Unpacking core concepts to teach (renal) physiology

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Acknowledgements

<u>THE CORE CONCEPTS GROUP</u>

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My agenda

1. Who am I (a mini-bio)?
2. What are core concepts?
3. What are the core concepts of ***physiology***?
4. What does it mean to unpack a core concept?
5. What makes core concepts useful tools for learning?
6. How can we use core concepts to teach renal physiology?
7. What are some problems with using core concepts?

(1). Who am I: a mini-bio

- PhD in mammalian neurophysiology
- Joined Rush in 1968; hired to teach neuro-physiology to Neurology residents and to help plan the curriculum for the about to be re-opened medical school
- Was Course Director of the 1st year physiology course for many years; taught Physio throughout my tenure at Rush
- Since 1980 my research has focused on science education research – specifically teaching/learning PHYSIOLOGY
- So, I am NOT a nephrologist or a renal physiologist! But I do have some ideas that will help your students learn whatever you want them to learn.

(2). A core concept is . . .

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[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."

Duschl RA, Schweingruber HA, Shouse AW (eds). Taking science to school: Learning and teaching science in grades K-8. National Academies Press, Washington DC

For me personally a core concept is . . .

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. . . what I want my students to remember some years in the future (1-2 years later when they are clerks, or 4-5 years later when they are residents) after they have undoubtedly forgotten the details of the physiology.

Where did the core concepts of physiology come from?

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NSF-sponsored CAB meeting

Core concepts group cogitation

Surveys of physiology faculty

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Surveys of physiology faculty

Ultimately, the list of core concepts came from physiology teachers at all levels of higher education: community college through professional schools and graduate schools.

(3). The 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	

(3). The core concepts of physiology and the kidney

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Core concepts particularly applicable to the kidney

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To be discussed later in this talk

Definition: *Homeostasis*

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The role of negative feedback in regulating the functions of the body is a particularly powerful core concept in that it describes so much of organ system physiology.

Definition: Flow down gradients

Flow down gradients: *The transport of "stuff" (ions, molecules, blood, and gas) is a central process at all levels of organization in the organism, and a simple model describes such transport.*

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Ions crossing a cell membrane, blood flowing in blood vessels, gas flowing in airways, and tubular fluid moving down the nephron are all processes that result from the interaction of an energy gradient and the resistance to flow that is present. This core concept does not encompass active transport mechanisms.

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- A core concept is by definition a “big idea” and “big ideas” are made up of smaller ideas.
- The process of “unpacking” a core concept consists of explicitly stating all of the smaller ideas and arranging them in a hierarchical manner. The result is what your 8th grade English teacher called an outline.
- The product of unpacking a core concept is a ***conceptual framework*** (or CF).

What does a conceptual framework (CF) look like?

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CORE CONCEPT ("BIG IDEA")
Critical components
Constituent ideas
Elaborations
Amplifications

Homeostasis conceptual framework

Homeostasis conceptual framework

Critical components
H1. The organism maintains a stable internal environment in the face of a fluctuating external environment.
H2. A substantial change in a regulated variable will result in a physiological response to restore it towards its normal range.
H3. Homeostatic processes require a sensor inside the body ("what can't be measured can't be regulated").
H4. Homeostatic processes require a control center (which includes an integrator).
H5. Homeostatic processes require target organs or tissues, i.e., "effectors."

Homeostasis CF expanded

Homeostasis CF expanded

Critical component	**H3. Homeostatic processes require a sensor inside the body ("what can't be measured can't be regulated").**
Constituent idea	H3.1. Sensors detect the regulated variable and respond by trans-ducing that signal into a different signal.
Constituent idea	H3.2. Sensors respond within a limited range of stimulus values.
Constituent idea	H3.3. Sensors generate an output whose value is proportional to the magnitude of the input to the sensor.

The size and complexity of CFs

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Core Concept (validated)	Items	Levels
Flow	20	3
Homeostasis	30	2
Cell-Cell Communication	51	4
Cell Membrane	27	4

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"Bigger" isn't better, more important, or more applicable . . . . "bigger" simply means the concept is more complex.

