# "Say Goodbye to Hasselbalch"; birth of a new paradigm?

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# Definition: "Paradigm"

- "A worldview underlying the theories and methodology of a particular scientific subject" (Wikipedia)

- example: stem cell research/genomics

- example: the Henderson-Hasselbalch Equation

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# "Paradigm Shift"

- "a dramatic change in methodology or practice" (from Answers.com)

- attributed to Thomas Kuhn, in "The Structure of Scientific Revolutions", University of Chicago Press, 1962

- stem cell/genomic research promises to revolutionize the practice of medicine

- Q: does the Acid-Base CLinIMApp (which we will describe) constitute a paradigm shift?

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# The Current Paradigm

The Henderson-Hasselbalch Equation

$$pH_a = 6.10 + \log_{10} \frac{[HCO_3^-]}{0.03 \bullet P_aCO_2}$$

published in 1916 by Karl Albert Hasselbalch

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# The Current Paradigm (cont'd)

"comprehensive"

"unambiguous"

"elegant"

"precise"

(quotes from someone who majored in Chemistry and minored in Physics and Mathematics)

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# Students' Complaints.....

- "cryptic....unintelligible....hairy....arcane....non-intuitive....esoteric....nebulous....mystifying....give me a break!"

- "pH is perverse" (as [H+] increases, pH decreases)

- "we don't like logarithms"

- "that complex quotient is a killer!"

# Penny's Glazed Expression



....typical of the confused affect exhibited by students when they are confronted by the Henderson-Hasselbalch Equation

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# My (futile?) project

- devise an alternative to the current paradigm that will be more intuitive and "user-friendly"....
- ....that doesn't invoke logarithms....
- ....or complex quotients
- Good luck!

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# The Concept of "pH"



devised by Søren Sørensen in 1909

definition: "the negative logarithm of the hydrogen ion concentration"

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# The Henderson Equation

Lawrence J. Henderson's brainchild

published in 1908



$$[H^+] = 24 \bullet \frac{P_aCO_2}{[HCO_3^-]}$$

**$[H^+]$ is expressed in nanomoles per Liter**

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# The Henderson Equation (cont'd)

does not invoke pH (why not?)

does not incorporate logarithms

the quotient (it does contain one) is not complex, but rather the ratio between two two-digit numbers

potential problem: because pH is conspicuously absent, we cannot apply the axiom "pH leads the way"

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# The Henderson Equation (cont'd)

**35 to 45 torr**

**35 to 45 nM/L**  $$[H^+] = 24 \bullet \frac{P_aCO_2}{[HCO_3^-]}$$

**22 to 26 mEq/L**

# The Henderson Equation (cont'd)

- is the ratio low? (is $[H^+] < 35$ nM/L?)....
- ....an acid deficit (alkalemia)
- is the numerator low? (< 35 torr?)
- ....a respiratory alkalemia....
- ....or is the denominator high? (> 26 mEq/L)
- ....a metabolic alkalemia
- we don't need "pH [to] lead the way"!

# The Henderson Equation (cont'd)

- is the ratio high? (is $[H^+] > 45$ nM/L?)....
- ....an acid surplus (acidemia)
- is the numerator high? (> 45 torr?)
- ....a respiratory acidemia....
- ....or is the denominator low? (< 22 mEq/L)
- ....a metabolic acidemia

# The Henderson Equation (cont'd)

- Example: $P_aCO_2 = 62$ torr; $[HCO_3^-] = 27$ mEq/L
- $[H^+] = ( 24 \cdot 62 ) / ( 27 ) = 55$ nM/L
- $[H^+]$ is high (acidemia)
- numerator is high (respiratory acidemia)
- denominator is high (metabolic alkalemia)
- "partially compensated respiratory acidemia"

