

CHAPTER 1



How Many Calories Should You Eat Each Day?

A FEW YEARS AGO, I used to love going to a chain restaurant—let’s call it “Tuscan Fields”—and ordering my favorite dish: fettuccine alfredo. The creamy, cheesy sauce smothering warm strips of fettuccine noodles did it for me, a self-confessed carb lover. I loved the dish so much that at one point I was eating at Tuscan Fields twice a month and making the dish at home. One day I spotted the restaurant’s nutritional information pamphlet while waiting for a table. I knew there was nothing in there but bad news. I wanted to continue living my delusion. But I couldn’t; I had to know. On page 3 I got the news—the fettuccine alfredo had 1,100 calories and 41 grams of saturated fat!

I was shocked. Every doctor I’ve had has urged me to keep my daily saturated fat intake under 10 grams. They didn’t give me a daily calorie limit to go along with that recommendation, but I was pretty sure that 1,100 calories was too much for one meal. That got me thinking: How many calories should I be eating, anyway? What foods should I avoid, and which ones should I eat more of? There are probably thousands of books on diet, nutrition, and exercise out there that address these questions. But read through the research studies mentioned in their bibliographies and you’ll quickly notice something: *mathematics is at the heart of it all*. From calculating “best fits” to the data to determining the error bars, math helps health researchers draw conclusions from their data. If you can understand the math, you have a better chance of understanding the research findings (and their limitations).

That’s the premise of this part of the book. I want to show you how to translate the research on nutrition and exercise into mathematics and

how doing so yields valuable insight that cannot be obtained otherwise.¹ In particular, as we'll see in the next chapter, this approach will help us build a research-based diet that improves cholesterol numbers, produces weight loss, and even helps extend life span (no joke—see section 2.3).

Before we get there we'll need some basic background in nutrition (and mathematics). That's the goal of this chapter. It will culminate with an understanding of how many calories we should eat every day, an invaluable piece of information for all of us. And there's no better place I can think to start at than a mathematician's favorite venue: a coffee shop.

1.1 THE LINEAR FUNCTIONS HIDDEN IN YOUR DIET

“Room for cream and sugar?” I'm sure you've heard that line before. I always say yes (almost instinctively). But today I'll slow things down, because the cream and/or sugar decisions contain the mathematics that will build the foundation for the rest of this chapter. But first we need some basic nutrition facts.

Sugar is a carbohydrate. These oxygen, carbon, and hydrogen (*carbohydrate*) molecules yield 4 calories of energy per gram once digested²—at least that's what we've been told. This “conspiracy” can be traced back to Wilber Atwater, a USDA scientist considered by many to be the father of modern nutrition research. Atwater conducted extensive experiments on human metabolism throughout the late 1800s that revealed wide ranges for the energy yields of each macronutrient.³ In 1896 he and his colleagues averaged the yields for each macronutrient, rounded those numbers to whole numbers, and created the *Atwater general factor system*. The result: the calorie counts now found on every nutrition

¹I'll only include the math I consider necessary to extract the understanding and insights we're after, and put any additional mathematical details—like calculations—in each chapter's appendix.

²North Americans call them “calories,” but they're actually *kilocalories*, which explains why food labels in other parts of the world show “kcal.”

³For example, he found that carbohydrates can yield anywhere between 2.7 and 4.1 calories per gram depending on the food (e.g., white bread vs. rolled oats).

label in the United States (and other parts of the world)—carbs and proteins yield 4 calories per gram, and fats yield 9 calories per gram [1].

Four calories for each gram of sugar isn't a lot. But it means that the added calories will be *four times* the total sugar I add to my coffee. Specifically, if I add x grams of sugar that will add $4x$ calories.⁴ Denoting by y the calories added, we get

$$y = 4x.$$

Voilà—we've just derived our first equation!

