



INTERDISCIPLINARY LIVELY APPLICATIONS PROJECT

AUTHORS:

Jodye I. Selco (Chemistry)
jodye_selco@redlands.edu

Janet L. Beery (Mathematics)
janet_beery@redlands.edu

University of Redlands
Redlands, CA

EDITOR:

David C. Arney

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Saving a Drug Poisoning Victim

MATHEMATICS CLASSIFICATIONS:

Calculus, Differential Equations, Mathematical Modeling

DISCIPLINARY CLASSIFICATIONS:

Chemistry, Biology, and Medicine

PREREQUISITE SKILLS:

Exponential growth and decay, Euler's method or other numerical method for solving systems of differential equations

PHYSICAL CONCEPTS EXAMINED:

Kinetics of drug uptake and elimination

MATERIALS INCLUDED:

TrueBASIC programs

COMPUTING REQUIREMENTS:

Numerical differential equations solver, spreadsheet, computer algebra system, or any computer programming language

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1. Setting the Scene

You are a physician in a hospital emergency room. A child has just been brought to the emergency room by a frantic parent. The parent takes the asthma medication theophylline in tablet form. Two hours before arriving at the hospital, the child ingested eleven 100-mg theophylline tablets. Like most oral drugs, theophylline is absorbed into the bloodstream at a rate proportional to the amount present in the gastrointestinal tract (stomach and intestines) and is eliminated from the bloodstream at a rate proportional to the amount present in the bloodstream.

Your quick check of the *Physician's Desk Reference (PDR)* [1999] reveals that the brand of theophylline that the child took has an absorption half-life of 5 hours and an elimination half-life of 6 hours. The *PDR* also warns that a blood-level concentration of 100 mg/L or more of the drug is seriously toxic and that a concentration of 200 mg/L or more is fatal.¹

You estimate that the child has 2 L of blood. You also determine that because of the 2-hour delay, the pills already have passed from the child's stomach to his intestines, so that it is too late to eliminate the drug by inducing vomiting. Your task is to determine if the child is in danger, and, if so, to save his life.²

2. Building a Model

You are interested in the amount of theophylline in the child's bloodstream over time. (Actually, you are concerned about the *concentration* of theophylline in the child's bloodstream over time; but since the amount is slightly easier to

¹These values are the concentrations at which 50% of the patients exhibit these symptoms. In the fatal case, the concentration of 200 mg/L—the lethal concentration for 50% of the population—is called the LC_{50} value.

²In reality, a physician in this situation would contact the local poison center, which would provide information about which symptoms to watch for as well as the appropriate medical treatment.



Figure 1. Compartment model for theophylline.

calculate than the concentration and since you can convert easily from one to the other, you decide to calculate the amount.)

To determine the amount over time, you also need to determine the amount of theophylline still in the child's gastrointestinal tract over time. You could calculate also the amount of theophylline eliminated from the bloodstream; however, since theophylline in this form is not dangerous, you decide not to keep track of the eliminated drug. The compartment model in **Figure 1** illustrates the progress of the drug through the child's body.

Requirement 1: First, predict the general shape of the graph of $G(t)$, the amount of theophylline in the child's gastrointestinal tract (in mg) after t (in hours), and of the graph of $B(t)$, the amount of theophylline in the child's bloodstream (in mg) after t hours. Using time $t = 0$ as the time at which the child first ingested the theophylline, make separate rough sketches of the graphs of $G(t)$ and $B(t)$. On each graph, label the point at $t = 0$. (If $t = 0$ is the time when the child first ingested the theophylline, what are the corresponding values for G and B ?) Remembering that the half-life for absorption of theophylline from the gastrointestinal tract into the bloodstream is 5 hours, label the points at $t = 5$ and $t = 10$ on your graph of $G(t)$. You need not label any other points on the graphs or mark any other values along their axes—yet.