# The Henderson Equation (cont'd)

- Example: $P_aCO_2 = 48$ torr; $[HCO_3^-] = 34$ mEq/L
- $[H^+] = ( 24 \cdot 48 ) / ( 34 ) = 34$ nM/L
- $[H^+]$ is low (alkalemia)
- numerator is high (respiratory acidemia)
- denominator is high (metabolic alkalemia)
- "partially compensated metabolic alkalemia"

# The Henderson Equation (cont'd)

- reduces acid-base balance to its' barest essentials!
- the primary component is revealed as that element of the equation (numerator or denominator) that drives the numerical result beyond its' (lower or upper) normal limits
- the equation also lends itself to describing acid-base interactions *diagrammatically*

# Why Should We Care About This?

- the ABG report is generated by a "black box"
- clinicians should always be prepared to verify the data supplied by a black box
- RCPs should interpret every ABG report
- safe practice demands it!
- I require students to verify/interpret ABG reports at the bedside in the absence of any printed/electronic adjuncts (a calculator is OK)
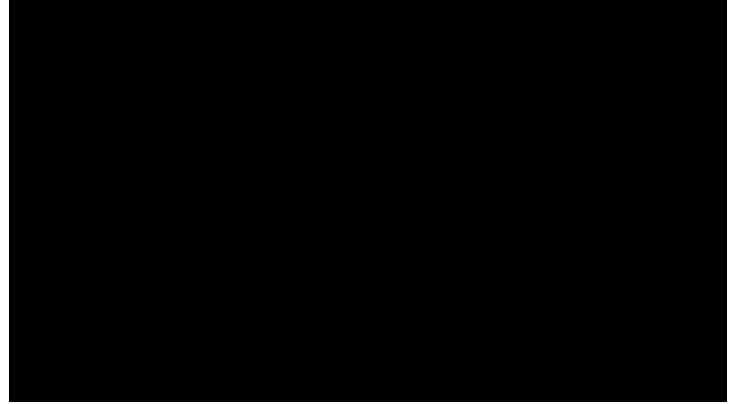
## Physiometrics

- "the development and application of interactive diagrammatic tools to facilitate the teaching, interpretation, and display of physiologic systems"

- for example, the "Tri-Axial System": Hastings and Steinhaus, 1931

- three axes embedded within one plane

- examine tri-axial images at www.CLinIMApp.com"

## The Tri-Axial System
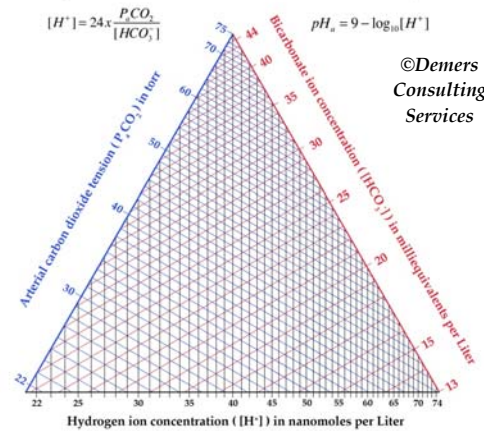
## Tri-Axial System (cont'd)

- remarkable attribute of the Tri-Axial system: when any $P_aCO_2$ / $[HCO_3^-]$ pair is plotted on the grid, the $[H^+]$ can be determined by geometric means alone!

- ........"that's very cool!"

## The Physiometric Acid-Base Triangle



$$[H^+] = 24 \times \frac{P_aCO_2}{[HCO_3^-]}$$

$$pH_a = 9 - \log_{10}[H^+]$$

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Arterial carbon dioxide tension ($P_aCO_2$) in torr

Bicarbonate ion concentration ($[HCO_3^-]$) in milliequivalents per Liter

Hydrogen ion concentration ($[H^+]$) in nanomoles per Liter

## Features of the Triangle

- the $P_aCO_2$ axis inclines to the right....

- ....increasing values for $P_aCO_2$ trigger rightward movement along the $[H^+]$ axis

- the $[HCO_3^-]$ axis inclines to the left....

