Script for the educational video entitled "Understanding graphs, charts, tables and equations"

Slide 1

This educational video, entitled "Understanding graphs, charts, tables, and equations", was composed by Bob Demers.

Slide 2

This module is a so-called "Interactive video". You will need to view it on a system which provides both audio and video. At various points during the presentation, a chime will sound. At that point, viewers are required to highlight the words or phrases in their handout which correspond to the words/phrases which display in yellow text in the video images. Before we proceed with the video, viewers should ensure that they have a hard copy of the handout, a highlighter, and a straightedge. If any of these is not available, pause this video at this time in order to secure them. In addition, at various points during the screening of the video, viewers will be directed to interrupt it, in order to undertake specific psychomotor tasks. The signal for pausing will coincide with this sound effect [auto skid sound effect]. If viewing the video by means of a computer, the video can be paused simply by hitting the spacebar on the computer keyboard. Resumption of play will be enabled by hitting the spacebar a second time. If using an alternative category of video player, the viewer should use the pause/resume control which is integral to that player for interruption and resumption of play.

Slide 3

At the conclusion of this module, viewers should be able to:

1) define the term "rectilinear coordinate system";
2) accurately plot specific coordinates on this type of grid;
3) connect those scribed points by means of a straightedge;

Slide 4

4) enunciate the general formula for a straight line;
5) define the slope of a line;
6) determine the slope of the straight line scribed during the earlier exercise;

Slide 5

7) specify the so-called "y-intercept" of the scribed line;
8) state the formula which applies to the scribed line;
9) use that formula to solve two problems which will be assigned;

Slide 6

10) identify one advantage which can be attributed to the verbal mode of data presentation;
11) cite two advantages associated with the tabular mode of data presentation;
12) specify two advantages which relate to the use of charts and figures in data presentation;

Slide 7

13) list two advantages ascribed to the use of equations and formulas as a data presentation mode; and

14) specify a Universal Resource Locator, or "URL", which can be used to access the Acid-Base CLinIMApp™.

Slide 8

Graphs, charts, tables and equations are sprinkled liberally throughout the medical, allied health, and nursing literature. If practitioners hope to stay abreast of the literature pertaining to their respective specialties, they need to thoroughly understand these categories of data presentation.

Slide 9

Most viewers of this module will have had exposure to rectilinear coordinate systems earlier in their training. "X/Y grids" are commonly used in algebra, geometry, and trigonometry courses in most secondary schools. We are going to draw two points upon a previously-prepared grid of this type and draw a straight line through them. This exercise will serve as a "refresher" to most of us. Once that's done, we will ascertain the equation which applies to the particular line we've drawn.

Slide 10

Inspect the full-page graphic in the handout which matches this image. In a moment, you will plot the point "0,32" on the grid. By convention, the first digit (zero) corresponds to the "x" coordinate, that point on the horizontal axis which is located zero units away from the origin. The "origin" is defined as the place where the two axes intersect; in other words, the point where the value of both "x" and "y" is zero units. The second digit corresponds to the "y" coordinate, the point on the vertical axis located 32 units away from the origin, or "zero point". Consequently, (0,32) is located zero units to the right of the y-axis (which corresponds to the y-axis itself) and 32 units up from the horizontal axis. Pause the video now so that you can place a dot at the indicated position and, after you have done so, resume the video.

Slide 11

Your grid should look like this, with a dot at the location shown here. In a moment, you will plot an additional point on the grid, having the coordinates (100, 212). This point will be displaced one hundred units to the right of the vertical axis, and displaced 212 units above the horizontal axis. Pause the video now, place a dot at the prescribed point, and resume the video when that task is completed.

Slide 12

At this juncture, your grid should look like this, with two dots located at the positions shown here. In a moment, you will use your straightedge to draw a line through the two points you've scribed. Pause the video in order to do this and, after you've finished, restart the video.

Slide 13

Your grid should now look like this. If you haven't already done so, enter the numerical "x" and "y" values in their respective cells in the enclosed table.