Requirement 2: Since you have more information about the rates of change of G and B than about G and B themselves, you decide to model the quantities G and B by writing equations for their rates of change (differential equations). Begin with the differential equation for G . Theophylline is absorbed into the bloodstream at a rate proportional to the amount present in the gastrointestinal tract. This means that theophylline is *leaving* the gastrointestinal tract at a rate proportional to the amount of the drug present there. Hence, taking k to be the positive constant of proportionality, you have

$$\frac{dG}{dt} = -kG \text{ mg/h}, \quad G(0) = 1100 \text{ mg}.$$

Use what you know about initial value problems of this form, along with the fact that the absorption half-life of theophylline is 5 hours, to write a formula for $G(t)$, the amount of theophylline (in mg) in the gastrointestinal tract at time t . (That is, solve the initial value problem for $G(t)$, then solve for k . Record k to four decimal places.) You now should have both a formula for $G(t)$ and a differential equation for G in which k has a numerical value.

Requirement 3: Now write a differential equation for B . Since theophylline is entering the bloodstream at one rate and leaving it at another rate, the differential equation for B is of the form

$$\frac{dB}{dt} = \text{absorption rate} - \text{elimination rate},$$

with units of mg/h.

Consider the first term, the absorption rate. Recall that theophylline is absorbed into the bloodstream at a rate proportional to the amount present in the gastrointestinal tract with an absorption half-life of 5 hours. This should sound familiar; use your work from **Requirement 2** above to write an expression for the absorption rate.

Now consider the second term, the elimination rate. Remember that theophylline is eliminated from the bloodstream at a rate proportional to the amount present in the bloodstream with a half-life of 6 hours. In order to find the constant of proportionality, assume that at some (future) time t_1 there is 20 mg of theophylline in the bloodstream and that no additional theophylline is entering the bloodstream—that is, assume for the moment that

$$\frac{dB}{dt} = - \text{elimination rate}, \quad B_1(t) = 20 \text{ mg}.$$

Under these assumptions, the amount of theophylline in the bloodstream is decaying exponentially. Use what you know about exponential decay to write an expression for the elimination rate. (Record the constant of proportionality to four places after the decimal point.)

You now should have a differential equation for B involving the variables G and B .

3. Using the Model

Now that you have differential equations for G and for B , you are ready to use them to determine if the child is in danger and, if so, how to treat him.

Unlike for the differential equation for G , there is not a simple closed-form solution for the differential equation for B . That is, you may not be able to write an explicit formula for $B(t)$ but instead may have to approximate values of $B(t)$ using Euler's method or another numerical method for solving differential equations. Your instructor will specify the degree of accuracy (number of significant figures) for your calculations.

Requirement 4: Determine the amount of theophylline in the child's bloodstream at the time of his admission to the hospital, $t = 2$ hours. Recalling that the child has 2 L of blood and that a blood-level concentration of 200 mg/L or more of the drug is fatal, what amount of theophylline in his bloodstream,

in mg, constitutes a lethal level for the child? Recalling that a blood-level concentration of 100 mg/L or more is seriously toxic, what amount constitutes a seriously toxic level for the child? What is his status at the time of his admission to the hospital? Does the amount of theophylline in his bloodstream pose any danger to him at this time?

Determine the toxic and lethal amounts of theophylline in the bloodstream for an adult with 6 L of blood.

Requirement 5: Determine the amount of theophylline in the child's bloodstream over several hours. Graph your results.

Does the amount of theophylline in his bloodstream ever reach a lethal level for the child? If so, after how many hours? How many hours after the child's hospital admission does this occur? Mark the lethal level and the time at which it occurs on your graph.

After how many hours does the amount of theophylline in the child's blood reach a seriously toxic level? How long before or after his hospital admission does this occur?

Requirement 6: Determine the largest amount of theophylline the child ever has in his bloodstream, and the time at which this maximum level occurs. How much theophylline remains in his gastrointestinal tract at this time?

The largest value for B occurs when $dB/dt = 0$ (why?) or, equivalently, when the absorption rate is equal to the elimination rate (why?). When you substitute your largest value for B and your corresponding value for G into your equation for dB/dt , do you get 0? Explain why you might not get 0.

Requirement 7: Determine the maximum number of theophylline tablets the child could have taken in a short interval without reaching the lethal blood-level concentration. Explain. How many could he have taken without reaching the seriously toxic blood concentration? Explain.

4. Saving the Child

Your results from **Requirements 5–7** should have shown that the child who ingested the 11 theophylline tablets is in grave danger. What can be done?