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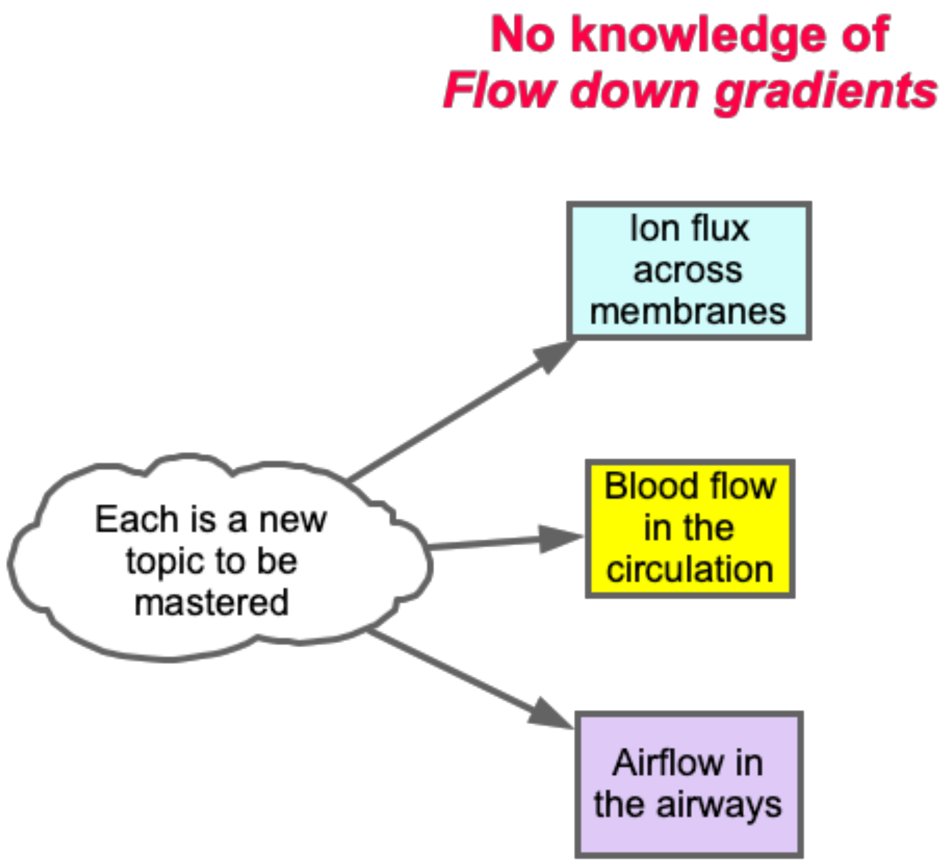
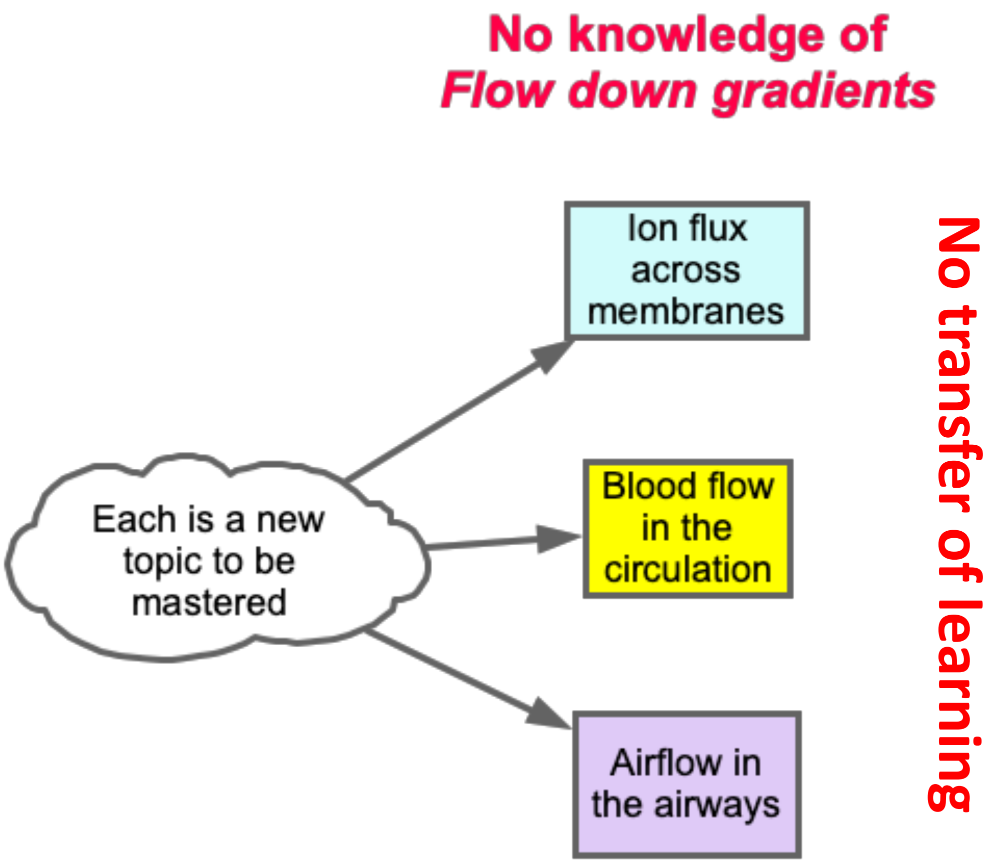
TRANSFER OF LEARNING!

