# Teaching Physiology in the Midst of a Knowledge Explosion: A Role for Core Concepts

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# Acknowledgements

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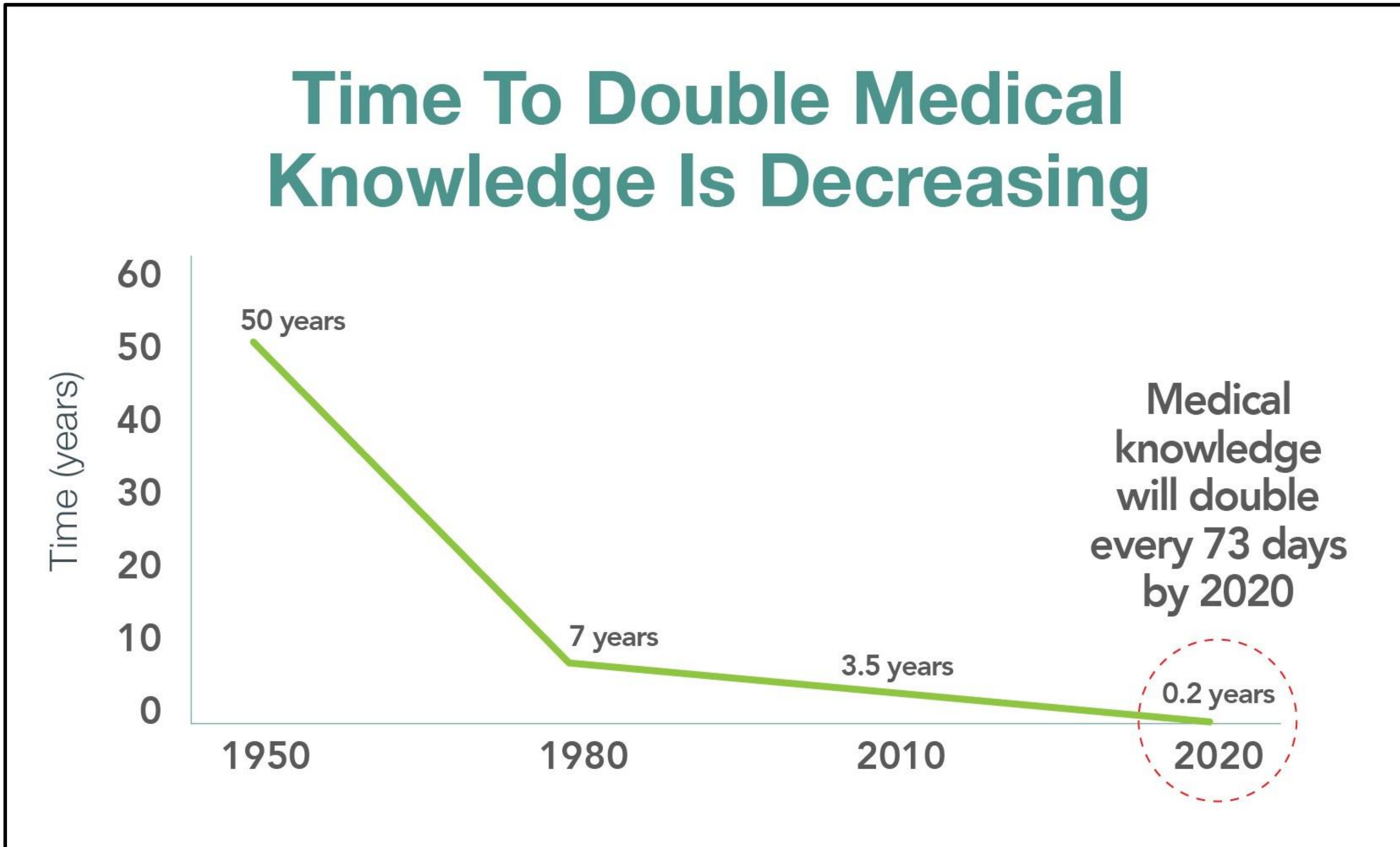
- Discuss the universal issue of what to teach and what not to teach
- Introduce you to the core concepts of physiology
- Discuss how a focus on the core concepts can help minimize the consequences of the knowledge explosion

# THE KNOWLEDGE EXPLOSION

# The knowledge explosion (1)




Graphic source, NCBI, “CHALLENGES AND OPPORTUNITIES FACING MEDICAL EDUCATION”
Peter Densen, MD, 2011

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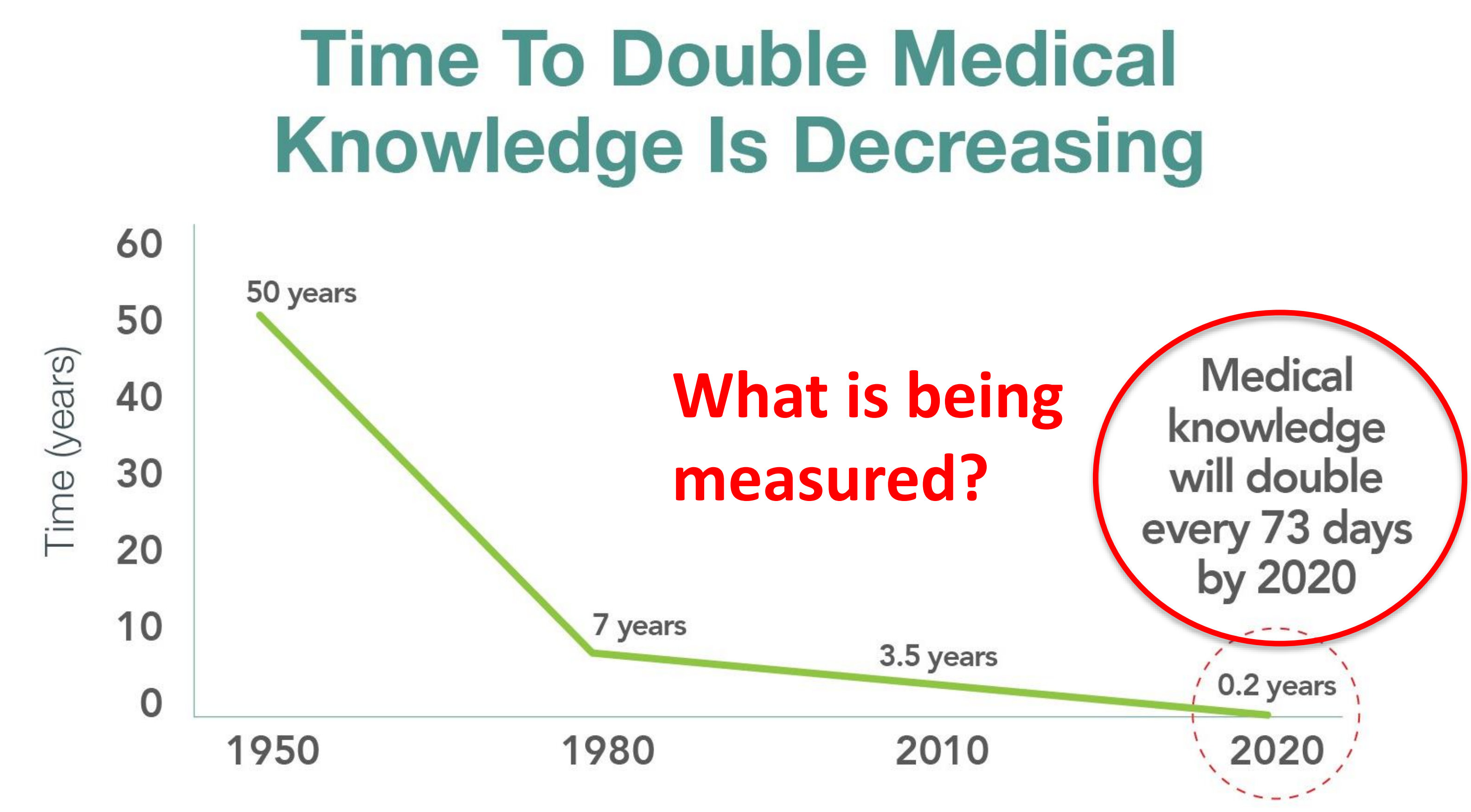


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# The knowledge explosion (2)

Some data about the size of physiology textbooks

| | | |
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| Human A & P | Saladin (8th), 2018 | 1100+ pp |
| | Marieb and Hoehn, 2018 | ≈1200 pp |
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**Average = 1100+ pages!**

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- It is clear that students cannot learn everything that is known about physiology!
- It follows that we must answer the question "what should we teach?"
- We must also consider how to make it easier for our students to learn.

# My thesis is that . . .

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# My thesis is that . . .

- a focus on the core concepts of physiology will
  - help you make decisions about what is important for your students to learn and what isn't important, and
  - help students learn the necessary physiology better and more "efficiently."

# *WHAT TO TEACH?*

# *What* should we teach?

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- This is, of course, a perennial question that we ask whenever we are planning a course.

# ***What* should we teach?**

- This is, of course, a perennial question that we ask whenever we are planning a course.
- The answer always depends on the specific course you are teaching, the curriculum of which your course is a part, and the needs of the students taking this course.

# *How* do we decide what to teach?

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# *How* do we decide what to teach?

- Teach what you taught last year?
- Teach what your predecessor taught?
- Teach what your teacher taught?
- I suspect that at some point in our career each of us has adopted one or more of these tactics for making a decision.