Slide 14

Hearkening back to high school, most of us will recall that the general formula for any straight line is of the form y = mx + b, where "m" represents the slope of the line, and "b" constitutes its' "y-intercept".

Slide 15

The slope, or inclination, of a line describes its "steepness", and is defined as its' "rise" divided by its' "run". Stated another way, the slope is the ratio of its' vertical displacement to its' horizontal displacement. For our particular line, the rise is the final vertical displacement, 212, minus the initial vertical displacement, 32 (remember, the line didn't start out at zero on the y-axis). Consequently, the rise is 180 units. The corresponding run is the horizontal displacement of the second point, one hundred in this case, from which we subtract the horizontal displacement at the beginning, which is zero. For this line, the run is 100 units. This renders the slope of our line 180 units divided by 100 units, or 9/5. This numerical value is represented by "m" in the general formula.

Slide 16

As we will recall, "b" in the formula corresponds to the point at which the line crosses the y-axis. For this particular line, that point is 32, so "b" represents the numerical value 32 in the formula for our line.

Slide 17

In summary, the equation for this particular line reads "y = 9/5x + 32".

Slide 18

Now that the formula for this line is established, we can employ it to solve for any number of points on the line, even those which might lie well beyond the points depicted on our grid. In actuality, the line shown here is merely a small <u>segment</u> of a line which extends an infinite distance in either direction.

Slide 19

Let's use the equation to determine the value of "y" for an "x" coordinate which lies within the range of the line segment illustrated here; that value is 37.0. We can now apply the equation to determine the value of "y" and, since the value of "x" was listed to three significant figures, we can determine the "y" value to the same level of precision, 98.6.

Slide 20

If, perchance, you did not recognize the equation for our line from the three values listed, it corresponds to the formula relating Centigrade temperature readings to their corresponding

Fahrenheit readings: F = (9/5•C) + 32. Notice that the first term to the right of the equal sign is enclosed in parentheses, and should be read "the quantity nine-fifths times C". This is necessary so that users are informed that "C" must be multiplied by 9/5 before 32 is added.

Slide 21

In a moment, you will be asked to pause the video in order to complete two exercises. In the first exercise, you will employ the equation you've derived to determine the temperature at which the Centigrade reading is numerically identical to the Fahrenheit reading. At first blush, this might appear to be impossible, because we have a single equation and two unknowns. If you'll remember from your high school algebra course, in order to solve for a number of unknowns, our system of equations must consist of at least an equal number of independent equations. The key here, however, is the realization that one of the unknowns can be expressed as a function of the other. Specifically, we've been told that "C" and "F" are numerically identical, so the substitution of one for the other will allow us to solve for each. In the second exercise, we'd be well advised to rearrange the formula we initially derived such that "C" stands alone on the left side of the equation. Once that's been done, we need only substitute the Fahrenheit reading we've been given into that formula to solve it. Pause the video now and complete these two exercises, after which point the video will be restarted.

Slide 22

The answer to each exercise is shown here. Write these answers onto your handout, and highlight them for your future reference. You can access a step-by-step solution of these exercises by consulting the appendix to the script for this module, accessible at this URL.

Slide 23

Viewers might, either consciously or subliminally, be inclined to dispute the value of acquiring an understanding of graphs and equations. In the next few slides, we will examine two classic papers which describe a disorder which is commonly encountered clinically-- hypercapnia. Carbon dioxide retention is often observed in patients afflicted with chronic obstructive pulmonary disease (COPD), and also in infants who have sustained bronchopulmonary dysplasia (BPD) as a result of their management in the neonatal nursery. When hypercapnic patients present to practitioners, it is important that those clinicians be aware of the natural history of that disorder in order to assess the patient's current state, as well as to implement a therapeutic strategy that will elicit optimal results. A thorough clinical mastery of the physiology which underlies chronic, acute, and acute-on-chronic hypercapnic states is considerably enhanced through the use of graphs and equations.