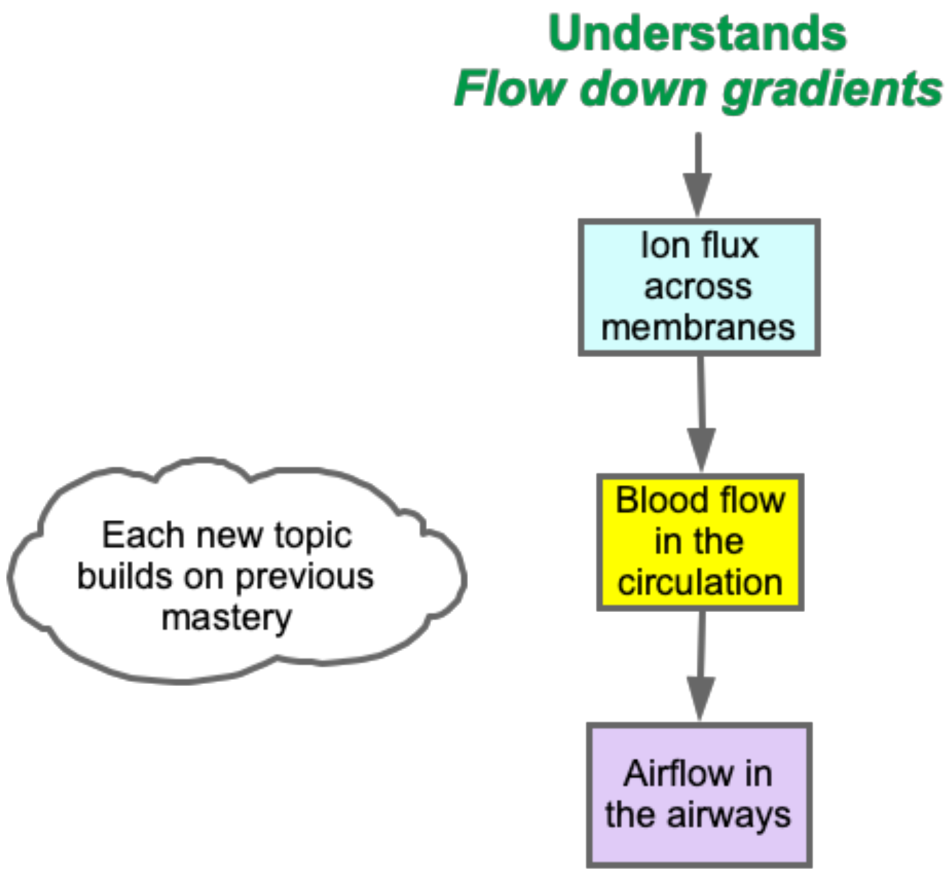
Common failure of transfer of learning



Common failure of transfer of learning



Core concepts and transfer of learning



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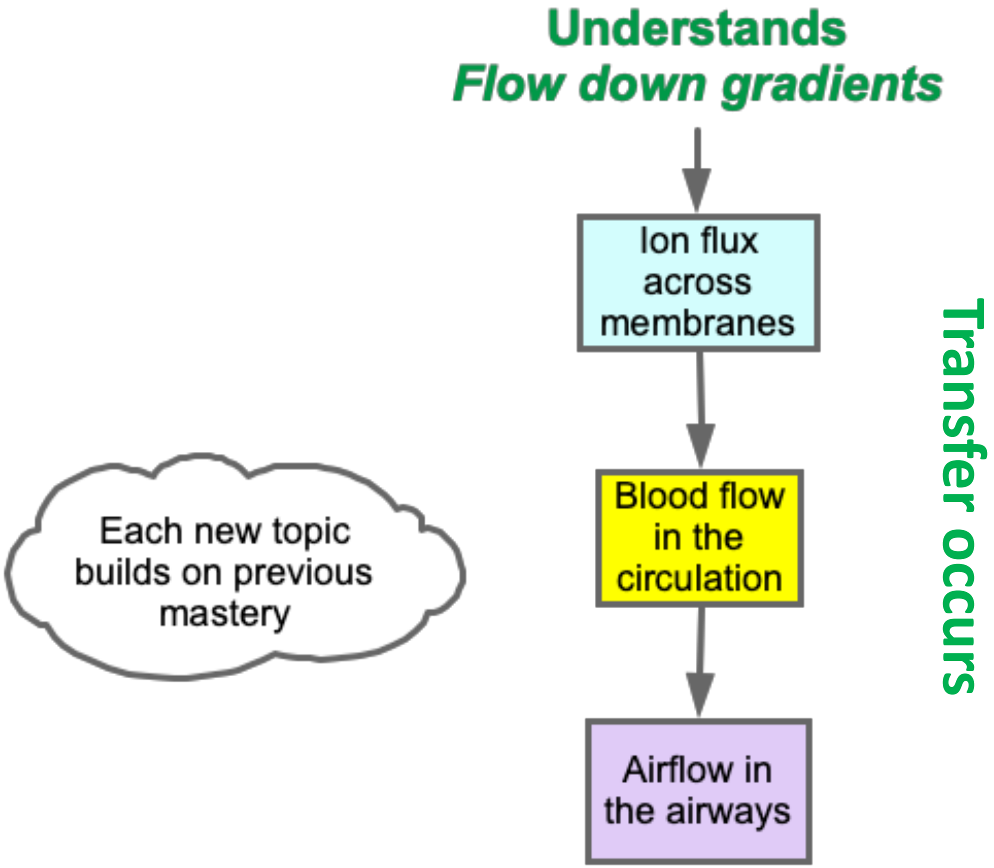

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This means less time and effort must be spent learning something you actually already know a lot about.