- ....stepwise increases in $[HCO_3^-]$ will elicit leftward shifts along the $[H^+]$ axis
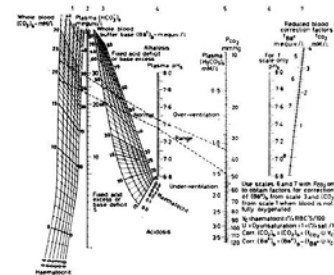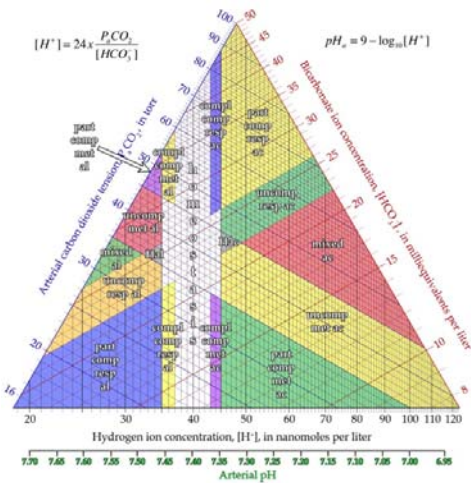
- acid-base balance rendered visible!

## Nomograms

- definition: "a graphical representation of numerical relations"

- Siggaard-Andersen acid-base nomogram

- Singer-Hastings acid-base nomogram

# Fun with the Diagrams

- it can be useful to assign sets of ABG data to students and have them apply the Acid-Base Triangle Diagram/Nomogram

- enhances their level of comfort with the concepts of acid-base

- augments their confidence in ABG interpretation

# Converting between [H⁺] and pH

$$pH_a = 9.00 - \log_{10} [H^+]$$

the devotees of Henderson need to communicate with the advocates of Hasselbalch

for example, if $[H^+]$ = 55 nM/L, pH = 9.00 - $\log_{10}$ 55

= 9.00 - 1.74 = 7.26

# Highly Precise Results

- limitations of a printed image preclude our ability to generate highly precise results

- but the preceding equation can be used to determine $[H^+]$ and/or pH to the second decimal place

- it's also a (far simpler!) substitute for the Henderson-Hasselbalch Equation

# What's Next?

- drafting tables and T-squares deployed at bedside?  We think not!

- the virtual drafting table(t)

- CLinIMApp™ software generates results on the iPad™ at the stroke of a key

- computers are servants....

- ....NOT masters!

## Summary

- the Tri-Axial concept was described almost eighty years ago....

- ....but it is yet to be widely applied at bedside

- hard-copy diagrams are cumbersome to apply, and lack the high degree of precision required of medical analytical tools

## Summary (cont'd)

- this situation is changing rapidly

- Medical Informatics technology is advancing

- portable computing platforms are plentiful and cheap

- students are now highly computer-literate

## Summary (cont'd)

- we are on the threshold of a new era of computer-assisted teaching and therapy

- the physiometric approach provides preceptors and their junior colleagues access to diagrammatic tools that can serve as powerful visual adjuncts

## Summary (cont'd)

- pictorial presentations of nebulous/arcane material can confer a visceral understanding

- their underlying equations can generate data as precise as we choose to make them

- caregiver teams that are well-versed in acid-base concepts constitute a win/win scenario!

## You Be the Judge!

- Q:  does the Acid-Base CLinIMApp constitute a paradigm shift?

- the Henderson Equation isn't new....

- ....nor is the nomogram a new concept....

- ....but an interactive nomogram which generates elements under computer control hasn't been previously described

- A:  to be supplied by users (....and the patent office)

## Thank You for Your Attention!

*visit "www.CLinIMApp.com" in order to apply the Acid-Base CLinIMApp to the ABG report(s) of your choosing*

*resources pertaining to this presentation can be accessed at "http://www.ambulatorypractice.org/education-research/respiratory-therapy-education/acid-base-clinimapp"*