Fortunately, charcoal absorbs theophylline quickly, so it can be used to increase the rate at which theophylline is eliminated from the bloodstream. For toxic levels of theophylline, the patient takes oral doses of charcoal, increasing the theophylline elimination rate to approximately twice the normal rate.

For potentially fatal levels of theophylline, charcoal must be added to the bloodstream extracorporeally (outside the body) in order to remove the theophylline quickly enough. This procedure is risky but may increase the theophylline elimination rate to six times the normal rate, according to the *Physicians*

Desk Reference [1999].³

Requirement 8: In **Requirement 3**, you expressed the rate of change of B as the difference between the absorption rate and the elimination rate. Since it is too late to change the rate of absorption from the gastrointestinal tract, you must change the elimination rate, which you have expressed as $-cB$ mg/h. Find the smallest value for the constant c that ensures that the concentration of theophylline in the child's bloodstream remains below the lethal level. For instance, would increasing c to 0.1200 suffice? What about $c = 0.1300$?

Warning: Since you have an opportunity to increase the value of c only after the child has been admitted to the hospital, be sure to begin your calculations with larger values of c at the time of admission.

To be safe, continue to increase c until you find the smallest value that causes the amount of theophylline in the child's bloodstream to decrease immediately upon treatment. Assume that treatment is administered exactly at the time of hospital admission. Sketch or print a graph of the amount of theophylline in the child's bloodstream from the time he ingests the pills to a few hours after his hospital admission and treatment. Your graph should show the effect of treatment on the child's theophylline blood level.

Without any further computer work, you could have determined the smallest value for c that causes the amount of theophylline in the child's bloodstream to decrease immediately upon treatment. Explain how. (Hint: See **Requirement 6**, second paragraph.)

Recall that you could have doubled the theophylline elimination rate by administering oral doses of charcoal. Would this treatment have been sufficient to cause an immediate decrease in the child's theophylline blood level? Explain. Remember that you can increase the elimination rate to six times the normal rate by filtering the blood through charcoal extracorporeally. Do you need to increase the elimination rate this much in order to cause an immediate decrease in the child's theophylline blood level? Explain.

References

The problem presented in the **Setting the Scene** section appeared in slightly different form in a physical chemistry textbook [Bromberg 1984, 905]. The tablet size and absorption and elimination half-lives appeared in the original problem statement and are consistent with the *Physician's Desk Reference* [1999] listings for various brands of theophylline tablets. Treatment methods for theophylline overdose are described in both the *Physician's Desk Reference* and the *Physician's Desk Reference Generics* [1998]. Some of the questions posed above were inspired by the development of the susceptible-infected-recovered (S-I-R) model for the

³Since the lethal concentration represents the response of 50% of the population and dialysis is both a dangerous and expensive, the physicians would resort to such drastic treatment only if the patient would not survive without it.

spread of an epidemic in the textbook *Calculus in Context* [Callahan et al. 1995, 1–69]. In particular, the True BASIC computer programs provided to your instructor were adapted from that textbook. The graphs provided to your instructor were created using the Excel spreadsheet program.

Bromberg, J. Philip. 1984. *Physical Chemistry*. 2nd ed. Boston: Allyn and Bacon.

Callahan, James, Kenneth Hoffman, et al. 1995. *Calculus in Context*. New York: W.H. Freeman.

Physician's Desk Reference. 1999. 53rd ed. Montvale, NJ: Medical Economics Co. See, for instance, pp. 875–878, 1457–1471, 2563–2569, 2607–2609, and 3164–3170.

Physician's Desk Reference Generics. 1998. 4th ed. Montvale, NJ: Medical Economics Co. See pp 2620–2633, especially pages 2626–2627.

Acknowledgments

The authors thank the staff at Redlands Community Hospital and the Southern California Poison Center for medical information.

Title: Saving a Drug Poisoning Victim

Sample Solution

Requirement 1: Although the graphs of $G(t)$ and of $B(t)$ should be sketched by hand on separate sets of axes, they should have essentially the shapes shown in **Figure S1**. The points $(0, 1100)$, $(5, 550)$, and $(10, 275)$ should be labeled on the graph of $G(t)$; the point $(0, 0)$ should be marked on the graph of $B(t)$. Students will have the opportunity to verify their predictions after they set up differential equations for G and for B .