# How do we decide what to teach?

Arthur J. Vander (1998)

SOME DIFFICULT TOPICS TO TEACH (AND NOT TO TEACH) IN RENAL PHYSIOLOGY

*Advan Physiol Educ* 20(1), S148 – S156

# How do we decide what to teach?

In commented on the problem of what to teach, or not teach, Vander said this:

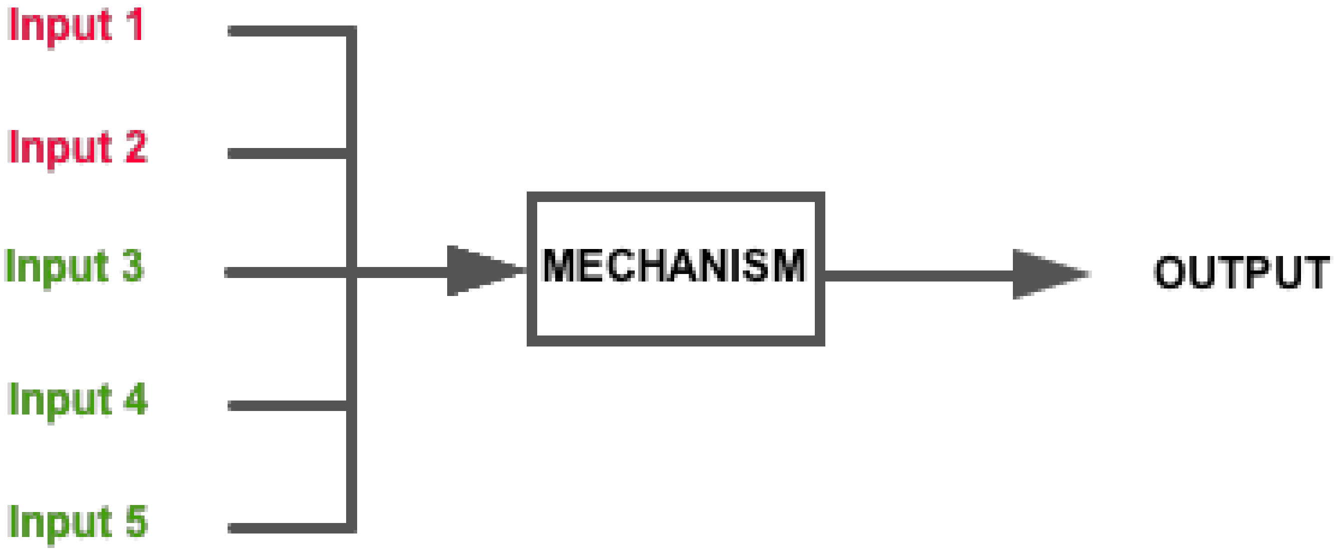
"This is in keeping with one of my major teaching rules—***you should never lie but you don't need to tell the entire truth***." (emphasis added)

# More words of wisdom

“. . . that we present the material in layers, the first layer being the absolutely essential primary inputs . . . as we add more layers we should keep referring back to the primary inputs and the bottom line.”

I will have more to say about “layers” in a few minutes.

# What do they need to know?



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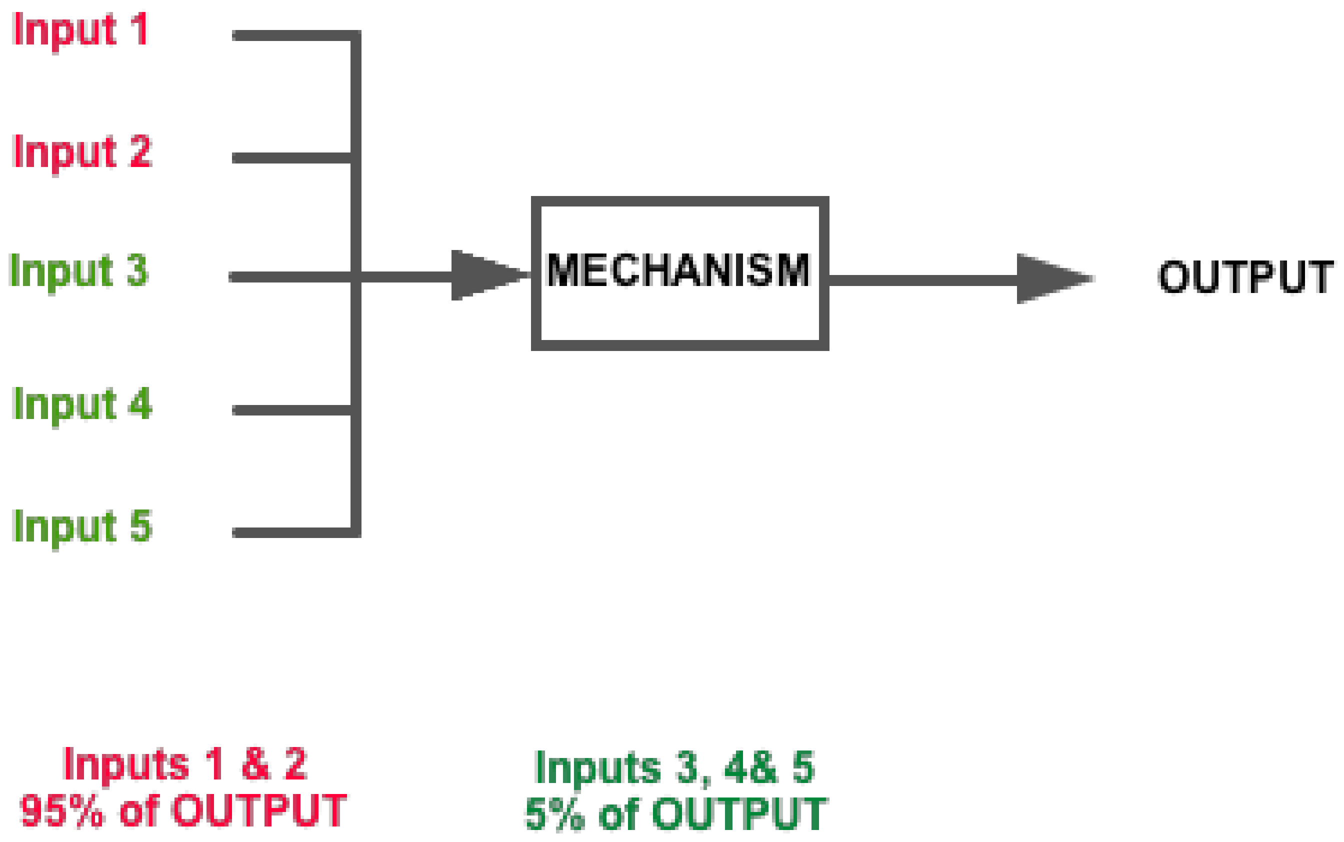

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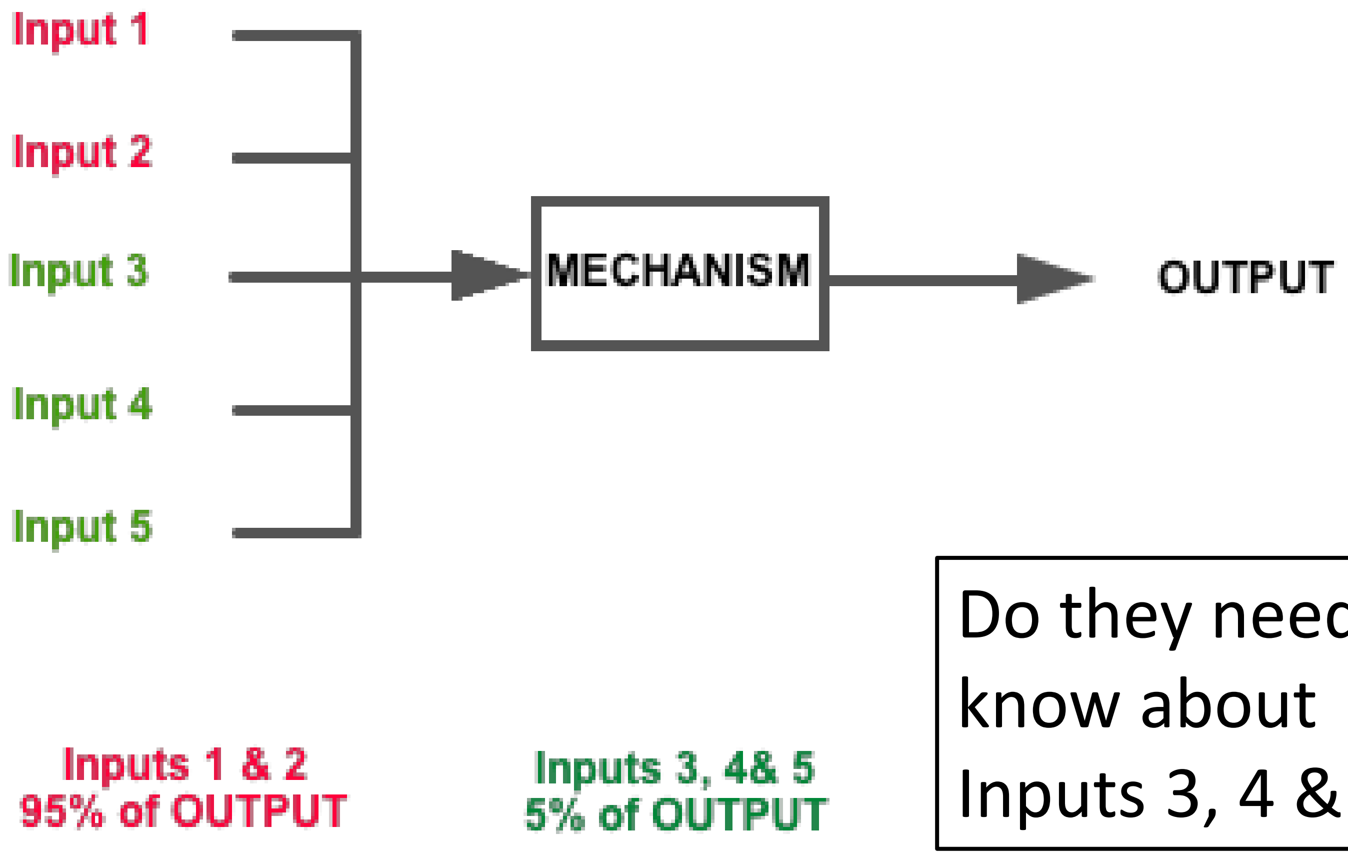
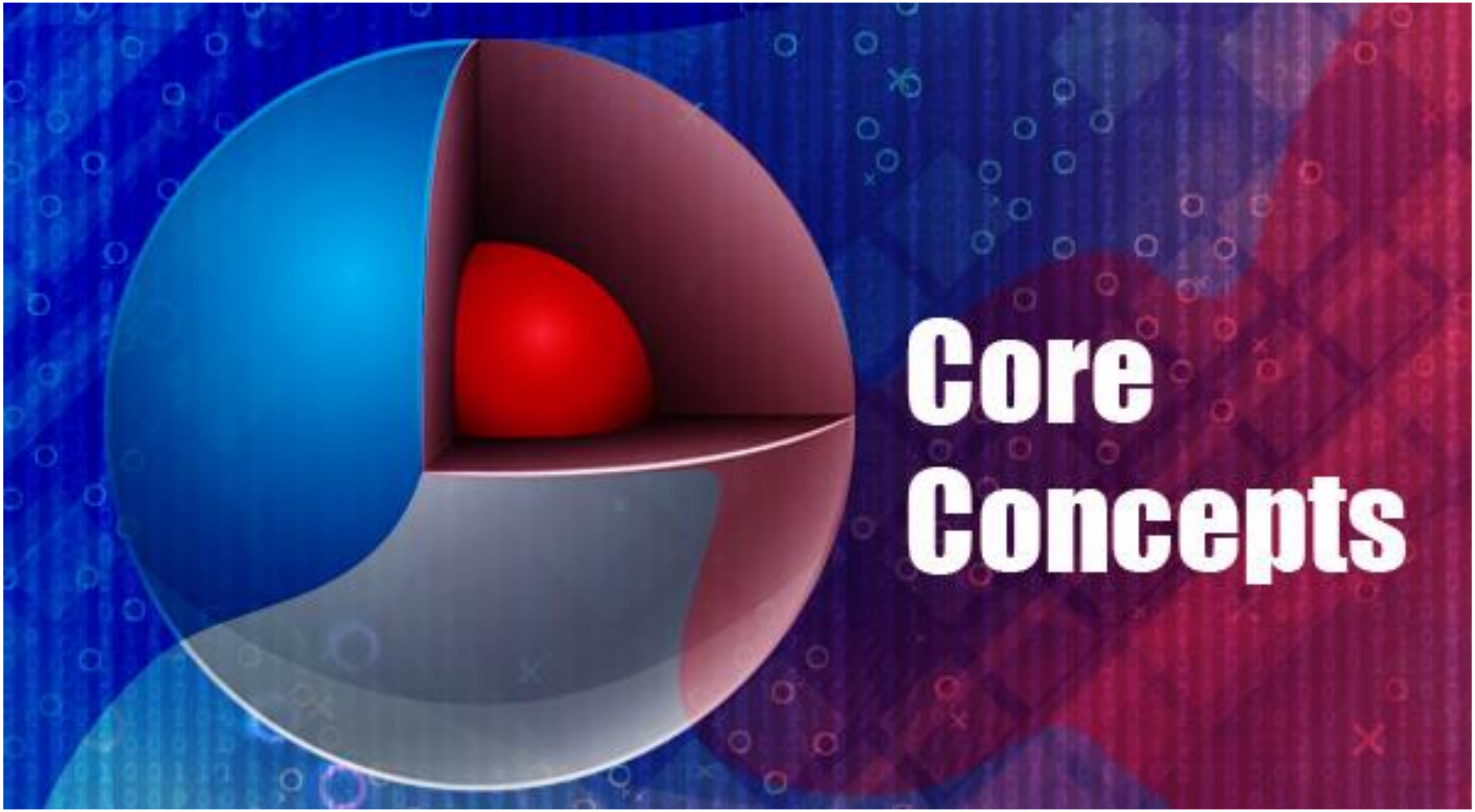