Now let's introduce some terminology. Since both x and y can vary, they're both examples of *variables*. To find y we need to know x , so we call y the *dependent variable*. (Indeed, the value of y *depends on* the value of x : for example, if $x = 4$ then $y = 20$, whereas if $x = 3$ then $y = 12$.) Similarly, we call x the *independent variable*, since its value doesn't depend on any other variables in the equation.

But $y = 4x$ only yields useful insights if we recognize it as a linear function, a family of functions that will come up often in this book. I explain what a function is in Appendix A, but since every equation we'll discuss defines a function, there's no need for you to know the precise definition. (For that reason I use function and equation interchangeably.) That $y = 4x$ is a *linear* function, however, is more important for our purposes. Here's the simplest definition of a linear function.⁵

How to Spot a Linear Function

An equation of the form

$$y = mx + b$$

is called a *linear function*. The number b is called the *y-intercept*, and the number m the *slope*.

⁴A quick remark about notation: " $4x$ " means "four times x ."

⁵The most general definition of a linear function is an equation of the form $Ax + By = C$. This allows for cases that result in vertical lines (when $B = 0$). But we won't encounter that in the book.

Comparing our “sugar function” $y = 4x$ to $y = mx + b$, we see that $b = 0$ and $m = 4$. The y -intercept is easy to interpret: if I use no sugar ($x = 0$) then I add no calories ($y = 0$). To interpret the slope, picture me pouring the sugar—very slowly—into my coffee. Each granule of sugar that comes out increases the x -value (the number of grams of sugar added to my coffee). When I get to 1 gram of sugar poured in, I’ve added $4(1) = 4$ calories. From there, each additional gram I pour in increases the calories by 4, the slope of our sugar function.

Aha! The slope of our sugar function is telling us how much the y -value increases (i.e., how many calories are added) when the x -value increases by one unit (i.e., when 1 gram of sugar is added). This interpretation for the slope holds true for a general linear function, too^{*1} (recall that starred superscripts point to calculations or other mathematical details in the chapter’s appendix). More formally, here’s the generalized slope interpretation: *when the x -value increases by one unit, the y -value of a linear function increases by m (if $m > 0$) or decreases by m (if $m < 0$).*

Our sugar function’s “right 1, up by 4” line dance can be visualized by graphing the function $y = 4x$. This is a useful way to *see* functions, so let me review how to construct the graph in Figure 1.1(b).

First, we create a table of values for x and y (the first two columns of Figure 1.1(a) show a few examples). Then we draw a set of axes perpendicular to each other—forming the xy -plane—and call their intersection the “origin.” We set a scale for the horizontal x -axis and the vertical y -axis (in Figure 1.1(b) the horizontal tick marks are spaced 0.5 unit apart and the vertical tick marks are spaced 5 units apart). Each location in the grid within these axes now has a particular x -value and a particular y -value (e.g., “5 units to the right of the origin and 20 units above the origin”). We combine these two values into the point (x, y) , and then plot these points on the grid (the third column of Figure 1.1(a) shows a few examples of points; they’re plotted as the dots in Figure 1.1(b)). Finally, we connect the dots to get the graph of the function (Figure 1.1(b)).

Constructing linear functions from given information, interpreting their slopes, and being able to read their graphs are essential skills we’ll use frequently in this book. My creamer decision provides

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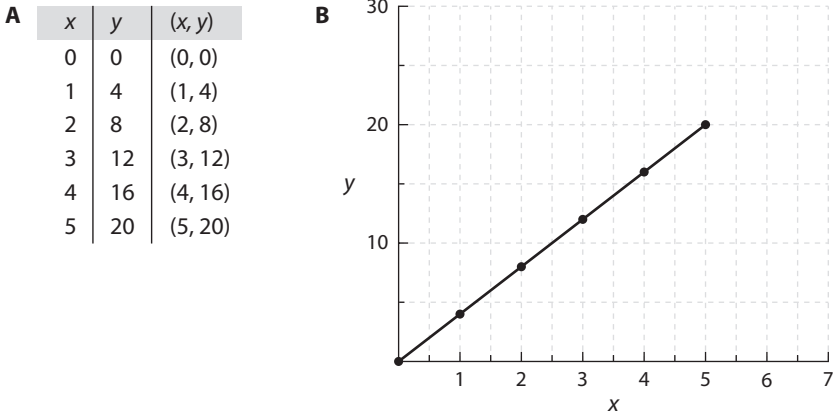