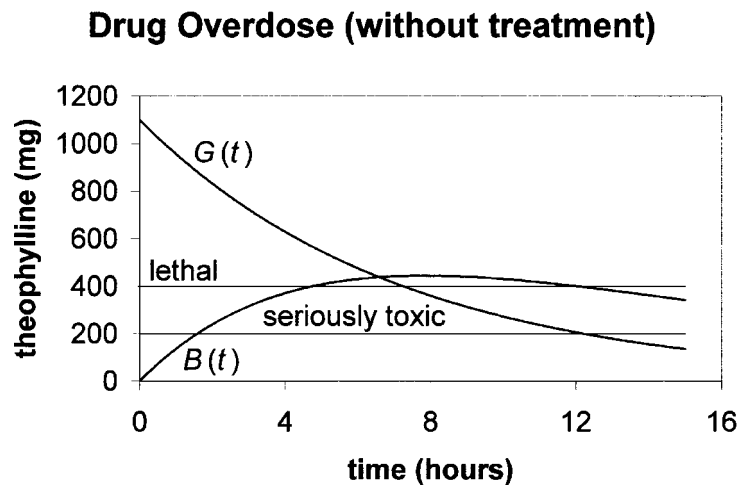


Figure S1. Graphs of $G(t)$ and $B(t)$.

Requirement 2: Students should recognize the differential equation for exponential decay and write $G(t) = 1100e^{-kt}$ mg. They then should use that $G(5) = 550$ mg to solve for k , obtaining $k = (\ln 2)/5 \approx 0.1386$. The formula for $G(t)$ then is $G(t) = 1100e^{-0.1386t}$ mg. The initial value problem for $G(t)$ is

$$\frac{dG}{dt} = -0.1386G \text{ mg/h}, \quad G(0) = 1100 \text{ mg}.$$

Requirement 3: The absorption rate is given by the expression $0.1386G$ mg/h from **Requirement 2**. To find an expression for the elimination rate, we assume that

$$\frac{dB}{dt} = -cB \text{ mg/h}, \quad B(t_1) = 20 \text{ mg},$$

yielding $B(t) = 20e^{-ct}$ mg. Students then should use $B(t_1 + 6) = 10$ mg to solve for c , obtaining $c = (\ln 2)/6 \approx 0.1155$. The elimination rate then is given by the expression $-0.1155B$ mg/h, and the initial value problem for $B(t)$ is

$$\frac{dB}{dt} = 0.1386G - 0.1155B \text{ mg/h}, \quad B(0) = 0 \text{ mg}.$$

Students may conjecture a solution to this initial value problem of the form

$$B(t) = \mp 1100e^{-0.1386t} \pm B_0e^{-0.1155t}$$

and should be encouraged to check to see that this is not a correct solution. A correct solution, obtained by matrix methods, is

$$B(t) = -6600e^{-0.1386t} + 6600e^{-0.1155t}.$$

Although this project could be modified to incorporate this analytic solution, we assume that students will solve the differential equation(s) numerically.

Requirement 4: Answers are given to 4 significant figures. (Please see the note on **Accuracy of Solutions** in the **Notes for the Instructor**.)

Applying Euler's method with a step size of $\Delta t = 0.0001$ to the initial value problem

$$\begin{aligned} \frac{dG}{dt} &= -0.1386G \text{ mg/h}, & G(0) &= 1100 \text{ mg}, \\ \frac{dB}{dt} &= 0.1386G - 0.1155B \text{ mg/h}, & B(0) &= 0 \text{ mg} \end{aligned}$$

yields $G(2) = 833.7$ mg and $B(2) = 236.5$ mg. Computing $G(2)$ using the formula for $G(t)$ yields $G(2) = 833.7$ mg. One also could use the formula for $G(t)$ to compute the values of G needed in the equation for dB/dt during the Euler's method computations.

The VALUE program listed in the **Appendix** is set up to approximate $G(2)$ and $B(2)$ using Euler's method with a step size of $\Delta t = 0.1$ (20 steps) and can be modified to perform the calculation with $\Delta t = 0.0001$ (20,000 steps).