Do they need to know about Inputs 3, 4 & 5?

# *WHAT ARE CORE CONCEPTS?*



# What is a core concept?

[A core concept is an idea that is] “well tested, validated, and absolutely central to the discipline. Each integrates many different findings and has exceptionally broad explanatory scope.  Each is the source of coherence for many key concepts, principles, and even other theories in the discipline.”

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# For me personally . . .

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a core concept is what I want my students to remember in five years even if they remember none of the details!

# Where did the core concepts come from?

- CAB meeting generated a list of **8 core concepts of BIOLOGY** (2007)
- Our "team" then generated a list of **9 core concepts of PHYSIOLOGY** (2009)
- Next we surveyed the community to tell us what the core concepts of physiology were
- The results led to the list of **15 core concepts** you will see next (2011)

# The 15 core concepts of physiology (in alphabetical order)

| | |
|---|---|
| Causality | Homeostasis |
| Cell-cell communication | Interdependence |
| Cell membrane | Levels of organization |
| Cell theory | Mass balance |
| Energy | Physics/chemistry |
| Evolution | Scientific reasoning |
| Flow down gradients | Structure/function |
| Genes to proteins | |

# The core concepts . . .

1. are NOT an attempt to systematically define the ***science of physiology.***
2. DO NOT define the content of a physiology ***course.***
3. DO NOT define the content of a physiology ***curriculum.***

# The core concepts . . .

1. Are meant to be useful; we wanted to produce something that will help teachers and students.
2. Therefore our list of core concepts is not unique and not definitive.

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1. Are meant to be useful; we wanted to produce something that will help teachers and students.
2. Therefore our list of core concepts is not unique and not definitive.
   - Different teachers, different courses, different curricula may find different core concepts useful.

# The core concepts . . .

1. are a tool that ***faculty*** can use in designing and teaching a physiology course.
2. are a tool which ***faculty*** can use in designing a curriculum.
3. are, not incidentally, a tool to be used by ***students*** in their attempt to master physiology.

# The core concepts are a multi-tool!

# Core concepts are general models

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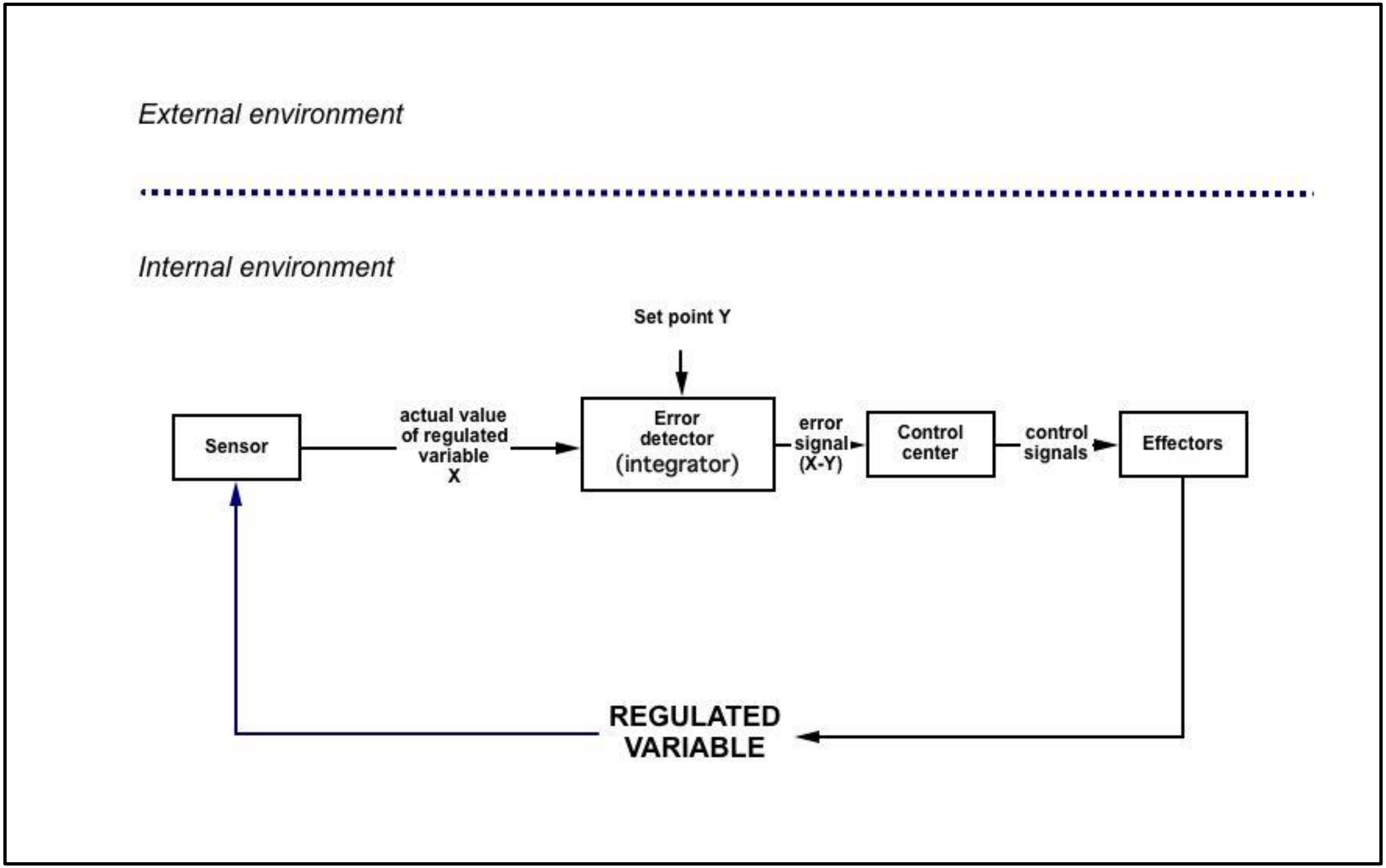
- In 2000 my colleague Harold Modell published a paper

  "How to help students understand physiology? Emphasize general models"

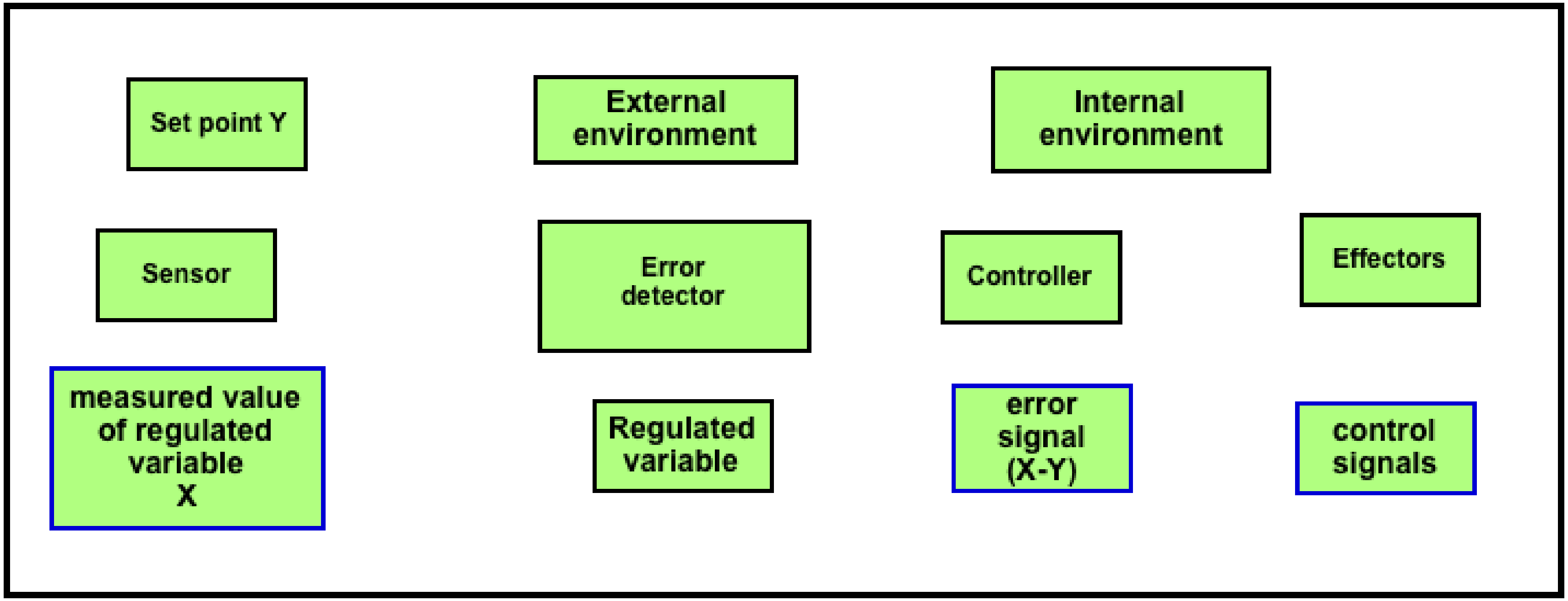
  *Adv Physiol Educ* 23: 101-107.