Figure 1.1. (a) A table of values and points for the linear function $y = 4x$. (b) The graph of $y = 4x$ for x -values between 0 and 5 (the maximum amount of sugar in one packet); the dots are the points in the table.

another example. Adding x tablespoons of cream (say, half-and-half) to my coffee would increase the caloric content by $9x$ calories.⁶ The higher slope here means that one tablespoon of creamer adds *more than double* the calories of 1 gram of sugar. No, thanks; I'll skip the cream today.

I've now made my cream and sugar decisions, but let me “mathematize” another scenario (that's my phrasing for the process of translating information into math), since it'll set the foundation for what we do in the next section. This one's motivated by the chocolate croissant I'm staring at: how much sugar can I add to my coffee if I plan on eating that chocolate croissant but want to limit the total calories to 400?

The little label I see next to the croissant says it contains 370 calories. So the total calorie count, which I'll denote by c , is 370 plus the calories from the sugar I add to my coffee ($4x$). That gives the linear function

$$c = 4x + 370.$$

The slope is again $m = 4$, but this time the y -intercept is $b = 370$. (If I add no sugar to the coffee my meal would still contain 370 calories.)

⁶I'm assuming that all the creamer's calories come from fat, which is nearly true.

Keeping the total calories under 400 is equivalent to $c \leq 400$ (“ c less than or equal to 400”), whose solution is $x \leq 7.5$ grams.*² So I can safely add a little sugar to my coffee *and* eat the croissant while keeping to my 400-calorie cap.

These analyses illustrate one of the many benefits of “mathematizing” a situation or problem: you get to use all the results and techniques mathematicians have developed to tackle the problem. Often this leads to new insights; in our case we discovered that the energy yields of carbs, protein, and fat are slopes of lines. (That’s the reason for this section’s title—slopes and linear functions are hidden inside every bite you take!) Sometimes “mathematization” leads to new applications. For example, the same approach to our coffee + croissant problem can help someone estimate how much protein, carbs, and fats they can eat while keeping to a prescribed calorie cap.*³

Now that we have a working understanding of the mathematics of calories, let’s move on to the mathematics of metabolism.

1.2 THE MATHEMATICS OF METABOLISM

From the corner where I’m sitting, I see slim people downing huge Frappuccinos (these can top 600 calories). Why is it that some people can eat more calories than others and not gain weight? That question has a complicated answer, but let’s see what math can do for us this time.

First, a few observations: the people sipping on those highly caloric drinks are tall and young. One guy sitting next to the coffee station—a few tables from me—is about 6 feet tall. He looks to be in his early 20s, with an athletic build. The barista just greeted him by name—Jason. Jason probably needs more calories to maintain his weight than most of us given that he’s tall, young, and athletic. But is any of this true? In short, yes.

Each of us has a *resting metabolic rate*, or *RMR*. By definition, this is the *daily* energy (calories) your body would burn in an awake, nonfasting, at-rest state.⁷ Translation: your RMR is the daily energy

⁷RMR measurements are made a few hours after a light breakfast [2].

needed by your body to complete its normal tasks (e.g., circulating blood). That should make you happy, because it means that *every day you burn your RMR in calories without having to lift a finger!*

To find out your own RMR you could visit a lab and have a sports scientist hook you up to an *Atwater-Benedict-Roth apparatus* (yup, that's the same Atwater from before); your RMR would then be determined by measuring how much oxygen you consume in a 6-minute period (while at rest). But that visit will cost you. Plus, it's a black-box answer—it doesn't tell you what variables RMR depends on.