Slide 24

To be sure, it's rather easy to qualitatively describe the effect of acute carbon dioxide retention on a patient's arterial hydrogen ion concentration, and its' correlate, arterial pH. In a nutshell, we can state that "as acute hypercapnia becomes more severe, hydrogen ion concentration will progressively increase". This is certainly a succinct and accurate statement. Regrettably, however, it conveys no information about the magnitude of change which we might expect, nor does it inform us whether the response will be linear or nonlinear.

Slide 25

In 1965, Brackett, Cohen and Schwartz published a paper describing a landmark clinical study that they had performed, wherein normal volunteers had breathed 7% and 10% carbon dioxide in order to examine the acid-base changes elicited by acute hypercapnia. This table lists the data points exhibited by the individual subjects, as well as the pooled data and the standard error of the mean for each parameter.

Slide 26

The table on the preceding slide is notable insofar as it provides the reader with very precise, quantitative results. Furthermore, the determination of the Standard Error allows us to ascertain the dispersion of each parameter around its' respective mean value. And, by grouping their data in columns, we are able to attribute each of the observed changes to the baseline condition which triggered it.

Slide 27

This figure was also an integral component of Brackett, Cohen, and Schwartz's paper. The data presented here is identical to the tabular data listed on Slide 25. But most readers would agree that presenting the data in the form of a graph renders it easier to understand the sequential changes which ensued during the progress of the clinical study.

Slide 28

One of the intrinsic virtues of a chart or figure is the ability of that form of data presentation to portray the magnitude of change in multiple variables. Figures can also depict the time course of change in empirically observed variables, such as was done here through the use of a "time" axis. In addition, the imposition of specific baseline conditions can be clearly displayed in diagrammatic form, as was done by Brackett and colleagues through the use of the "7% Carbon Dioxide" and "10% Carbon Dioxide" graphic elements.

Slide 29

Finally, Brackett and co-workers employed statistical tools in order to generate the so-called "line of best fit" pertaining to their data, demonstrating that the hydrogen ion concentration varies in linear fashion as a function of arterial carbon dioxide tension, when that variable is altered acutely. They proceeded to derive the formula for that line of best fit, and that formula is displayed on their figure.

Slide 30

Equations, such as the one derived empirically by Brackett, Cohen and Schwartz, can be invaluable for allowing clinicians to characterize the normal physiologic response of a universe of subjects. In other words, we are able to infer the behavior of , not merely individual subjects/ patients, but, indeed, the entire species, based on carefully collected data. Armed with that information, general physiologic laws can be enunciated which, when implemented within the clinical environment, enable caregiver teams to accurately identify patients on the basis of the initial presentation of those patients. For instance, if a patient presents to the Emergency Department with blood gas data that conform to that shown in the previous slide, the practitioner is entitled to infer that the patient is suffering from acute hypercapnia. In a few moments, we will see that man's physiologic response to either chronic or acute-on-chronic hypercapnia is fundamentally different than that shown in Slide 29. The diagrammatic depiction of the regression line also allows users to decide the degree to which the empirically observed data points conform to the regression line, whether the regression line is linear or nonlinear, and, if it is linear, the slope of the line. Admittedly, one of the shortcomings associated with any graphic is the limited precision attainable with geometric representations. Even diagrams which are painstakingly generated suffer from the inability of the viewer to determine the value of a data point to the first or second decimal place. Equations can yield data which mirror the precision of the raw data. For example, if the clinical lab provides us with a carbon dioxide tension value which is precise to the first decimal place, we will be able to validly ascertain the resultant hydrogen ion concentration to the tenth of a nanomole per liter. Perhaps the single biggest drawback associated with equations is the fear which they often elicit from clinicians. For whatever reason, medical, allied health, and nursing students typically vocalize apprehension if clinical educators employ equations when attempting to teach physiology.