  His general models overlap with the core concepts I have been discussing.

# Here's a model for *homeostasis*



# Core concepts are BIG!




These are the “component ideas” that make up the core concept of ***homeostasis***.

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- Thus, it is essential that we systematically "unpack" a core concept to explicitly reveal its component parts.
- The product of "unpacking" is a ***conceptual framework (CF).***

# Conceptual frameworks: opening up a core concept

# CF for *cell membrane*

**CM2**: The cell membrane participates in a variety of mechanisms that maintain the integrity of cells . . . . . .

**CM2.1** . . . . . . . . .

**CM2.2** The cell membrane helps to determine solute concentrations inside the cell . . . . . .

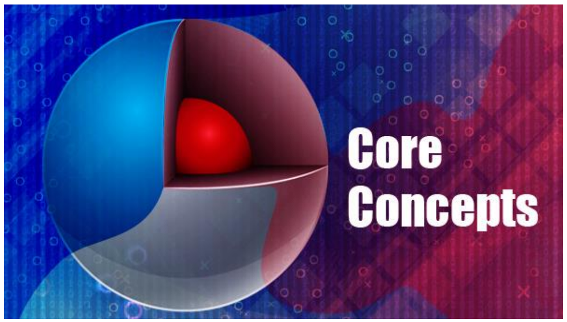
**CM2.2.1** . . . . .. . .

**CM2.2.2** Water and water-soluble substances (ions, most organic molecules) can only cross the membrane via mechanisms . . . . . .

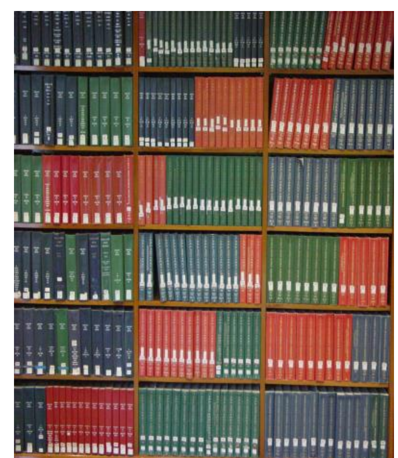
**CM2.2.2.1** Water and some ions traverse the membrane by passive diffusion down . . . . .

**6 components of a CF made up of 27 items**

# *CORE CONCEPTS & THE KNOWLEDGE EXPLOSION*




Mitigation?



# Core concepts and the info explosion

- In organizing and planning our courses, a focus on the ***core concepts*** of physiology may provide at least a partial solution to the problem of students learning all they need to learn in the limited time available to them.

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# Core concepts and the info explosion

- In organizing and planning our courses, a focus on the ***core concepts*** of physiology may provide at least a partial solution to the problem of students learning all they need to learn in the limited time available to them.
- It provides teachers a way to make decisions about what to teach and what not to teach.
- It offers students tools to make their learning "more efficient."

# What should they know (1)?

- What do (or did) I want my students, first year med students, to remember five years after they took my class?
- I want them to remember ***homeostasis***, the general process that regulates the state of the internal environment.
- It probably doesn't matter if they remember the <u>***details***</u> about the difference between carotid and the aortic baroreceptors.

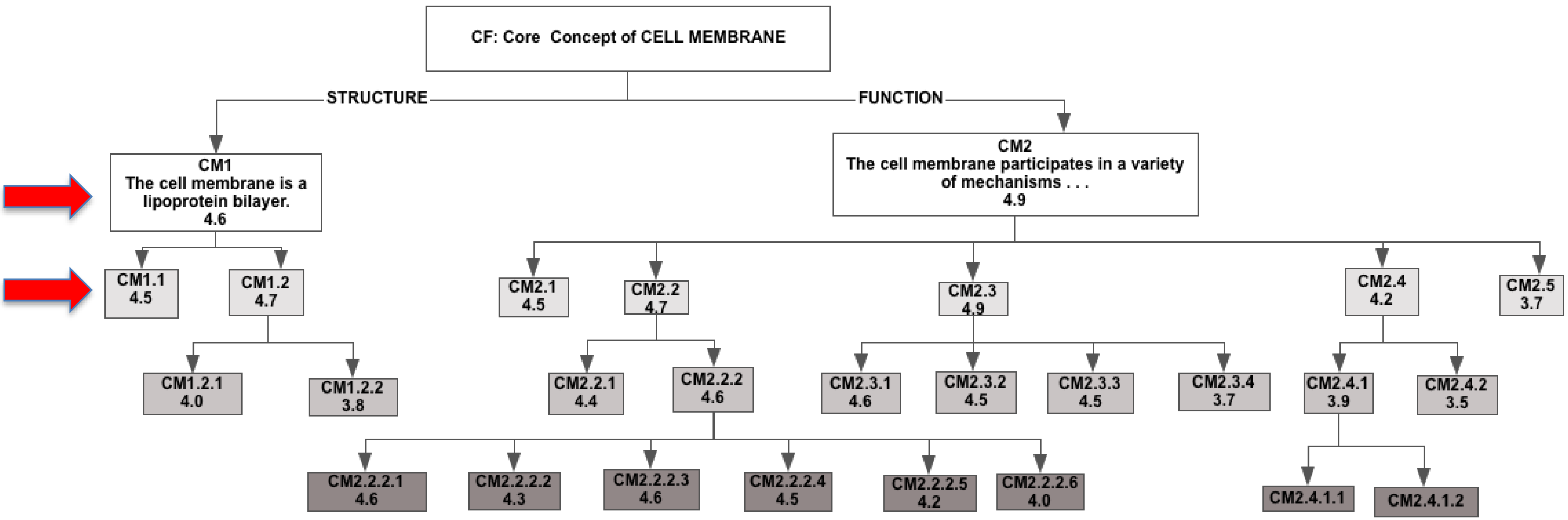
# What should they know (2)?

- I want them to remember the ***cell-cell communications*** mechanisms present in endocrine and neural systems,
- even if they don’t remember of the <u>***details***</u> of the second messenger pathways activated by epinephrine.

# What are the ***details***?

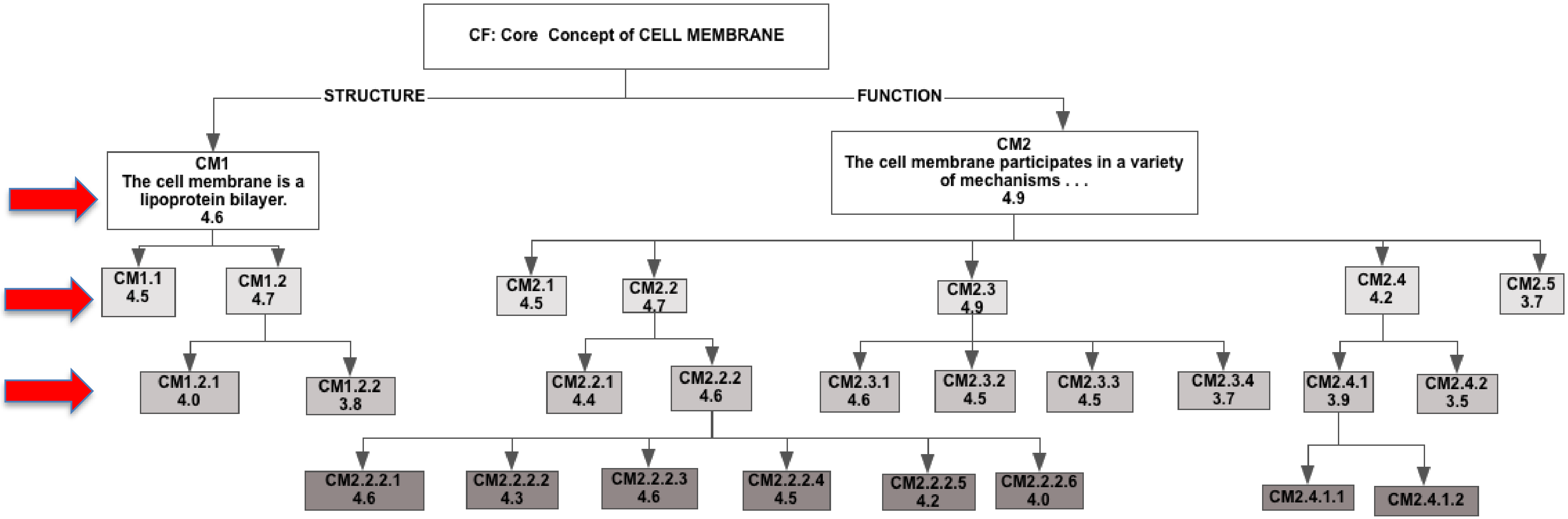
- How would I define, if only for myself, what details the students don’t need to remember?
- Art Vander talked about “layers” of knowledge and I think that a conceptual framework can reveal the layers in a very explicit way.