Since the child has 2 L of blood, a lethal blood level of theophylline for him would be 400 mg, well above his current 236.5-mg blood level. However, only 200 mg would constitute a seriously toxic blood level for him, and his current 236.5-mg blood level already is in the seriously toxic range.

For the adult with 6 L of blood, 600 mg would be seriously toxic, while 1200 mg would be fatal.

Requirement 5: By computing values of B from $t = 0$ to approximately $t = 10$, students can see that the amount of theophylline in the bloodstream increases and then decreases, and that it does eventually exceed the lethal level (**Figure S1**). The amount of theophylline in the bloodstream reaches $B = 400.0$ mg after $t = 4.866$ h (2.866 h after the child's admission to the hospital), and $B = 200.0$ mg after $t = 1.609$ h (approximately 23 min, 28 sec before the child's hospital admission).

By changing t_{final} to 10 or more hours in the VALUE program, students can see that B increases and then decreases, and that it does eventually exceed 400 mg. Running the PLOT program illustrates this behavior even more clearly. To determine how many hours it takes for B to reach the lethal level of 400 mg,

students may use the DOWHILE program. Running the DOWHILE program with $\Delta t = 0.0001$ yields $B = 400.0$ mg after $t = 4.866$ h, and $B = 200.0$ mg after $t = 1.609$ h.

Requirement 6: A step size of $\Delta t = 0.0001$ yields $G = 368.4$ mg and $B = 442.1$ mg after $t = 7.893$ h. Note that $B = 442.1$ mg exceeds the child's lethal level of 400 mg.

Substituting $G = 368.4$ and $B = 442.1$ into the equation for dB/dt yields $dB/dt = 0.0023$, indicating that our solution technique is approximate rather than exact and/or that round-off error has occurred. Students may use the formula for $G(t)$ to obtain the value of G at the time at which the largest amount of theophylline in the child's bloodstream occurs or to check the accuracy of their numerical approximations. Computing $G(7.893)$ using the formula for $G(t)$ yields $G = 368.4$ mg.

Requirement 7: If the child had taken only 9 tablets ($G(0) = 900$ mg), the largest amount of theophylline in his bloodstream would have been 361.7 mg ($\Delta t = 0.0001$), which is below the lethal level. If he had taken only 4 tablets, his highest blood level of the drug would have been 160.8 mg; 10 tablets and 5 tablets, respectively, would have resulted in maximum blood levels of just over 400 mg and 200 mg. These computations can be made by changing the initial value for G in the DOWHILE program.

Requirement 8: Starting at the time of hospital admission ($t = 2$ h), students should increase c . They may need to use that $G(2) = 833.7$ mg and $B(2) = 236.5$ mg from **Requirement 4**. Students who did not record $G(2)$ in **Requirement 4** can compute $G(2)$ easily from their formula for $G(t)$.) Using $c = 0.1442$ results in a maximum value for B of $B = 399.9$ mg, whereas using $c = 0.1441$ results in a maximum value for B of $B = 400.0$ mg.

Using $c = 0.4833$ results in a maximum value for B of $B = 236.5$ mg, whereas using $c = 0.4832$ results in a maximum value for B of $B = 236.6$ mg. Or students may notice that using $c = 0.4886$ results in the maximum value for B of $B = 236.5$ mg occurring at time $t = 2.000$ h, whereas using $c = 0.4885$ results in the maximum value for B occurring when $t = 2.001$ h. These results can be obtained by using a step size of $\Delta t = 0.0001$ and initial values of $G = 833.7$ mg and $B = 236.5$ mg in the DOWHILE program.

A graph showing the effect of treatment on the child's theophylline blood level is shown in **Figure S2**.

Note that B decreases when $dB/dt < 0$, or, equivalently, when the elimination rate is greater than the absorption rate. If we set

$$\frac{dB}{dt} = 0.1386G - cB = 0$$

at time $t = 2$, we obtain $(0.1386)(833.7) - c(236.5) = 0$, so that $c = 0.4886$.