Slide 31

Four years after Brackett co-authored the paper cited on Slide 25, he teamed up with three other physicians to examine man's response to chronic hypercapnia of increasing severity. This figure is analogous to that shown on Slide 29, but it also incorporates the findings of Brackett's team with respect to a separate subpopulation of patients-- those who presented with chronic carbon dioxide retention. By displaying the distinctly different response to chronic hypercapnia diagrammatically, the viewer is able to contrast man's fundamentally altered acid-base defense against CO_2 retention of long duration to hypercapnia of recent onset. The ability of caregivers to correctly discriminate between acute and chronic hypercapnia at the bedside can be crucially important, simply because the optimal therapeutic interventions usually employed for each category of patients differ vastly from one another. A patient who presents with straightforward chronic carbon dioxide retention is likely to benefit from conservative therapy, in the form of low-flow oxygen administration via a nasal cannula. This approach is decidedly different than that typically used to treat acute hypercapnia, inasmuch as patients of that type are usually treated rather aggressively, up to and including intubation and mechanical ventilation.

Slide 32

In their 1969 monograph, Brackett, Wingo, Muren and Solano portrayed the so-called "95% Confidence Bands" pertaining to their data. The use of a confidence band entitles practitioners to form an inference when confronted with actual patients. For example, if a given patient exhibits data that fall within the 95% Confidence Band derived by Brackett and colleagues, we can infer, with 95% confidence, that the patient is suffering from chronic hypercapnia, as opposed to acute or acute-on-chronic carbon dioxide retention. Here again, the ability to discriminate between those states allow knowledgeable clinicians to intelligently select the appropriate type of therapy based on solid clinical evidence.

Slide 33

Because a 95% confidence band must, by definition, embrace that percentage of the empirically generated data points, an inspection of the graphic shown earlier would necessarily imply that the 95% confidence band pertaining to chronic hypercapnia be wider than the counterpart confidence band for acutely hypercapnic subjects. This applies simply because the data points referable to chronic CO_2 retention are more widely scattered around their regression line than is the case with acute hypercapnia. The authors disclosed the dimensions of the 95% confidence bands in tabular fashion in their papers.

Slide 34

In this figure, I have taken the tabular results of the respective research teams and converted them to a graphic. The use of this figure can enhance one's ability to discriminate between acute, chronic, and acute-on-chronic hypercapnia quickly and easily. Note that, as predicted earlier, the 95% confidence band applicable to acute CO_2 retention is considerably narrower than its' chronic counterpart, owing to the more widely scattered data points observed in the latter category of patients. In this figure, I have scribed a horizontal and a vertical line corresponding to a hydrogen ion concentration of 50 nanomoles per liter and a carbon dioxide tension of 62 torr, respectively. It can be seen that these lines intersect within the yellow region labelled "compatible with acute-on-chronic hypercapnia". A patient presenting with those values would lead us to infer, with 95% confidence, that s/he had sustained an episode of acute-on-chronic hypercapnia which would, in turn, prompt us to: 1) employ conservative therapy; but 2) be prepared to intubate and mechanically ventilate the patient if his/her clinical condition were observed to deteriorate.

Slide 35

As convenient as a graphic such as that displayed on the previous slide might be, mobilizing a large-format hard-copy graphic to the bedside would be admittedly cumbersome and impractical. Happily, the advent of the "Digital Revolution" has rendered the use of diagrammatic aids to be surpassingly easy. High-resolution graphics, sophisticated algorithms, and powerful software are now, quite literally, at our fingertips, through the use of computers and so-called "smartPhones".

Slide 36

Consider this diagram, which incorporates the type of rectilinear grid we manipulated earlier in this module. On the vertical axis, a range of arterial CO_2 tensions between zero and ninety torr is depicted. On the horizontal axis, bicarbonate ion concentrations ranging between zero and 35 milliequivalents per liter are displayed. The homeostatic range for p_aCO_2 is shaded blue here, while the normal range for [HCO_3^-] is shaded red. In a moment, you will be asked to pause the video in order to place a legible mark at the coordinates (24, 38) on the full-page version of this grid which is incorporated in your handout. Turn to that page of your handout, and prepare to scribe the dot at the coordinates given. Pause the video now and restart it after you have completed that task.

Slide 37

Compare your diagram to that shown here. Notice where the point you have scribed resides. Observe that this data pair lies well within the homeostatic range for both [HCO_3^-] and p_aCO_2. In other words, this patient's blood gas data lie within the homeostatic range. Next, you will be asked to pause the video in order to place a mark at the coordinates (10, 50) on your grid. Pause the video now and restart it after you have completed that task.