# What should they know?



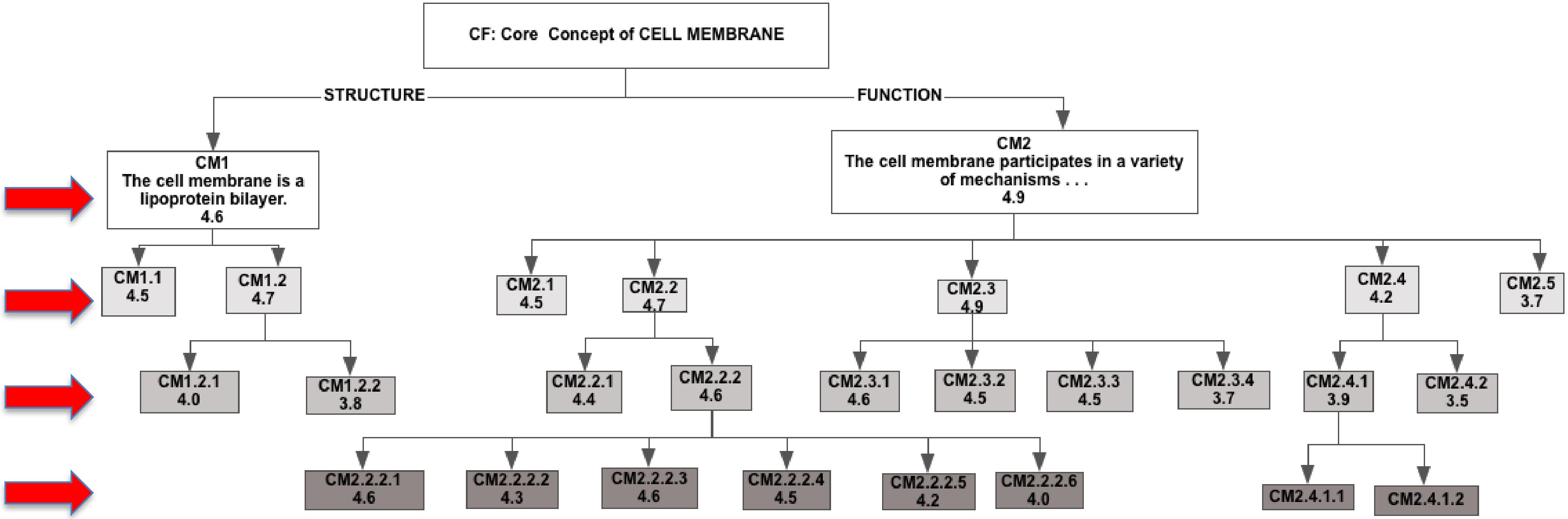

**Introductory course**

# What should they know?



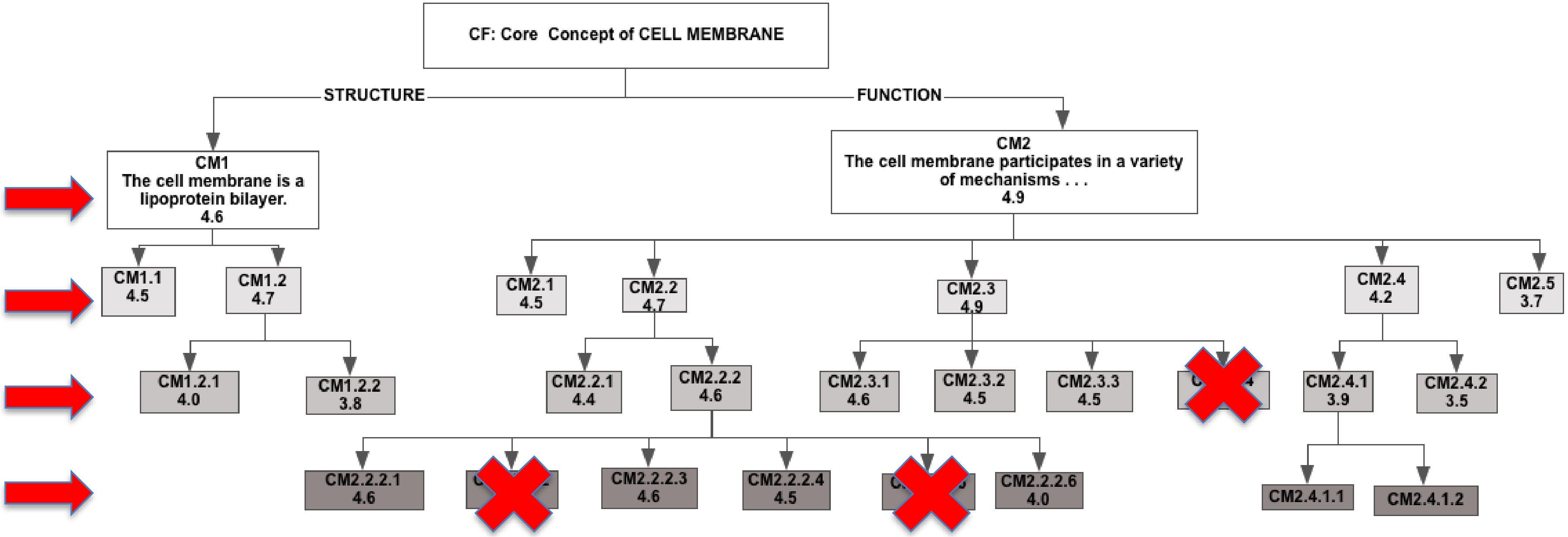

Intermediate course

# What should they know?




Advanced course

# What should they know?




Advanced course

# For physiology teachers

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- The conceptual frameworks therefore make possible considered decisions about what to teach, and what not to teach, in a particular course.

# For students in physiology

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  – As I will discuss later, the core concepts are tools to facilitate the transfer of learning.

# For students in physiology

- The core concepts are tools with which to build, or rebuild, models for specific mechanisms not yet learned or already forgotten.
- The conceptual frameworks can function as checklists to keep track of what has already been mastered and what needs to be mastered.

# A common experience?

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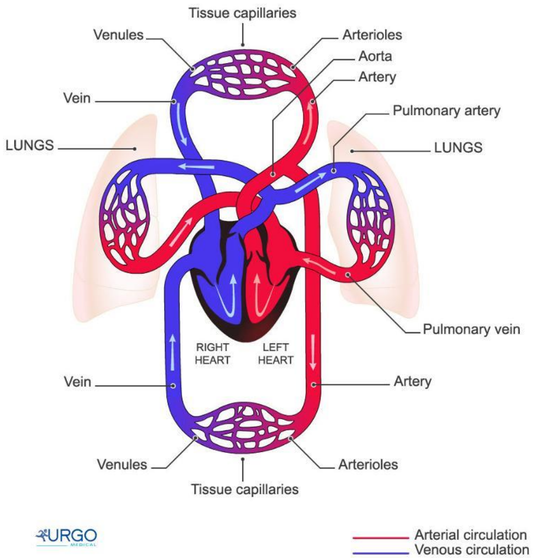
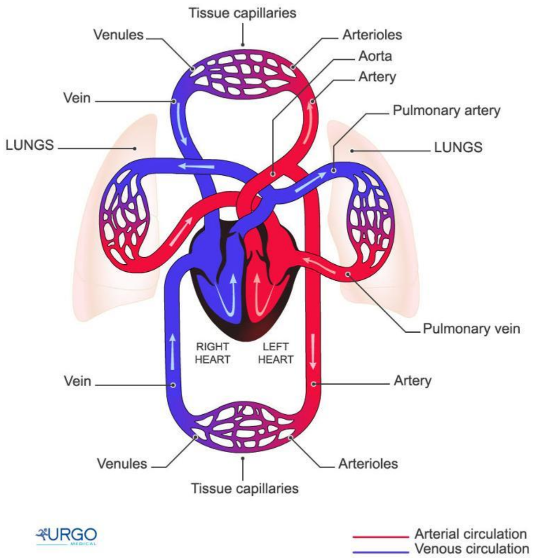


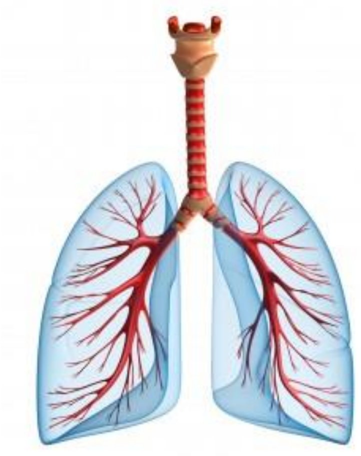

Blood flow

**Mastered hemodynamics**

# A common experience?




4 weeks later

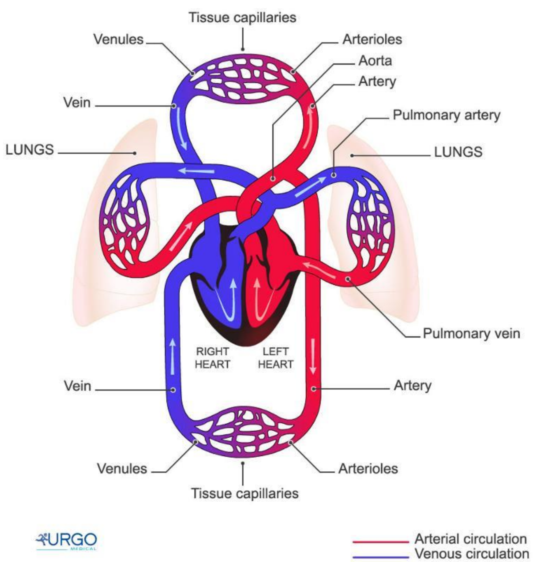


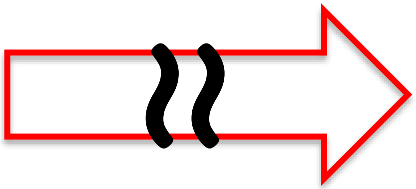
Blood flow

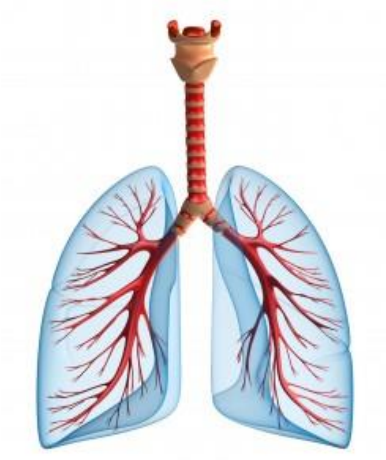
Air flow

**Mastered hemodynamics**

# A common experience?





Blood flow

**Mastered hemodynamics**

Air flow

**Struggled to understand air flow**

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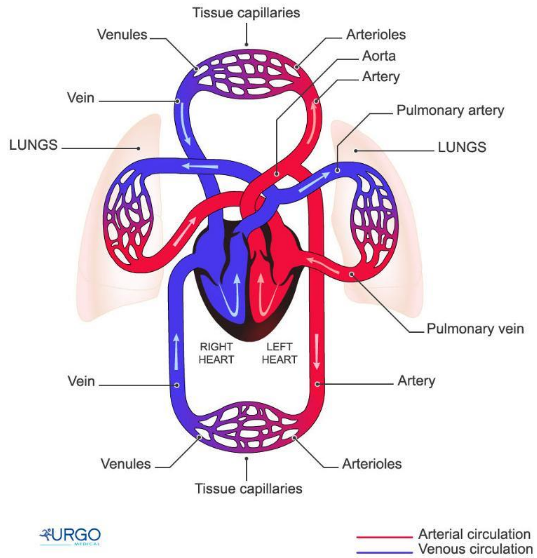


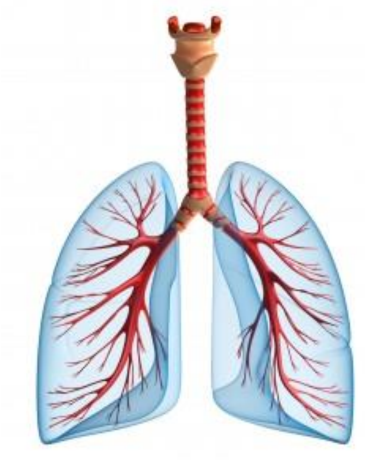

Blood flow

Air flow

**Mastered hemodynamics**

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**Failure to TRANSFER learning**

# Facilitating learning

- When students are able to use core concepts or general models they are able to apply things they already know to the task of learning something that appears new.

