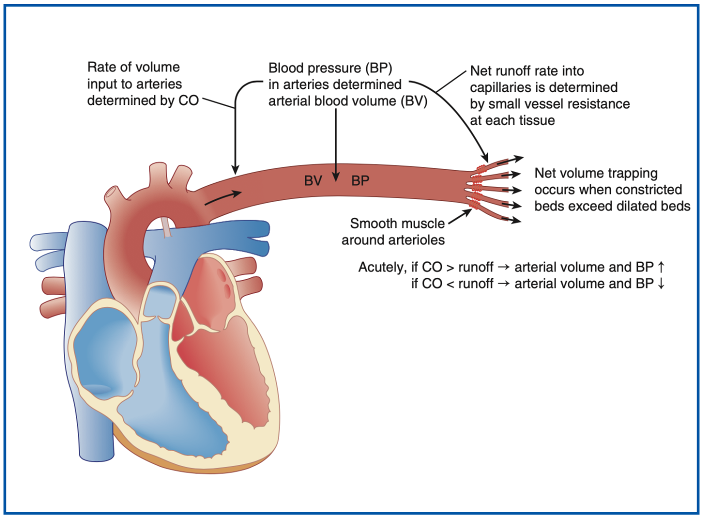



Here, labels, arrows, and a legend provide a guide to the content within, effectively covering ("chunking") this topic into one unit that, with some effort, will provide a clear picture of ventricular function over time – a logical "story". While figure legends are often simply titles, shouldn't those be used as tools as well, helping students orient themselves to the graph or figure at hand? The second pressure-volume loop certainly contains more information, but that content turns something fairly useless (and extremely frustrating to students) into a very worthwhile learning tool. A more explanatory version might also include the right ventricle loop (below) for comparison, as students often do not grasp the differences (pressures and work) and similarities (volumes) between functioning of left and right heart.




## Simplifying Before Elaborating

In many cases, figures used in teaching have become stale, with few deviating significantly from the historical norms. It is essential that information be presented using novel figures and literal explanations. We can use regulation of blood pressure as a suitable example. The physiology involved here is so complex that instructors regularly devote significant effort to its explanation (as they should). Surprisingly, however, its broad simplicity is rarely conveyed as determined by how much blood is in the arterial circuit at a given instant. Looked at in this way, blood pressure is simply proportionate to the ratio of blood entering (via cardiac output) to blood leaving (runoff from) those vessels over time. The figure below brings the concept to life for readers and puts all subsequent (and more detailed) information into context:




The regulation of blood pressure is then easily linked to factors affecting heart function (cardiac output) and those determining vascular resistance. This figure also very simply explains the existence of arterial systolic and diastolic pressures, since the heart is an intermittent pump, yet runoff is continual. It even makes vessel compliance a relatively easy topic to address. If arteries distend ("give") more readily, they can accept more blood with smaller increases in pressure.

## Supporting And Then Testing Student Understanding

Engendering critical thinking in your students requires presentations based in logic, both oral explanations and readings, and practice!! Let's assess a "level 3" question from one textbook:

**If the heart ventricle becomes damaged, what specific wave(s) of the ECG would be altered?**

First of all, there are two ventricles…so wording here is misleading. Second, there are non-wave "segments" of the ECG that can and would also be altered. Answering this question accurately (as worded) requires only memorizing which ECG waves correspond with ventricular activity and reinforces the notion that committing that information to memory is the goal in physiology. On the other hand, here is a corresponding question on the same topic, focused differently;

> **Can you put it together?** Systemic hypertension causes left ventricular hypertrophy (enlargement). Given what you know about dipole current, how would this condition alter the ECG?
>
> **Answer**: Enlargement of the ventricle would increase the size of the ventricular dipoles created, making the QRS complex and T wave larger.

This question requires students to link the biophysics of dipole current, caused by regional differences in electrical activity, to the waves of the ECG. It also necessitates that they know what waves correspond with ventricles. In other words, it tests factual recall within a conceptual question about the physiology of electrical events in the heart. Even if students struggle with parts of this question, upon reading the answer, they will be reviewing the key physiological principles and facts.

### Essential Physiology Often Overlooked

It is fundamental to teach physiology critical to human survival. Understanding these adaptive traits is key to application of knowledge, yet many examples are often overlooked, possibly due to ignorance or that they seem too complicated to convey. One fitting example is the Fähraeus-Lindqvist effect and the anomalous viscosity of blood. While it may sound complex, this topic can easily be presented in a way that is clear, and adds an absolutely essential element to the description of blood flow (i.e., that blood flows oddly in small vessels, with cells flowing along the axis, reducing resistance to blood flow). Honestly, without this particular physical action, blood flow would cease and we would die - yet it is entirely absent from most descriptions!

A few other instances of key, but often underrepresented, topics include: protein marginal stability theory and how much of homeostasis acts to protect protein function, solute reflection and its impact on differences between osmotic and effective osmotic pressure, internal-to-external tension transfer in skeletal muscle contraction dynamics and the Hill model, and the significance of renal clearance in assessing renal function. These, and similar concepts, should be addressed to provide readers with a more thorough comprehension of physiological mechanisms at work and the logic behind them.