Slide 38

Compare your grid to that shown here. Notice the location of the dot you have scribed. Observe that this data pair lies below the homeostatic range for [HCO_3^-] (which constitutes a metabolic acidemia), and above the upper limit of normal for p_aCO_2. (a respiratory acidemia). We would have no trouble classifying this condition as a mixed acidemia. Next, you will be asked to pause the video in order to place a mark at the coordinates (30, 20) on your grid. Pause the video now and restart it after you have completed that task.

Slide 39

Compare your grid to this one once again. Notice the location of the dot you have just scribed. This data pair lies above the homeostatic range for [HCO_3^-] (a metabolic alkalemia), and below the lower limit of normal for p_aCO_2. (a respiratory alkalemia). Hence, it classifies as a mixed alkalemia. Note that we need to know neither the [H^+] nor the pH in order to classify the acid-base status of the patients represented by the three data pairs that we have scribed thus far. Next, you will be asked to pause the video in order to place a mark at the coordinates (27, 80) on your grid. Pause the video now, and restart it after you have completed that task.

Slide 40

Once again, compare your grid to this one. The point which you have just scribed lies just above the homeostatic range for [HCO_3^-] (a mild metabolic alkalemia), and substantially above the upper limit of normal for p_aCO_2. (a moderate-to-severe respiratory acidemia). On this basis, we can anticipate that it will be classified as a partially compensated respiratory acidemia. In a moment, you will place a mark at the coordinates (29, 53) on your grid. Pause the video now, and resume it after you have completed that task.

Slide 41

Compare your grid to this diagram one last time. The point which you have just scribed lies just above the upper limit of normal for [HCO_3^-] (a mild metabolic alkalemia), and just above the upper limit of normal for p_aCO_2. (a mild respiratory acidemia). The position of this point makes it difficult to determine which is the primary component and which the compensatory. In order to definitively determine this, it would be useful to create a grid which displayed hydrogen ion concentration together with p_aCO_2 and $[HCO_3^-]$.

Slide 42

We are certainly not accustomed to portraying three variables, and three axes, simultaneously. Ever since we attended high school, we have been required to draw, manipulate, and inspect x-y grids, such as the one we considered on the previous six slides. But the presentation of three variables presupposes that we acquire the ability to chart three axes within a two-dimensional plane, which is clearly impossible...........or is it?

Slide 43

In point of fact, two researchers developed such a system way back in 1931. Hastings and Steinhaus described a graphical strategy which incorporates three axes, each oriented one hundred twenty degrees from the others. The scale marked out on the axes is logarithmic. Hence, successive gridlines are not equally spaced. Rather, each hashmark lies at a decreasing distance from the one which precedes it. In the following slide, we will "build" a tri-axial coordinate system.

Slide 44

The first (blue) axis will be used to identify the prevailing carbon dioxide tension. It is oriented 120 degrees from the horizontal. The second axis, colored red here, pertains to bicarbonate ion concentration. It is oriented 120 degrees clockwise from the first. The third axis, scribed in black, represents hydrogen ion concentration values. Because it lies 120 degrees from the last, it is 120+120+120, or 360 degrees from the horizontal, such that it is itself horizontal.

Slide 45

Notice that a set of lines which are perpendicular to each of their respective axes have been scribed. These lines are called "isopleths", and they constitute the locus of all points which pertain to their specific numerical value. When I solicited input from students with regard to this radial array of axes, they allowed that it was a bit too cluttered for their liking. This was a valid observation, so I was prompted to translate each axis outward from the central point in order to achieve spatial separation. The geometric figure which resulted was an equilateral triangle, which is depicted on the following slide.

Slide 46

A remarkable attribute of this diagram resides in its' ability to enable users to determine the unique hydrogen ion concentration value associated with any $p_aCO_2/[HCO_3^-]$ data pair by geometric means alone. We will demonstrate this trait on the next slide by plotting the point with the coordinates 53 torr and 29 mEq/L. Turn to the full-page version of this diagram in your handout. After you pause the video, draw a line over the isopleths that coincide with 53 torr and 29 mEq/L.