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- When students are able to use core concepts or general models they are able to apply things they already know to the task of learning something that appears new.
  - They are better able to transfer what they know to new topics.

# Facilitating learning

- When students are able to use core concepts or general models they are able to apply things they already know to the task of learning something that appears new.
- ***Teachers*** spend less time helping students learn new stuff.  ***Students*** spend less time learning new stuff, leaving them more time for important details.

# My proposal

- As you struggle to insure that everything your students need to know is included in your course, THINK ABOUT CORE CONCEPTS OR GENERAL MODELS!
- Plan to help your students learn the core concepts and give them practice <u>recognizing</u> where they are applicable.
- Give them practice <u>using</u> core concepts as they learn.

# How do we do this?

- Let’s start by mapping one of the the most important core concepts onto the contents of a typical physiology course (as described by the TOC of a textbook).

# Which core concepts to use?

| | Flow | Homeostasis | Cell-Cell | Cell membr | Mass Bal |
|---|---|---|---|---|---|
| | | | | | |
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I've picked what my colleagues and I more or less agree are the five most important (or most applicable) in a typical physiology course.

# Which core concepts to use?

| | Flow | Homeostasis | Cell-Cell | Cell membr | Mass bal |
|---|---|---|---|---|---|
| Cell physio | | | | | |
| Cell membr | | | | | |
| Neuronal | | | | | |
| CNS/PNS/ANS | | | | | |
| Muscle | | | | | |
| Blood | | | | | |
| CV | | | | | |
| Resp | | | | | |
| Renal | | | | | |
| Acid/Base | | | | | |
| GI | | | | | |
| Endo | | | | | |
| Reprod | | | | | |

This list of physiology topics came from the table of contents of a number of the textbooks on my bookshelf. It is not meant to be prescriptive.

# Which core concept to use and where does it apply?

- I am going to do this exercise using the most widely applicable core concept of physiology, ***flow down gradients.***

# Which core concepts to use?

| | Flow | Homeostasis | Cell-Cell | Cell membr | Mass bal |
|---|---|---|---|---|---|
| Cell physio | ✓ | | | | |
| Cell membr | ✓ | | | | |
| Neuronal | ✓ | | | | |
| CNS/PNS/ANS | | | | | |
| Muscle | ✓ | | | | |
| Blood | | | | | |
| CV | ✓ | | | | |
| Resp | ✓ | | | | |
| Renal | ✓ | | | | |
| Acid/Base | | | | | |
| GI | ✓ | | | | |
| Endo | ✓ | | | | |
| Reprod | ✓ | | | | |

**I would suggest that flow down gradients applies to all of the topics that have been checked (one could make the case that it actually applies everywhere).**

# Which core concepts to use?

| | Flow | Homeostasis | Cell-Cell | Cell membr | Mass bal |
|---|---|---|---|---|---|
| Cell physio | ✕ | | | | |
| Cell membr | ✕ | | | | |
| Neuronal | ✕ | | | | |
| CNS/PNS/ANS | | | | | |
| Muscle | ✕ | | | | |
| Blood | | | | | |
| CV | ✕ | | | | |
| Resp | ✕ | | | | |
| Renal | | | | | |
| Acid/Base | | | | | |
| GI | | | | | |
| Endo | | | | | |
| Reprod | | | | | |

**But the purposes of this exercise let's just consider the six topics I have checked.**

# Flow down gradients: A lesson plan

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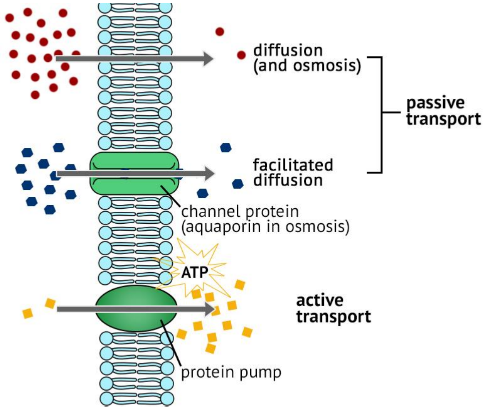
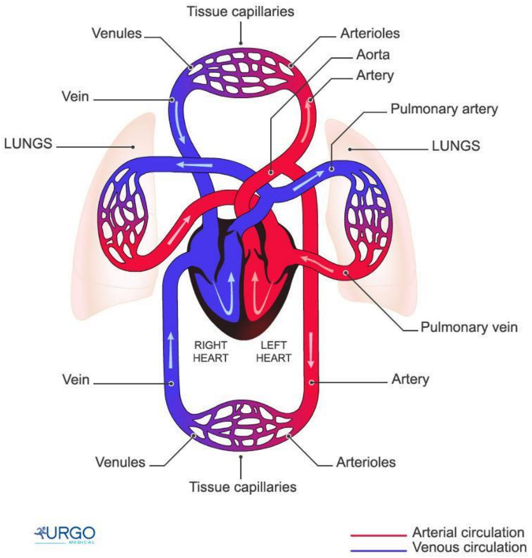
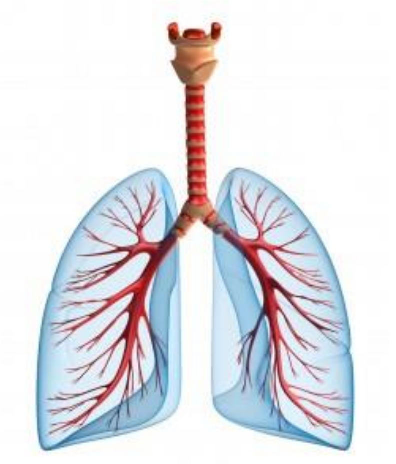



Ion/molecule flow




Blood flow

Air flow



# For transfer for occur

- Initial learning must occur
- Some level of abstraction of that knowledge is needed (ie, core concepts or general models)
- Transfer is an active process and thus does not occur passively

*How People Learn*, Bransford et al.

# Why is it hard to generalize?

- Why doesn't an understanding of ion and molecule movement across membranes help students understand why blood flows in the circulation or air flows in the airways?

# One reason it is hard to generalize

- Fick's 1st Law of Diffusion

  $J = (DA/\Delta x)\Delta C$
- Poiseuille's Law

  $Q=(\pi r^4/8\eta l)(P_i - P_o)$
- Airflow in airways

  V(dot) = $P(\pi r^4/8\eta l)$

From
Berne & Levy
Physiology, 6th Edition,
Koeppen and Stanton,
2008

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  $\dot{V} = P(\pi r^4/8\eta l)$

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- **Flow**
- **Resistance to flow**
- **Energy gradient**

FLOW DOWN GRADIENTS!

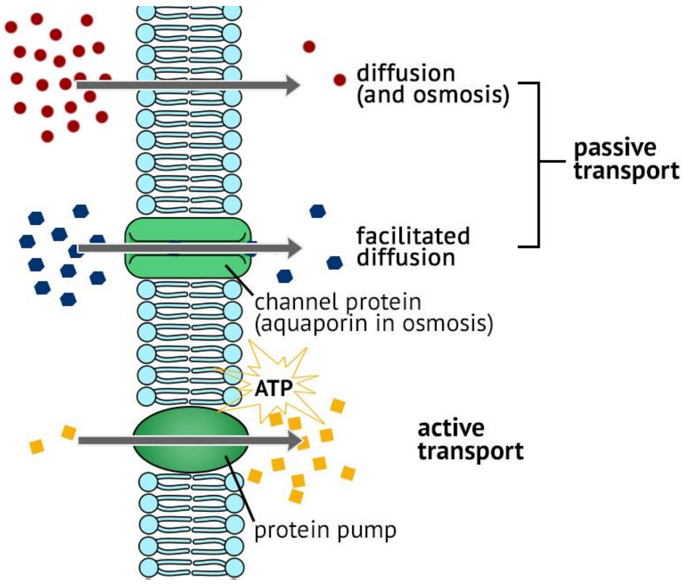
Flow = Energy grad/Resistance

# A “lesson plan” for flow

# A “lesson plan” for flow

- It’s intent is to help students understand the core concept/general model of ***flow down gradients***, and develop the ability to use it as a tool for learning physiology.
- The plan is “fictitious” in that it’s not a part of a real course.
- It’s very much a work in progress.