That's where we come back to Atwater. His experiments kicked off a century of research into the science of metabolism, and one of the first things to be quantified was RMR (by Harris and Benedict in 1918). They came up with a formula that depends on just three variables: your weight, height, and age. Subsequent experiments led to more accurate equations. A recent comparison of the available formulas crowned the winner: the 1990 *Mifflin-St. Jeor* equations [3].⁸

Estimating Your RMR with the Mifflin–St. Jeor Equations

$$\text{RMR}_m = 4.5w + 15.9h - 5a + 5, \quad (1.1)$$

$$\text{RMR}_w = 4.5w + 15.9h - 5a - 161. \quad (1.2)$$

The first equation estimates the resting metabolic rate for men, the second for women, and both assume you're at least 19 years old. In both equations w is weight in pounds, h is height in inches, and a is age in years.



(Remember, I've created online calculators on the book's website for formulas with computer icons next to them.)

The first thing you may have already noticed is that the equations are almost the same; the only difference is the last term (“+5” versus “−161”). In fact, adding 166 to (1.2) gives (1.1). Thus, the

⁸These formulas aren't perfect; see the bibliography for a short discussion of the researchers' comments regarding their accuracy.

Mifflin–St. Jeor equations predict that *a man needs 166 more calories than a woman of the same weight, height, and age*. Score another one for new insights from math!

The other numbers in the equations, the “coefficients” 4.5, 15.9, and -5 , also have a story to tell. Let’s discover their meaning by using Jason as a guinea pig. Let’s say he’s 23, so that $a = 23$. Since he’s 6 feet tall, $h = 72$ inches. Plugging in these values into (1.1) gives

$$\text{RMR}_{\text{Jason}} = 4.5w + 1,034.8. \quad (1.3)$$

Aha! That’s a linear function (with slope 4.5). Had we gone back to (1.1) and plugged in Jason’s weight and age instead, we’d have been left with another linear function, this time with slope 15.9. So, the Mifflin–St. Jeor equations contain *multiple linear* equations as special cases. *Indeed, the RMR equations are examples of multilinear functions*. I would even describe them as “linear in the w -variable with slope 4.5,” “linear in the h -variable with slope 15.9,” and “linear in the a -variable with slope -5 .” (The graphs of multilinear functions require three or more dimensions; check out the 3D graph in the appendix*⁴ for an illustration.)

But wait, there’s more! Now that we’ve connected the Mifflin–St. Jeor equations with linear functions, we can apply our slope interpretation to the coefficients in (1.1)–(1.2). Focusing on the 4.5 coefficient of w , for example, the equations predict that *for every pound you gain, your RMR goes up by 4.5 calories*. Table 1.1 summarizes the insights gained by interpreting the other slopes.⁹

Table 1.1 suggests that Jason, who’s busy chatting with the barista, does indeed have a high energy requirement—he’s tall and young, both of which raise his RMR. The older gentleman sitting across from me who looks short and slim, however, likely has a lower RMR. In fact, now that I’m looking around at everyone else in this coffee shop, I can almost “see” each person’s RMR, as if each had a speech cloud containing their

⁹Since the RMR_m and RMR_w equations have the same coefficients, the conclusions of Table 1.1 apply to both men and women.

TABLE 1.1.

The predicted effect on RMR of a one-unit increase in weight, height, or age. The direction of RMR change is reversed for one-unit decreases (e.g., “up” becomes “down”).

<i>If you ...</i>	<i>Your RMR should go ...</i>
Gain 1 pound	Up by 4.5 calories
Grow 1 inch taller	Up by 15.9 calories
Age 1 year	Down by 5 calories

particular number. So not only are linear functions hidden in every bite you take, multilinear functions are hidden *inside of you*.

Now remember, RMR is defined relative to an at-rest state. If we so much as get up and go for a walk, we’re burning more calories than our RMR predicts. In the next section we’ll learn how to quantify those extra calories.

1.3 BURN THOSE CALORIES! WORK THOSE QUADS!

Most of us associate the word *exercise* with a physically demanding activity, like running or swimming. But any activity requiring physical effort constitutes exercise. That means even the busy baristas making drinks in this coffee shop are exercising. They may not be huffin’ and puffin’, but by the end of the day they’ll have burned more calories than their RMR.