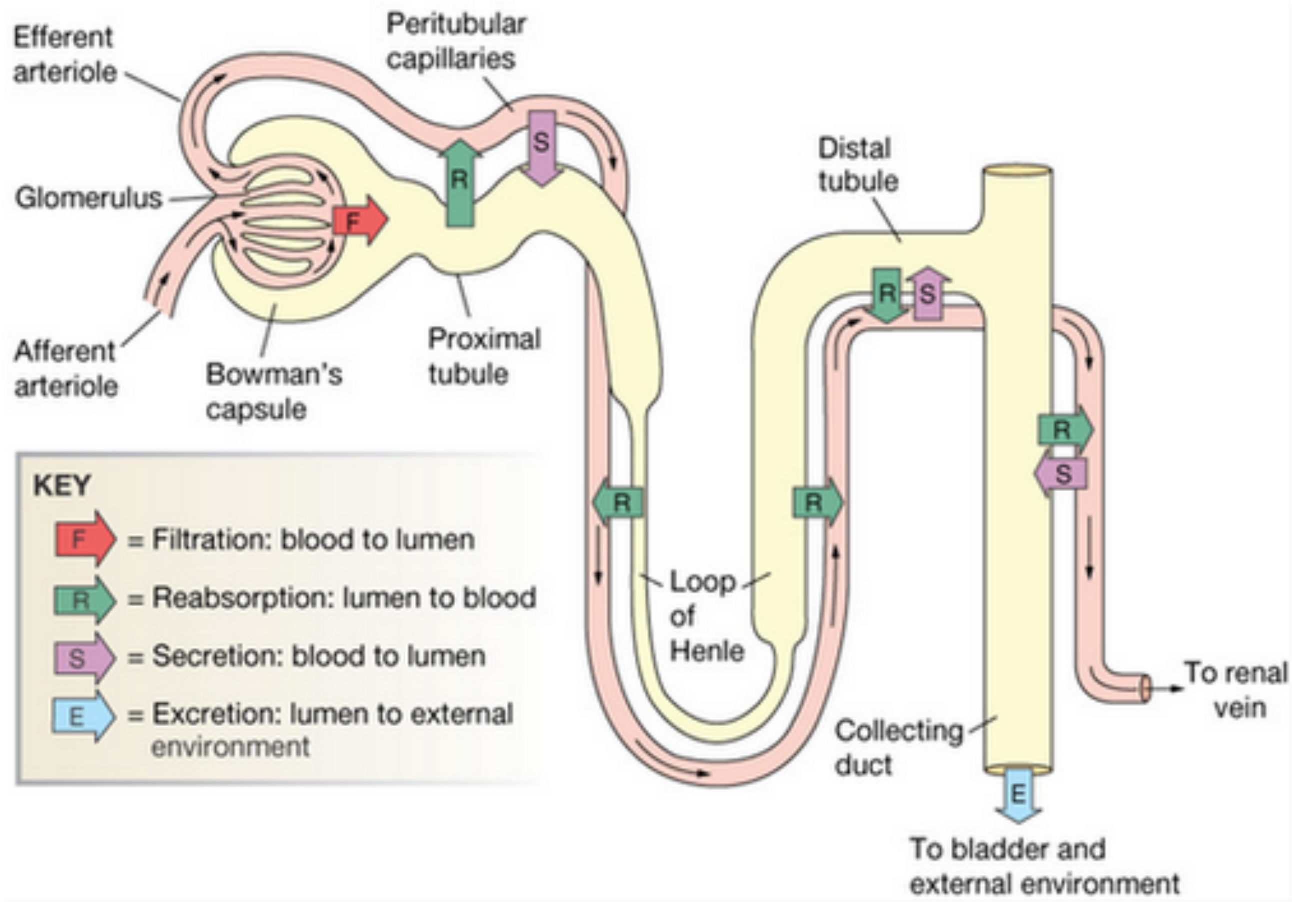
(6). Core concepts and the kidney

- Will talk about only two of the many core concepts that have widespread application in the kidney