## Our Response

Over the last decade, we have produced a book that is different from others because we consciously made it so. We seek to explain physiology, to teach students to think about it, not to just tell the reader about it. In doing so, we are not just being more accurate or stylistically different, but rather combining content with the effectiveness of a logic-based teaching and learning methodology. We lead with the "why", at all levels of explanation. By "why" we mean not only the broad adaptiveness of physiology to survival, but also the much more focal "why" of logically linking the steps of functioning mechanisms. To push back against the tendency toward focus on the "what" and the "how" in physiology publications, and consequently, in teaching, we present a textbook with a primary focus on explaining physiology using a framework of logic and common sense. While not shirking the details, these elements are subordinated to the role of illuminating broader concepts. Our hope is to provide a model for how students should think about all physiology, making comprehensive coverage of content (an impossible task!), much less important.

Honestly, very little is typical about Mechanisms and Logic in Human Physiology, except its organization around organ systems, which we believe is the best packaging of information for this student population. Examples of breaking from the norm of other textbooks (elaborated upon above) include;

1. Regularly employing key unifying principles
2. Addressing historical errors and misconceptions
3. Deconstructing (and then reconstructing) complex topics
4. Provision of mental “chunking” tools (ways to organize information)
5. Simplifying before elaborating
6. Shifting the focus from details to the “big picture”
7. Guiding student thinking
8. Supporting, and then testing student understanding, not memorization
9. Coverage of topics essential to normal function, yet which are often overlooked

## Key Text Components

In addition to the writing itself, Mechanisms and Logic in Human Physiology includes a variety of pedagogical elements supporting the goals of conveying understanding and fostering critical thinking. While some are novel “pedagogical aids”, it is really more about how they are employed and what skills they promote, not that they are employed.

### “Can You Put It Together?” Questions

Most texts utilize embedded questions, however, in many cases these reflect and emphasize student memorization of key components (e.g., what is the protein the binds calcium in striated muscle?). Conversely, our questions go well beyond reiteration of key content. We might ask something like, “if there were a mutation in the gene for troponin that resulted in a dysfunctional active (binding) site, what would be the effect on muscle tension development?”. Here, students must recall or review the same factual information required of the preceding content level question, but must also put that function into context, thinking about the importance of this protein’s role in the broader framework of muscle function.

This regularly embedded tool tests student comprehension of why physiological functions exist and how their sequencing is logical. It also fosters the development of analytical thinking skills. CYPIT questions are not ancillary to the text. They are absolutely essential to its most effective use by students. In this book (as well as in classroom teaching), illustrations and graphs are employed to convey ideas or processes that are more difficult and may require step by step explanations alongside a visual representation. In our experience, following use of these is a great time to step back and ask the students if they truly understand the specific concept. While a few of the questions we pose are factual in nature, most are more integrative and compel students to synthesize and apply their knowledge. This process requires use of the factual content, yet goes further, requiring students to think about the material at hand. Hopefully, these same questions will provide fodder for instructors as well. We are well aware that coming up with novel scenarios or applications is time consuming and difficult. Hopefully, our providing many such elements will enhance your lectures or even point out interesting aspects you may have overlooked in the past. Every day we work on this book we learn new things, often correcting, refining, or building upon our earlier thinking! Helping you be more effective in delivering content and its adaptive logic is a major goal of this book.

### Art

Figures that are not cookie-cutter. This art has been developed to portray essential mechanisms and concepts in a manner that does not leave the student floundering for explanation. Art is often designed specifically to overcome historically difficult content through novel presentation and descriptive labeling. As you will see, our figures differ from those found in many texts in that they contain not only labels, but also explanations that provide elucidation. By closely linking the figures with explanations in this way, we hope students may avoid the need to go back and forth to the text in order to assimilate the concept being considered. The students' mastery of the material is then regularly tested via use of the "Can You Put It Together" tool. The figure legends are themselves a learning tool, helping to explain the figures and minimizing the need for students to search the text for explanation, which could discourage students from using the figures effectively.

### "The Big Picture" Introductions

The purpose of this tool is to provide not only a lead-in to the content of a new topic, but also convey that topic's broader meaning and logic. In this way, students are shown the "forest" prior to hearing about the "trees". Our thought is that, by first providing the students with the "physiological gist" of a new topic without all the potentially confusing specifics, they will be better able to later insert these details into a conceptual framework already established.

### Integration/Application Topics

This tool is intended to encourage readers to think more broadly about previously presented material. As the title suggests, these may be "mini" integration topics, where specific information or concepts from previous sections (in the current chapter) are synthesized within a slightly broader functional scenario and put into action. In its other form, this tool may provide a pathological or physiological example of the principles just learned. The objective here is to, in carefully selected situations, make human physiology applied, rather than purely theoretical. Our intent is to spark greater interest on the part of the readers. These topics are intended as a resource for teachable integration and application topics once the organ system basics have been thoroughly covered. Please keep in mind that there is an entire Unit dedicated to broader integrative physiology that incorporates roles of multiple organ systems.

### Chapter summaries

Chapter summaries frequently appear to be offered by other authors because of some unwritten rule that they should be present. Often there is a single page summary of what might be a 30-50 page chapter. Similar to our thoughts on figure legends, we feel chapter summaries could be an effective teaching tool if properly developed. Our summaries leave out many details, but convey *all* of the key topics with enough information to serve as a functional review for students preparing for exams or looking for a quick review of concepts.

Learn more about Mechanisms & Logic in Human Physiology here.