To quantify that extra caloric burn, let’s focus on *aerobic* exercise (i.e., exercise that requires you to breathe faster than normal). Faster breathing means more oxygen consumption, and thanks to those Atwater-inspired experiments, we know that about 5 calories are burned for each liter of oxygen consumed. (It’s no wonder aerobic exercise is the most effective way to get rid of body fat [4].) Sports scientists use this factoid to estimate an individual’s *aerobic caloric burn* (ACB)—the calories burned per minute of aerobic exercise. Like RMR, researchers have come up with several equations to estimate ACB.

Here's a relatively accurate one that's a function of weight, age, and heart rate [5]:



Estimating Calories Burned per Minute of Aerobic Exercise

$$\text{ACB} = 0.02w + 0.05a + 0.15r - 13. \quad (1.4)$$

Here ACB is calories burned per minute of aerobic exercise, w is your weight (in pounds), a your age (in years), and r your heart rate (in beats per minute [bpm]).

There are several neat things to notice about this formula. The first is that it applies to all types of aerobic exercise.¹⁰ Another feature is something I hope you've already noticed: it's another multilinear function! That means we can interpret the coefficients of w , a , and r in much the same way we did for the RMR equations. Some of the ensuing insights are obvious (e.g., the higher the heart rate, the higher the ACB), but one result seems counterintuitive: the older you are, the higher the ACB. The multilinear nature of (1.4) also means we can use the same approach that reduced the Mifflin–St. Jeor equations to a linear function to make the formula more useful for practical applications. For example, let's plug in Jason's age ($a = 23$) and weight (about $w = 150$). This reduces (1.4) to

$$\text{ACB} = 0.15r - 8.85, \quad (1.5)$$

a linear function. The 0.15 slope says that for each additional 1 bpm Jason's heart beats, he burns 0.15 more calories per minute. To put this in context, let's say Jason wanted to burn the 400-calorie coffee + croissant snack I ate earlier in 20 minutes. That's an ACB of 20 calories per minute, and according to (1.5) he'd need to sustain a heart rate of about $r = 192$ bpm for those 20 minutes to burn off that snack.*⁵ That's very high (a racing pulse is as low as 140 bpm). In fact, 192 bpm is higher than Jason's theoretical "maximum heart rate."

¹⁰However, as with any formula produced from experiments on humans, there are limitations; see the bibliography for comments on the formula's accuracy.

Loosely speaking, an individual's *maximum heart rate* (MHR) is the highest heart rate that can be sustained during prolonged exercise. Lucky for us, researchers have gotten many brave individuals to exercise at their MHRs in the name of science. These experiments have yielded equations that estimate MHR based on just age. You may already be familiar with the most popular formula: $MHR_{\text{pop}} = 220 - a$ (a linear function). But let's work out our quads instead—*quadratic polynomials*, that is—and use the formula with the smallest error [6]:

Estimating Your Maximum Heart Rate

$$MHR = 192 - 0.007a^2. \quad (1.6)$$

Here MHR is your maximum heart rate (in bpm) and a is your age (in years).



This function is *quadratic* because the highest power of the independent variable (a in this case) is 2. Unlike linear functions, quadratic polynomials (and other nonlinear polynomials too) have “curvy” graphs.¹¹ Figure 1.2 shows a table and graph comparison of the two MHR formulas so you can see what I mean.

At Jason's age ($a = 23$) equation (1.6) says that his MHR is about 188 bpm, lower than the 192 bpm he would to achieve to burn off my snack. The linear MHR equation, however, disagrees—it says that Jason's *current* MHR is $220 - 23 = 197$. That's why the researchers responsible for (1.6) point out that “the traditional equation, $220 - \text{age}$, *overestimates* [MHR] in young adults and *underestimates* it in older people” (emphasis original). That's exactly what Figure 1.2(b) shows, too (the linear graph is above the quadratic one until just before 40).¹² We conclude that Jason probably can't safely burn 400 calories in 20 minutes through aerobic exercise.