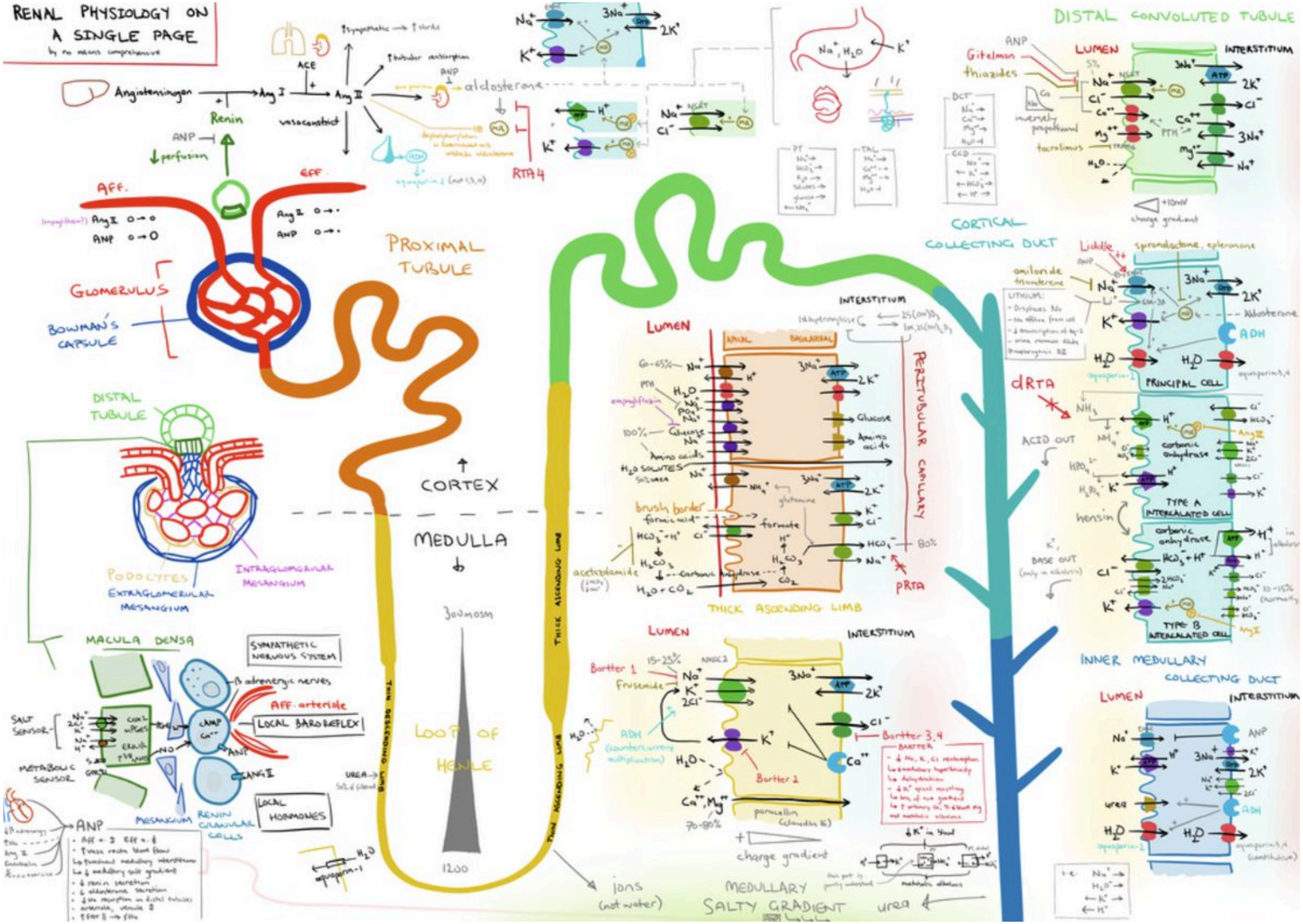
    - ***Flow down gradients***

    - ***Homeostasis***

The simplified kidney