When you have done so, drop a line vertically from the point where those two isopleths intersect. When you have completed these tasks, restart the video.

Slide 47

Your diagram should look like this (your isopleths will probably all be the same color, but that's an unimportant difference). Now that we are provided with a hydrogen ion concentration axis, it is apparent that this particular $p_aCO_2/[HCO_3^-]$ data pair constitutes a completely compensated respiratory acidemia, because the prevailing $[H^+]$ value lies just below the upper limit of normal for that datum. This Acid-Base Triangle Diagram was subsequently modified to create an Acid-Base Triangle Map, which will be pictured on the following slide. The use of the map will facilitate the classification of any and all acid-base disorders that we might encounter clinically.

Slide 48

Examine the full-page copy of this figure incorporated in your handout. Notice that colors and labels have been added to various regions of the diagram, with each region representing a specific acid-base dysfunction. I have added a "pH" axis just below the triangle's base. By extending a vertical line through this axis, the pH value corresponding with a given $[H^+]$ value can be ascertained at a glance. In a moment, you will pause the video, and plot the same data pair as before. When that task has been completed, you will restart the video.

Slide 49

Your full-page counterpart of this map should display as shown here (you needn't worry if your isopleths are all the same color). Note that the point of intersection of the isopleths clearly lies within the blue region which bears the label "completely compensated respiratory acidemia". The prevailing $[H^+]$ value is revealed as being 44 nm/L, while the pH_a is observed to be 7.36 units. The $[H^+]$ and pH values have each been determined geometrically, and we have not explicitly employed any equations whatsoever. This statement is somewhat disingenuous, however, simply because the configuration of the Acid-Base Triangle Map itself is governed by a set of equations. A detailed explanation of the map can be accessed at the Universal Resource Locator shown here.

Slide 50

Hopefully, you have not found the psychomotor exercises in which you have been participating thus far to be excessively laborious. In various workshops conducted previously, some participants have even declared them to be "fun". Nevertheless, a steady diet of such manual chores would undoubtedly become onerous within a fairly short timeframe. Perhaps you would agree that it would be extremely convenient if we could identify a willing and dutiful minion to undertake these tasks on our behalf! Actually, this has been done. A computer application (or "app") has been created, whereby the steps which we have undertaken manually are implemented under computer control. This app, which bears the title "Acid-Base CLinIMApp™", is accessible at this URL. Anyone who has access to a browser can use the app, free of charge, and at any time. In the next slide, a screen capture video will depict the implementation of this app to a p_aCO_2 value of 30 torr and an $[HCO_3^-]$ level of 20 mEq/L.

Slide 51

The user launches the app by keying in the values for p_aCO_2 and $[HCO_3^-]$ embedded within the patient's ABG report. This particular data pair is uniquely associated with a hydrogen ion concentration of 36.0 nm/L and a pH value of 7.44.

Slide 52

Viewers who wish to explore the details of the diagrammatic approach described in the previous six slides are encouraged to consult the videos accessible at these URLs.

Slide 53

Up to now, we have been considering equations which are fairly straightforward. For instance, the general formula for a straight line involves merely three terms. But some of the mathematical relationships which govern other aspects of physiologic behavior can be formidably complex, to such an extent that their manual solution is too complicated, too tedious, and/or too time-consuming to warrant our attention. A suitable example of this is the mathematical expression which describes the oxyhemoglobin dissociation curve. Most of us have encountered this area of physiology at one or more points in our training, and are aware that the diagrammatic plot of oxygen tension versus oxygen saturation assumes the form of a sigmoid, or "S"-shaped, curve. The shape of this curve ensures that the equation by which it is governed is extremely complex. A British mathematician, G. Richard Kelman, derived a polynomial expression for the curve in 1966.