¹¹If you're interested in learning more about quadratic (and higher-order) polynomials, see entry 6 in this chapter's appendix. A preview of what's there: linear functions are special cases of polynomials.

¹²Bonus: can you work out the exact age? See entry 7 in this chapter's appendix for the answer.

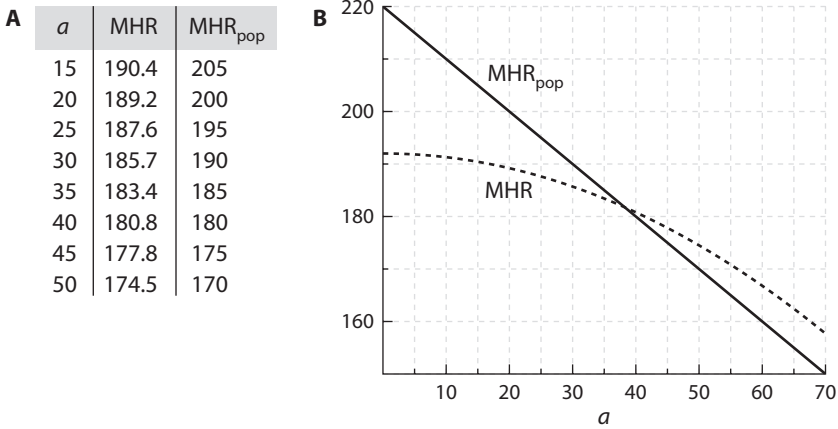


Figure 1.2. (a) A table of values of the quadratic function MHR (1.6) and the linear function $MHR_{pop} = 220 - a$. (b) The graphs of $MHR = 192 - 0.007a^2$ (dashed curve) and $MHR_{pop} = 220 - a$ (solid line).

Armed with (1.5) and (1.6), we can now answer other, more useful questions. Here’s a classic one: if you exercise at $x\%$ of your MHR, how long will it take to burn c calories? This is such a common question, and I think it’s neat we can now answer it using math.*⁸ Plus, you could follow the steps in the appendix and answer that question for yourself using your own versions of (1.5) and (1.6).

We now have a better understanding of precisely how RMR and aerobic exercise contribute to our *total daily energy expenditure* (TDEE). These are actually the two largest components, but there’s one more contributor that’s worth discussing: the “thermic effect” of food. In brief, this is the energy (calories) our bodies use up digesting food (this is additional energy not included in RMR). It turns out that certain foods require more energy to digest. I’ll tell you which ones those are in the next section, and then we’ll finally write down a formula for TDEE.

1.4 THE CALORIES REQUIRED TO DIGEST FOOD

The coffee shop I’m in probably gets its food shipments once a week. At those times, the employees expend energy moving the boxes out of

TABLE 1.2.

The thermic effect of each macronutrient and the net energy yield of ingesting 100 calories of each macronutrient [7, 8].

<i>Macronutrient</i>	<i>Thermic Effect (% of Cal.)</i>	<i>Energy Yield (Cal.) of 100 Calories</i>
Protein	20–35	65–80
Carbohydrate	5–15	85–95
Fat	3–15	85–97

the truck, unpacking them, and distributing the contents to the right places in the store. This is pretty much what our bodies do when we eat. That new shipment of calories requires unpacking (digestion) and distribution (absorption), and just like those coffee shop employees, our bodies expend energy (burn calories) doing all that. This additional energy needed to digest, absorb, and dispose of the food we eat is called *diet-induced thermogenesis* (DIT).

Each macronutrient has its own DIT effect. As Table 1.2 shows, proteins require the most energy to metabolize, followed by carbs and fats.

The thermic effect of food means, for example, that a 100-calorie snack *does not* provide your body with 100 calories—if the snack is pure protein, your body gets only 65 to 80 calories out of it, whereas if it’s pure fat it gets 85 to 97 calories.