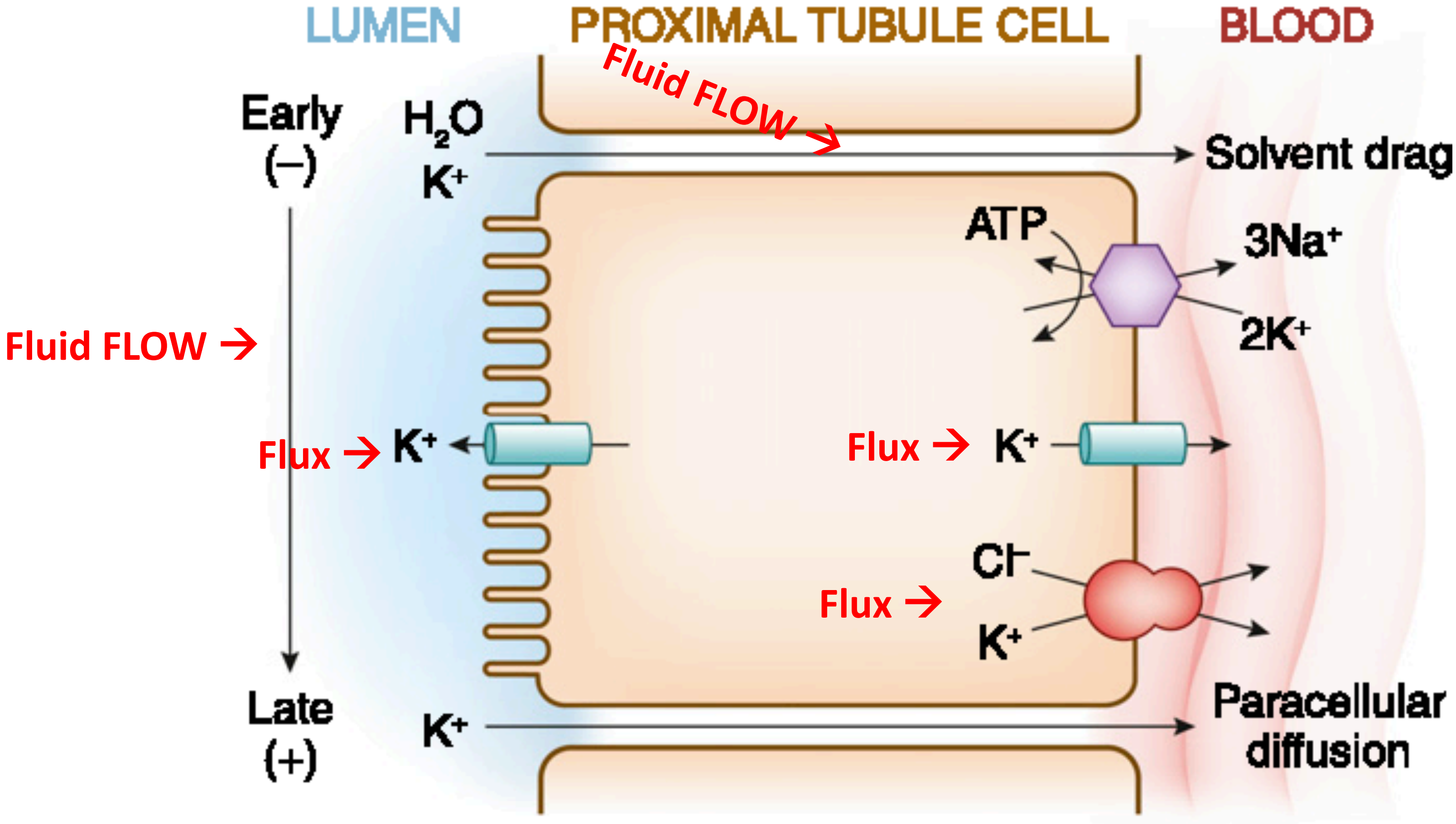
Every arrow in this diagram is a ***flow*** of something or a ***flux*** of a solute