Slide 54

Note that this expression is comprised of no less than nine separate terms, and that the magnitude of each individual term is imposing. The coefficients for each term range between unity and 936,000! The manual solution of this equation, for just a single "% saturation" value, will necessarily involve some serious number-crunching!

Slide 55

To demonstrate this point, I have solved Kelman's equation for a p_aO_2 value of 100 torr here. Even though I chose an oxygen tension value which rendered computation easier than would have been the case if that value had not (conveniently) represented an integer power of ten, it took me fully eleven minutes to generate a solution! Of course, the performance of the requisite number of numerical operations is child's play for a digital computer.

Slide 56

In fact, the implementation of spreadsheet software which is available for virtually any computer can solve Kelman's equation in mere fractions of a second. The ability to generate a solution for a single point within such a short timeframe allows users to generate a long series of solutions within a time window which is practical in the clinical environment. This capability will enable us to ascertain multiple points along the oxyhemoglobin dissociation curve in rapid succession. On the following slide, a video loop will depict, in real-time, the solution of Kelman's equation for ninety separate data points. The rapidity by which the computer completes these repeated operations is striking.

Slide 57

This is a screen-capture video of spreadsheet software being used to calculate the percent saturation values for ninety individual data points, ranging from an oxygen tension of 100 torr down to 10 torr. The prevailing pH value, initially 7.27, will be changed to 7.40 units. This elicits changes in certain intermediate factors, and requires that the Kelman equation generate a new percent saturation value for each oxygen tension figure. This operation was repeated, or "iterated", for each of the ninety oxygen tension values. Observe the rapidity with which the equation was applied to each data point in succession. A total of ninety "percent saturation" values was generated within a time window of only 31 seconds. Hence, the computer completed each calculation of saturation in 344 milliseconds!

Slide 58

Another, supremely convenient, feature embodied within spreadsheet applications allows users to generate plots of computer-generated data at the stroke of a key. This implies that, once we've determined the x/y coordinates of a series of points, we will not be required to "connect the dots" through the use of a rigid French curve, a flexible French curve template, or any other manual drafting tools. The software will perform those tasks for us. The following slide will depict a computer-generated graphic of oxygen tension versus oxyhemoglobin saturation.

Slide 59

In this image, the oxyhemoglobin dissociation curve which is referable to both an arterial and a venous blood sample is pictured. The blood is oxygenated at the lung, wherein, in this example, the pH is 7.35 units, the p_aCO_2 is 40 torr, and the p_aO_2 is 100 torr. It is subsequently delivered to tissue, which is mildly acidotic in this hypothetical case, such that the pH falls to 7.26, the pCO_2 rises to 55 torr, and the pO_2 falls to 40 torr. The software has created the oxyhemoglobin dissociation curves which apply to both arterial and venous blood, enabling us to measure and illustrate these changes with accuracy and precision.

Slide 60

The changes pictured in the preceding slide are consistent with what we've been taught about the intrinsic tendency of the oxyhemoglobin dissociation curve to "shift", or change its' position, secondary to alterations in pH, p_aCO_2, and/or body temperature. Of course, the manner by which these shifts occur *in vivo* are dynamic, and take place within a very short timeframe. Because spreadsheet applications can perform computations quickly, as demonstrated in Slide 57, their power can also be exploited to scribe graphical representations of those mathematical manipulations just as rapidly. Consequently, they can furnish us with dynamically-generated graphics which simulate the changes taking place *in vivo* to an uncanny degree. In the following slide, the shift which would occur in an oxyhemoglobin dissociation curve secondary to a change in a single variable, pH, will be illustrated dynamically. In that video, I've chosen to decrease pH from 7.40 to 7.26 units. The oxyhemoglobin dissociation curve associated with the former pH will be scribed in red, while the curve referable to the latter will be scribed in blue.

Slide 61

The pH reading is changed from 7.40 to 7.26 in the uppermost cell on the left, which elicits changes in certain other cells within that row of the table. Then, by "dragging" the contents of that cell downward, the corresponding cells in those lower rows, including the percent saturation value, are sequentially recalculated. The software proceeds to plot those points as soon as they are generated, providing us with a view of an oxyhemoglobin dissociation curve which is shifting downward before our very eyes!