# Flow down gradients: A lesson plan




Ion/molecule flow

Fick's 1st Law of Diffusion:

$J = (DA/\Delta x)\Delta C$

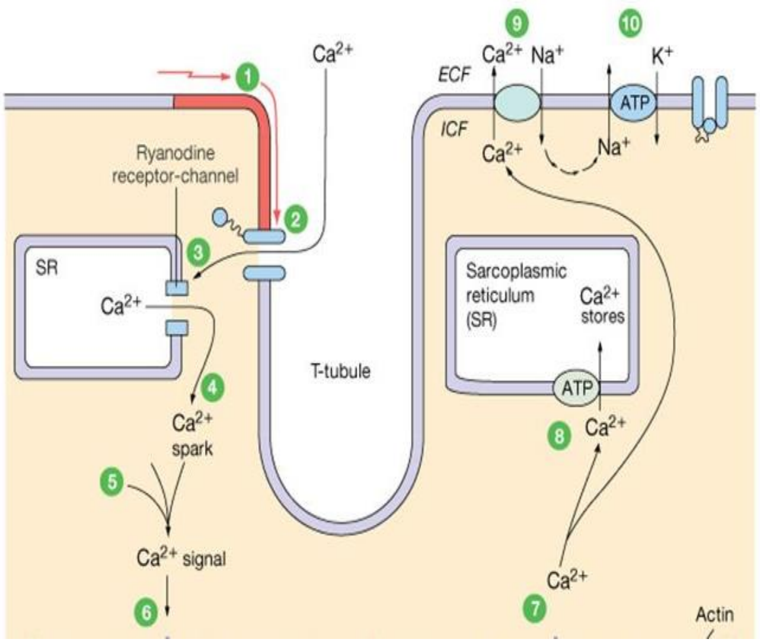
Where:

**J** is the flux (flow)

**(DA/Δx)** are the variables that determine opposition (resistance) to flow

**ΔC** is the concentration (energy) gradient

# Flow down gradients: A lesson plan




E-C coupling in skeletal muscle

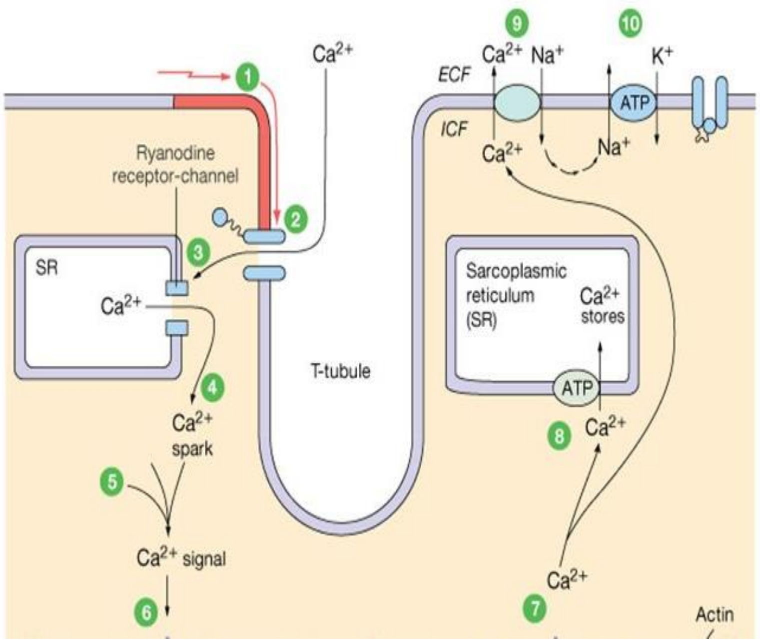
$Na^{+}$ and $Ca^{2+}$ ions move across the sarcolemma and the SR.

QUESTION: What causes these ions to move?

ANSWER: Flow down gradients!

QUESTION: What causes the gradients to be present?

# Flow down gradients: A lesson plan



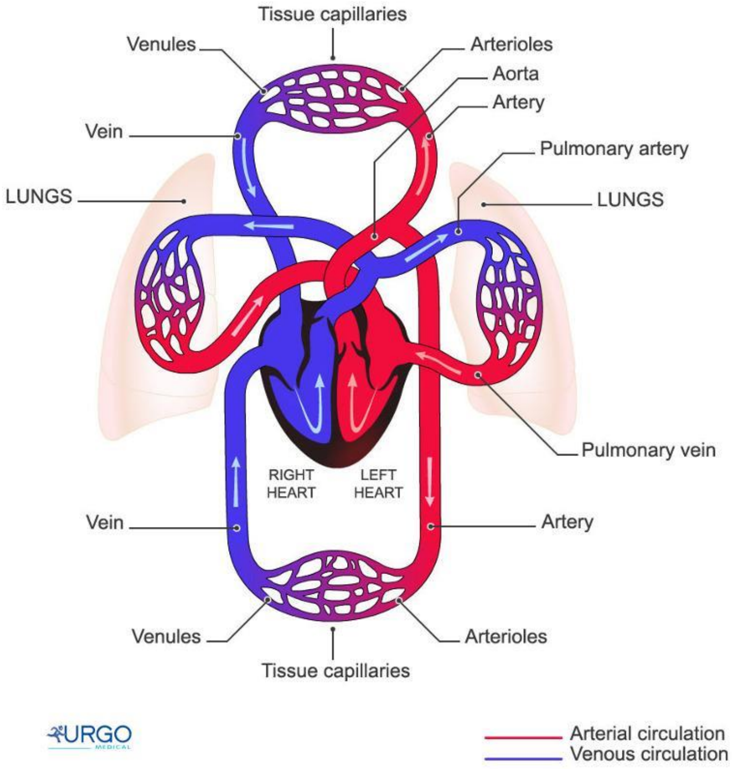

E-C coupling in skeletal muscle

Fick's 1st Law of Diffusion (passive):

$J = (DA/\Delta x)\Delta C$

Active transport also occurs ($\Delta C$ created by the expenditure of energy)

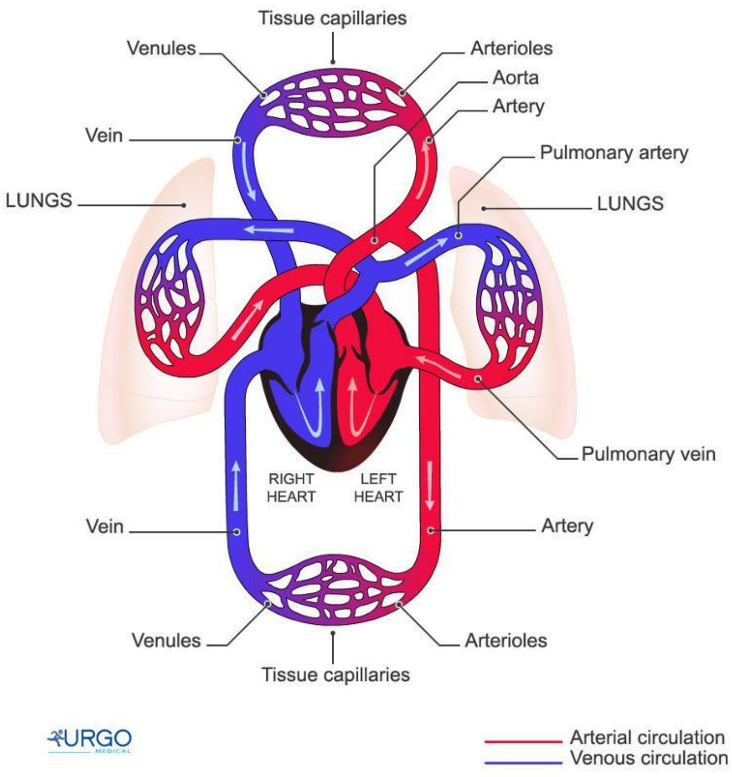
# Flow down gradients: A lesson plan




Blood flow in the circulation

QUESTION: For flow to occur in the circulation what must be present?
ANSWER: A pressure gradient.
QUESTION: What is the source of the pressure gradient?
ANSWER: Contraction of the heart and elevation of pressure in the aorta.
QUESTION: What is the general model we are dealing with here?
ANSWER: ***FLOW DOWN GRADIENTS***!

# Flow down gradients: A lesson plan



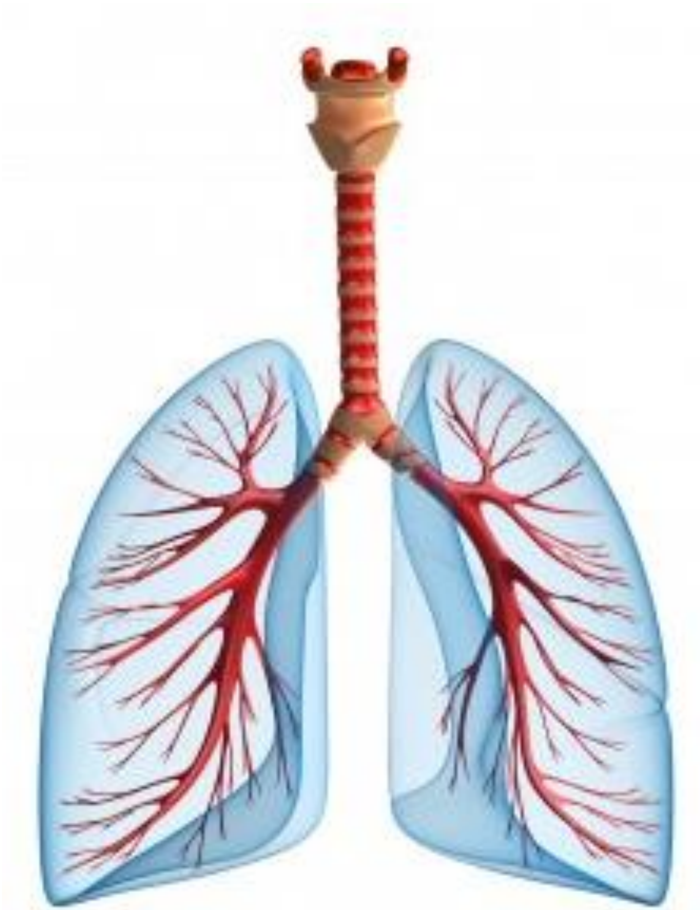

Blood flow in the circulation

Poiseuille's Law

$$Q=(\pi r^4/8\eta l)(P_i - P_o)$$

Determines the flow in any vessel and the flow throughout the entire system.

# Flow down gradients: A lesson plan



Air flow in the airways

QUESTION: What general model (core concept) do you expect to have to work with here?

ANSWER: ***FLOW DOWN GRADIENTS***

QUESTION: What is the source of the pressure gradient?