Renal physiology on a single page!

Flows/fluxes **and** ***homeostasis***

Flow down gradients



How to approach flow/flux in the kidney

How to approach flow/flux in the kidney

- Start with the conceptual framework for ***flow down gradients***

Flow down gradients conceptual framework

Critical components
F1. Flow is the movement of stuff.
F2. Flow occurs because of the existence of an energy gradient.
F3. The magnitude of the flow is a direct function of the magnitude of the gradient.
F4. More than one gradient may determine the magnitude and direction of flow.
F5. There is resistance or opposition to flow in all systems.

Questions to ask about flow/flux in the kidney

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What is the source of the opposition ("resistance") to flow?

- For fluid flow it is the diameter of the vessel
- For solute flux it is the presence (number) of channels,
- And, whether channels are open or closed

Questions to ask about flow/flux in the kidney

What is the source of the energy gradient and what determines its magnitude?

What is the source of the opposition ("resistance") to flow?

- For fluid flow it is the diameter of the vessel
- For solute flux it is the presence (number) of channels,
- And, whether channels are open or closed

The questions should be asked of every example of solute flux in the kidney.

- These examples are NOT separate items to be memorized; they are all related by the core concept.

Homeostasis and the kidney (1)

- P_aO_2/P_aCO_2
- [K^+]
- [Ca^{+2}]
- [H^+] (pH)
- Blood glucose concentration
- Core body temperature
- MAP
- Blood volume
- Blood osmolality

The kidneys play a significant role in the regulation of each of these variables.

Modell et al (2015). A physiologist's view of homeostasis. *Adv Physiol Educ* **39**:259-266.

Homeostasis and the kidney (2)

- The kidneys play a role in the following:
  - Sodium and Water homeostasis
  - Acid-Base homeostasis
  - Potassium homeostasis
  - Divalent cations and phosphate homeostasis

Hoenig, M and Zeidel, M (2014). Homeostasis, the milieu interieur, and wisdom of the nephron. *Clin J Am Soc Nephrol* **9(7)**: 1272-1281.