Slide 62

Those viewers who might want to drill down on the material contained in this video are encouraged to navigate to this URL. A fifty-minute video, entitled "Internal Respiration: A quantitative and illustrated review", explores these concepts in considerable depth.

Slide 63

In conclusion, practitioners need to understand data presented in forms other than the printed word if they hope to be discerning readers of the medical, allied health, and nursing literature. Graphs, charts, tables and equations can be used to great advantage by authors in conveying a comprehensive explanation of clinical concepts and principles. The proliferation of digital computers within the clinical environment, and society in general, in recent years has enhanced our ability to generate, assimilate and present data. We would do well to expoit these valuable tools in order to enhance our clinical skills inventories.

References:

1. Brackett NC Jr, Cohen JJ, Schwartz W. Carbon dioxide titration curve of normal man. **New Engl J Med** 1965; 272: 6-12.

2. Brackett NC Jr, Wingo CF, Muren O, Solano JT. Acid-base response to chronic hypercapnia in man. **N Engl J Med** 1969; 280: 124-131.

3. Hastings AB, Steinhaus AH. A new chart for the interpretation of acid-base changes and its' application to exercise. **Am J Physiol** 1931; 96: 538-540.

4. Kelman GR. Digital computer subroutine for the conversion of oxygen tension into saturation. **J Appl Physiol** 1966; 21: 1375-1376.

Appendix:

On Slide 22 of the video, we were asked to determine the temperature at which the Centigrade and Fahrenheit readings are numerically equal. To do this, we begin with the equation:

$$F = (9/5\ C) + 32$$

This represents a system of one equation in two unknowns, which is not solvable. However, the condition which requires that the numerical value of both the Centigrade and Fahrenheit readings be equal allows us to substitute "F" for "C", such that:

$$F = (9/5\ F) + 32$$

We now have a system of one equation in one unknown, which is amenable to solution. Subtracting "F" (or its' equivalent, " 5/5 F") from either side of the equation yields:

$$0 = (4/5 \bullet F) + 32$$

Next, we subtract 32 from either side of the equation, which yields:

$$-32 = 4/5 \bullet F$$

This result prompts us to multiply either side of the equation by 5/4 in order to generate a value for "F" itself:

$$(5/4) \bullet (-32) = F$$

and

$$-40 = F$$

It's always a good idea to check one's work, and we can do this easily by substituting this numerical value into our original equation, which, as you'll recall, read F = (9/5C) + 32:

$$-40 = (9/5 \bullet [-40]) + 32$$

which reverts to:

$$-40 = (-72) + 32$$

or

$$-40 = -40$$

and our solution is verified as being corrrect.

The second exercise posed on Slide 22 required us to convert the temperature 68° F to its' corresponding Centigrade reading. To undertake this task, we are well advised to rearrange the formula "F = (9/5C) + 32" to a form where "C" stands alone on one side of the equation. The first step of this process consists of subtracting "32" from either side of the equation:

$$F - 32 = 9/5\ C$$

Notice that "9/5 C" appears on the right-hand side of the equation, whereas we want that term to read "C" itself (that is, "1.0 C"). That can be accomplished easily by multiplying each term on either side of the equation by the fraction "5/9":

$$5/9 \bullet (F - 32) = 5/9 \bullet (9/5\ C)$$

or, its' equivalent:

$$5/9 \bullet (F - 32) = C$$

The equation is now in a form which renders it easy to convert any Fahrenheit temperature into its’ corresponding Centigrade temperature. In our particular case, the Fahrenheit reading is 68 degrees, which leads us to insert that numerical value into the equation:

$$C = 5/9 \bullet (68 - 32)$$

or

$$C = 5/9 \bullet (36)$$

which reverts to

$$C = 180 \ / \ 9 = 20.0$$

Hence, a room temperature of 68° Fahrenheit coincides with a temperature of 20° Centigrade.

Once again, if we wish to check our work, we can do so by substituting these numerical values into our initial equation.