# Critical features for transfer

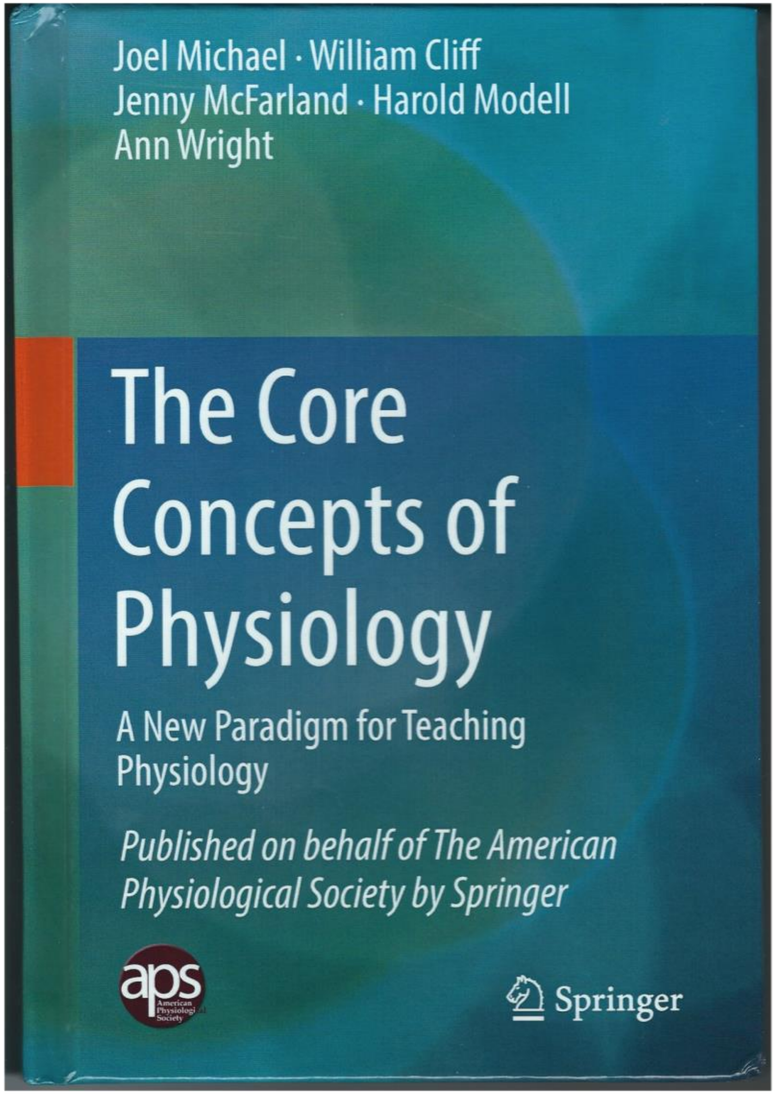
- ***Explicit description*** of the core concept
- Opportunities to ***practice*** recognizing the applicability of the concept and using it
- ***Consistency*** in terminology and visual representations

# What's the payoff?

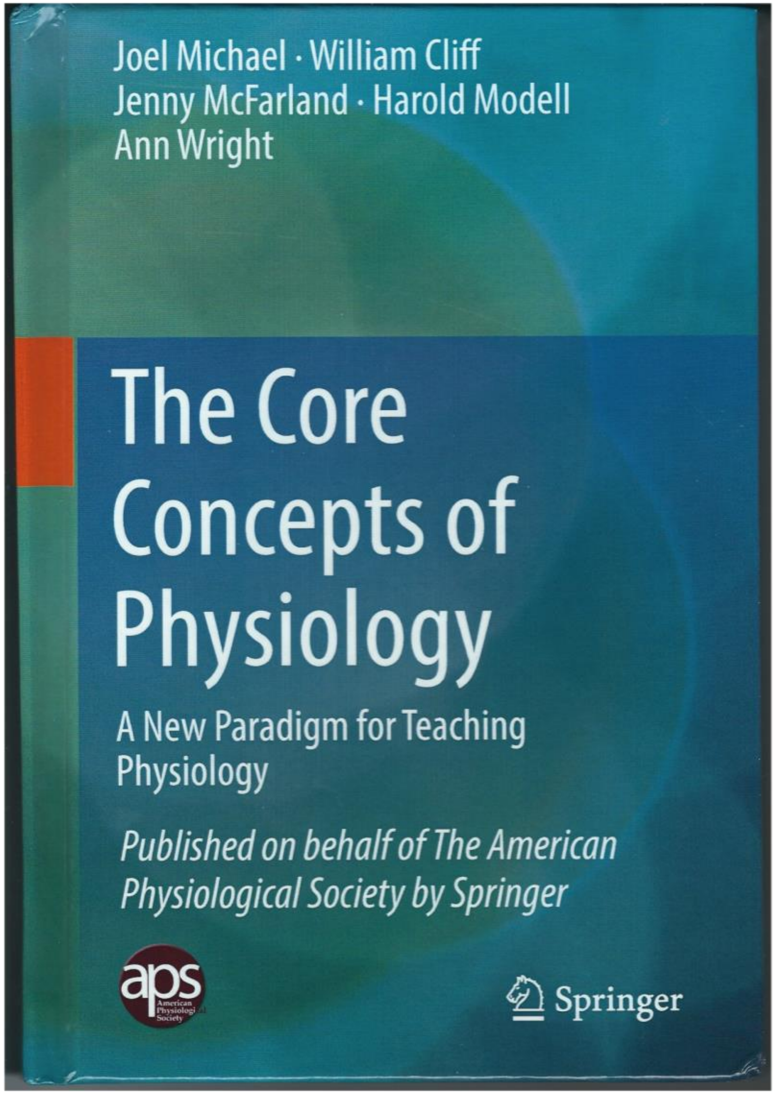
- Students understand (can use) the core concepts.
- Students can identify where the core concepts are applicable.
- Therefore students are not learning each new topic or phenomenon from scratch; they already know something about it.
- Students have a general model to which they can add details as they need them.

# Some take home messages

- We know more than students can or need to learn (the information explosion).
- Teachers must decide what their students should learn.
- Students need as much help as possible to learn it all.
- A focus on the concepts of physiology can help both teachers and students.




The full story about the core concepts approach to teaching physiology, including the history, can be found in our book seen here.




If you are a member of APS you can download it for free. If you are not a member it can be purchase.

We get no royalties for sales of the book!

# Relevant publications


1. Michael, J., Modell, H., McFarland, J., and Cliff, W. (2009). The "core principles" of physiology: What should students understand? *Adv Physiol Educ*, **33**: 10-15.
2. Michael, J. and McFarland, J. (2011) The core principles ("big ideas") of physiology: Results of faculty surveys. *Adv Physiol Educ* **35**: 336-341.
3. Modell, H., Cliff, W., Michael, J., McFarland, J, Wright, A. ,Wenderoth, M.P. (2015) A physiologist's view of homeostasis. *Adv Physiol Educ* **39**(4): 259-266.
4. McFarland, J, Michael, J., Modell, H., Wenderoth, M.P., Cliff, W., Wright, A. (2016) A conceptual framework for homeostasis: Development and validation. *Adv Physiol Educ* ***40**: 213–222.*
5. Michael, J, Martinkova, P, McFarland, L, Wright, A, Cliff, W, Modell, H. (2016) Validating a conceptual framework for the core concept of cell-cell communication. *Adv Physiol Educ* **41**: 260-265.

# Relevant publications


6. Michael, J, Cliff, W, McFarland, J, Modell, H, Wright, A. (2017) *The Core Concepts of Physiology: A New Paradigm for Teaching Physiology*. New York: Springer Nature. (Available from APS website)
7. **Michael, J and Sircar, A. (2011). *Fundamentals of Medical Physiology*. New York: Thieme. (Physiology presented in a clinical context and with references to general models/core concepts imbedded throughout the text.)**

# Check us out at

**physiologyconcepts.org**

You will find most of our
papers and presentations on
core concepts of physiology there.

# You might be interested in

# physiologymajors.org

PMIG, the Physiology Majors Interest Group, is being spearheaded by Erica Wehrwein at Michigan State. This group is promoting undergraduate physiology majors. A committee is working on applying core concepts to course and curriculum planning.

# I would be interested in

- hearing from anyone has already, or plans to, incorporate core concepts in their physiology course.
- Get in touch today or at a later date.
- My e-m ail address is

**jmichael40@gmail.com**

# Thanks . . .

- to the organizers of this meeting for inviting me to attend and giving me the opportunity to tell our story and thank you for your attention.
- To all for you for your attention.

- We have time for some questions and answers.
- Finally, this afternoon I will be doing a breakout session about using core concepts to help students learn to transfer what they know about an old topic to the next new topic.

INDIANA
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SOCIETY

INDIANA
PHYSIOLOGICAL
SOCIETY



INDIANA
PHYSIOLOGICAL
SOCIETY

# How did we develop the list of core concepts of physiology?

Conceptual assessment in **biology** (CAB) meeting (2007)

Deliberations on core concepts of **physiology** (2007-2009)

Surveys of **physiology** teaching faculty (2008-2011)

Discussions and workshops at EB and HAPS meetings (2007-      )

RUSH

MICHIGAN

# What can you do with core concepts?

**A great many things!**

RUSH

MICHIGAN STATE UNIVERSITY

| | | | | |
|---|---|---|---|---|
| 1 | CC1 | | | |
| 2 | | CC1.1 | | |
| 3 | | CC1.2 | | |
| 4 | | CC1.3 | | |
| 5 | | CC1.4 | | |
| 6 | | CC1.5 | | |
| 7 | | CC1.6 | | |
| 8 | | CC1.7 | | |
| 9 | CC2 | | | |
| 10 | | CC2.1 | | |
| 11 | | | CC2.1.1 | |
| 12 | | | CC2.1.2 | |
| 13 | | | CC2.1.3 | |
| 14 | | CC2.2 | | |
| 15 | | CC2.3 | | |
| 16 | CC3 | | | |
| 17 | | CC3.1 | | |
| 18 | | CC3.2 | | |
| 19 | | CC3.3 | | |
| 20 | | | CC3.3.1 | |
| 21 | | | CC3.3.2 | |
| 22 | | CC3.4 | | |
| 23 | | CC3.5 | | |
| 24 | | CC3.6 | | |
| 25 | | CC3.7 | | |
| 26 | CC4 | | | |
| 27 | | CC4.1 | | |
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| 31 | | CC4.2 | | |
| 32 | | CC4.3 | | |
| 33 | | | CC4.3.1 | |
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| 35 | | | CC4.3.3 | |
| 36 | | | | CC4.3.3.1 |
| 37 | | | | CC4.3.3.2 |
| 38 | | | CC4.3.4 | |
| 39 | | | | CC4.3.4.1 |
| 40 | | | | CC4.3.4.2 |
| 41 | CC5 | | | |
| 42 | | CC5.1 | | |
| 43 | | CC5.2 | | |
| 44 | CC6 | | | |
| 45 | | CC6.1 | | |
| 46 | | CC6.2 | | |
| 47 | | CC6.3 | | |
| 48 | CC7 | | | |
| 49 | | CC7.1 | | |
| 50 | | CC7.2 | | |