Homeostasis and the kidney (3)

- ***Regulation*** of renal blood flow and the glomerular filtration rate
- ***Regulation*** of NaCl and water reabsorption
- ***Control*** of body fluid osmolality: urine concentration and dilution
- ***Control*** of extracellular fluid volume and ***regulation*** of renal NaCl excretion
- Potassium, calcium, and phosphate ***homeostasis***

Unnamed medical physiology textbook, recent edition

How to approach *Homeostasis* in the kidney

How to approach *Homeostasis* in the kidney

- Start with the conceptual framework for ***homeostasis***

Homeostasis conceptual framework

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Questions to ask about *Homeostasis* and the kidney

What is the <u>regulated variable</u>?

What is the <u>sensor</u>, where is it, how does it work?

How is the <u>set-point</u> determined?

Where is the <u>comparator</u> and how does it work?

What are the <u>effectors</u> that determine the value of the regulated variable?

Questions to ask about *Homeostasis* and the kidney

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What is the <u>sensor</u>, where is it, how does it work?

How is the <u>set-point</u> determined?

Where is the <u>comparator</u> and how does it work?

What are the <u>effectors</u> that determine the value of the regulated variable?

Even if answers to all these questions are NOT available (or not available at any great level of detail), it is still useful to get students to think about them!

(7). How to successfully adopt a core concept approach

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- The key to successful use of core concepts is **explicit**, **consistent**, and **repeated** reference to and use of whichever ones you want your students to use. Success also requires that students are held accountable for their ability to use the core concepts (ie, their performance must be tested).

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- The key to successful use of core concepts is **explicit**, **consistent**, and **repeated** reference to and use of whichever ones you want your students to use. Success also requires that students are held accountable for their ability to use the core concepts (ie, their performance must be **tested**).
- This should start with the students' first introduction to physiology.

Two problems with adopting a core concepts approach

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- Adopting a core concepts approach is difficult for two reasons:
  - Students learn physiology one organ system at a time and will encounter the core concepts in each of them.
    - Terminology etc varies from block to block
  - Unless the physiology course is taught by a single instructor (rare in medical schools) different instructors are teaching different system (or different parts of the same system)
    - It is very difficult to get all of your colleagues to tell "the same story" and use the same terminology!

Example of one of the problems

- 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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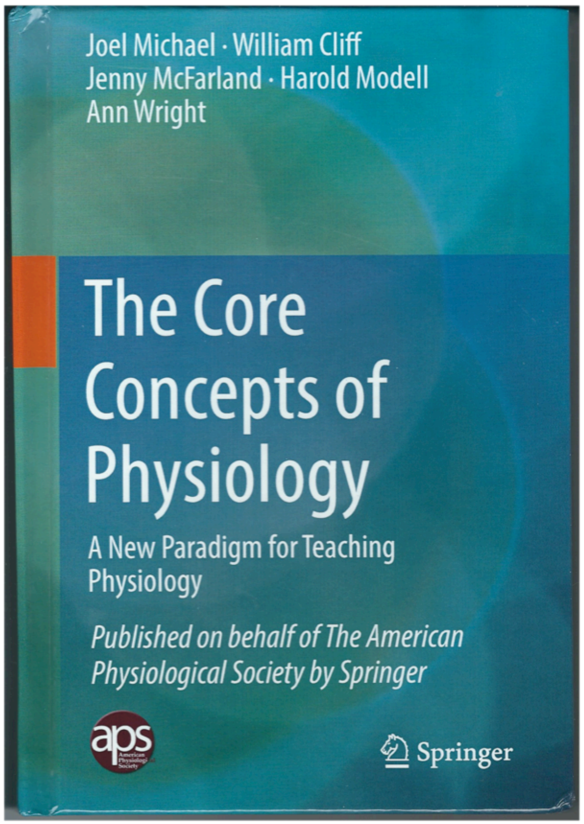
2008

All are examples of ***flow down gradients*** although the differences in terminology and the symbols being used can obscure this fact for students.

But. . . .

- The gains are worth the pains!
- That is to say, it is worth working to get your teaching faculty on the “same page” so that your students can build a toolkit full of useful gadgets for thinking about the functions – the physiology – of the body and especially the kidneys!

To get the full story



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

Relevant papers from the Core Concepts Group

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.

Michael, J. and McFarland, J. (2011) The core principles ("big ideas") of physiology: Results of faculty surveys. *Adv Physiol Educ* **35**: 336-341.

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.

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.*

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

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)

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.)

Thank you for the invitation to address your meeting,

and

thank you for your attention!