Since $2 \times 0.1155 = 0.2310 < 0.4833$, administering oral doses of charcoal would not have been sufficient to cause the child's theophylline blood level to

decrease immediately. Since $6 \times 0.1155 = 0.6930$, we did not need to increase the elimination rate by six times the normal rate in order to cause B to decrease immediately. In fact, our value for c is approximately 4.2×0.1155 .

Drug Overdose (with treatment)

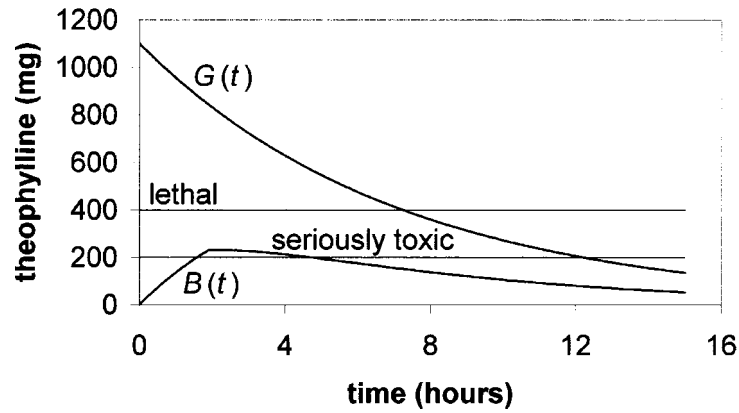


Figure S2. Effect of treatment on the theophylline blood level.

Title: Saving a Drug Poisoning Victim

Notes for the Instructor

Suggested Course Use

This ILAP was designed for a calculus course in which students learn Euler's method. It also would be appropriate for a differential equations course or a mathematical modeling course and perhaps even for very ambitious pre-calculus students. Briefly, the ILAP is a differential equations modeling project in which students, posing as hospital emergency room physicians, save a child who has accidentally overdosed on asthma medication. They begin by setting up a system of linear first-order differential equations (DEs) describing the medication's absorption into and elimination from the child's bloodstream. By solving the differential equations numerically, students discover that the child almost certainly will die if they, as physicians, do not intervene. They then determine by how much they need to increase the drug's elimination rate in order to save the child.

The Model

Problems involving drug absorption and elimination appear in many calculus texts, especially "reform" texts, among collections of mixing problems. What distinguishes this problem from any that we have seen in a calculus text is our assumption that the absorption rate is proportional to the amount yet to be absorbed, rather than constant, as it is in standard mixing problems. Specifically, our differential equation for the amount y of the drug in the bloodstream is of the form

$$\frac{dy}{dt} = ax - by,$$

where a and b are constants and x is the amount yet to be absorbed, rather than of the form

$$\frac{dy}{dt} = a - by.$$

The latter DE has a closed-form solution, easily found by separating variables. Assuming the DE for $x(t)$ to be of the same form as that for $y(t)$, a closed-form solution for the former DE can be found using matrix methods. Although this project could be adapted to incorporate analytic rather than numerical solutions, we assume that students will solve the differential equations numerically.

Computing Requirements

To complete the project, students need technology to implement Euler's method or another numerical method for solving systems of differential equations, such as a spreadsheet program, computer algebra system, differential equations solver, or virtually any computer programming language, including that available on a graphing calculator. The project also can be adapted for use with a computer algebra system or other differential equations solver capable of providing analytic solutions to systems of linear first-order differential equations.

One of the authors has her calculus students complete the project by modifying True BASIC programs set up to analyze a Lotka-Volterra predator-prey population model using Euler's method. True BASIC programs set up to analyze this ILAP's drug uptake and elimination model using Euler's method are provided in the **Appendix**.

Accuracy of Solutions

The instructor should specify the number of significant digits to which students are to work, based on such considerations as software speed. We assume that the tablet weights and the absorption and elimination half-lives given in **Setting the Scene** are exact—or at least are accurate to the number of significant digits the instructor specifies. For instance, when we give answers in the **Sample Solution** accurate to 4 significant figures, we assume that the absorption half-life is 5.000 hours.

Title: Saving a Drug Poisoning Victim**Appendix: True BASIC Computer Programs**

```
!Program VALUE (True BASIC)
```

```
!Program uses Euler's method to estimate values of G and B
!tfinal hours from start.
```

```
LET tinitial = 0
LET tfinal = 2
PRINT " t"," G"," B"
LET t = tinitial
LET G = 1100
LET B = 0
PRINT t, G, B
LET Gprime = - 0.1386*G !Compute G', B' for t = 0.
LET Bprime = 0.1386*G - 0.1155*B
LET numberofsteps = 20
LET deltat = (tfinal-tinitial)/numberofsteps
FOR k = 1 TO numberofsteps
    LET deltaG = Gprime*deltat
    LET deltaB = Bprime*deltat
    LET t = t + deltat
    LET G = G + deltaG
    LET B = B + deltaB
PRINT t, G, B
    LET Gprime = -0.1386*G
    LET Bprime = 0.1386*G - 0.1155*B
NEXT k
!PRINT t, G, B !Use for larger numbers of steps.
END
```

```
!Program PLOT (True BASIC)
```

```
!Program uses Euler's method to plot graphs of G and B together.
!Program also plots horizontals at 200 mg toxic
!and 400 mg lethal doses.
```

```
SET WINDOW 0, 36, 0, 1100
LET tinitial = 0
LET tfinal = 36
```

```

LET t = tinitial
LET G = 1100
LET B = 0
LET numberofsteps = 3600
LET deltat = (tfinal-tinitial)/numberofsteps
FOR k = 1 TO numberofsteps
  LET Gprime = -0.1386*G
  LET Bprime = 0.1386*G - 0.1155*B
  LET deltaG = Gprime*deltat
  LET deltaB = Bprime*deltat
  PLOT t, G
  PLOT t, B
  PLOT t, 200
  PLOT t, 400
  LET t = t + deltat
  LET G = G + deltaG
  LET B = B + deltaB
NEXT k
END

```

!Program DOWHILE (True BASIC)

!Determines when amount of drug in bloodstream reaches 400 mg,
!or when amount of drug in bloodstream peaks.
!Plots both graphs up to point of interest.
!Uses Euler's method.

```

SET WINDOW 0, 20, 0, 1200
LET tinitial = 0
LET t = tinitial
LET G = 1100
LET B = 0
LET Gprime = -0.1386*G    !Compute G', B' for t = 0.
LET Bprime = 0.1386*G - 0.1155*B
LET deltat = 0.01
DO WHILE B < 400          !We'll stop when B = 400 (or when B > 400).
!DO WHILE Bprime > 0     !We'll stop when B' = 0 (or when B' < 0).
!This is the beginning of the DO-WHILE loop.
  LET deltaG = Gprime*deltat
  LET deltaB = Bprime*deltat
  LET t = t + deltat
  LET G = G + deltaG
  LET B = B + deltaB
  PLOT t, G
!To make program run faster,

```

```
PLOT t, B                                !hide these PLOT commands.
LET Gprime = -0.1386*G
LET Bprime = 0.1386*G - 0.1155*B
LOOP                                     !This is the end of the DO-WHILE loop. Just
                                         !like NEXT k, it sends the computer back up
                                         !to the top of the loop.
PRINT "t ="; t,"G ="; G,"B ="; B
END
```

About the Authors

Jodye Selco, professor of chemistry at the University of Redlands since 1987, earned her B.S. in chemistry from the University of California, Irvine, in 1979 and her Ph.D. in chemistry from Rice University in 1984. She is a physical chemist specializing in spectroscopy (meaning that she uses a lot more mathematics than other chemists!). She enjoys performing her Chemistry Magic Show at local schools, star-gazing, growing all her own vegetables, and making long commutes on the Southern California freeways.

Janet Beery, professor of mathematics at the University of Redlands since 1989, earned her B.S. in mathematics and English literature from the University of Puget Sound in 1983 and her Ph.D. in mathematics from Dartmouth College in 1989, specializing in permutation group theory. She has a new-found interest in history of mathematics and currently is writing historical modules with high school teachers. Since her undergraduate days, she has enjoyed reading novels without having to write papers about them, as well as traveling to rainy locales.

Jodye Selco and Janet Beery both enjoy teaching with technology, writing and assigning classroom projects, and helping students discover ideas for themselves.