Since DIT is usually the smallest component of TDEE, and since we’ve now discussed the major ones, let’s finally write down an approximate formula for TDEE:¹³

$$\text{TDEE} \approx \text{RMR} + 24\text{-hour ACB} + \text{DIT}. \quad (1.7)$$

(There are other factors that contribute to TDEE, but those three are the main ones.) Two quick comments: (1) the middle term here—24-hour ACB—accounts for all your day’s aerobic exercise, and (2) since what you eat and how much you exercise varies day to day, *TDEE also varies day to day*.

Calculating TDEE each day can itself be a workout. That’s why many fitness experts prefer to use a simpler formula.

¹³The \approx symbol in the formula means “is approximately” (the Glossary of Mathematical Symbols in Appendix A explains this and other symbols used in the book).



Estimating Your Total Daily Energy Expenditure

$$\text{TDEE} \approx \text{RMR} \times \text{Activity Factor} + 0.1C. \quad (1.8)$$

Here TDEE is your total daily energy expenditure, RMR is the appropriate value from either (1.1) or (1.2), the Activity Factor is one of the values from Table 1.3, and C is your caloric intake for the day.

The “activity factor” in this formula describes how active your day was. Table 1.3 lists a few reference values.

After multiplying your RMR by the appropriate activity factor, (1.8) then adds 10% of your day’s caloric intake to approximate the DIT term in (1.7).

Equations (1.7) and (1.8) were the end goals of this chapter. They give you a rough idea of your daily maintenance calories—the level needed to maintain your current weight. Health professionals tell us that eating fewer calories than our TDEE will create a *caloric deficit* and should lead to weight loss,¹⁴ and that eating more calories than our TDEE will create a *caloric surplus* and should lead to weight gain. I’ve deliberately inserted the words “rough” and “should” because nutrition is not an exact science. From the Atwater general factor system’s simplification of the energy yields of each macronutrient to

TABLE 1.3.

Activity factors; multiply your RMR by the appropriate factor to estimate your energy expenditure from RMR plus physical activity.

<i>Level of Activity</i>	<i>Activity Factor</i>
Little to no physical activity	1.2
Light-intensity exercise 1–3 days/week	1.4
Moderate-intensity exercise 3–5 days/week	1.5
Moderate- to vigorous-intensity exercise 6–7 days/week	1.7
Vigorous daily training	1.9

¹⁴But be careful not to spend too much time in a caloric deficit state—after a while your body adapts to the lower energy intake, a phenomenon known as *metabolic adaptation* [9]. This reduces (or may eliminate) your caloric deficit. Many of us know this outcome as the “plateau effect.”

the approximations in (1.7)–(1.8), there’s plenty of inaccuracy to go around. But there are ways to tame these errors. For example, after my Tuscan Fields shocker I capped my daily calories at my RMR and started eating more protein. The larger DIT effects of my protein-rich meals, along with the fact that I’m not a 24-hour couch potato, made it more likely that I was in a caloric deficit.

Our TDEE equations, and my response to the Tuscan Fields fiasco, illustrate perhaps the most important “equation” I can offer you:

$$\text{math} + \text{discipline-specific research-based knowledge} = \text{empowerment.} \quad (1.9)$$

Indeed, we’ve already built a solid foundation for healthy living by mathematizing the studies on nutrition and exercise—the “discipline-specific knowledge” part—presented in this chapter. In the next chapter I describe how the insights we’ve gained can help build a diet that improves cholesterol, lowers the risk of developing heart disease and diabetes, and may even add years to your life.

Chapter 1 Summary

MATHEMATICAL TAKEAWAYS

- Functions describe a special relationship between one or more variables, called the dependent variables, and one or more other variables called independent variables.
- We can visualize functions by graphing them. For a function with one dependent variable and one independent variable, each point on the graph is of the form (x, y) , where x is the value of the independent variable and y the value of the dependent variable. The horizontal axis sets the scale for the x -values and the vertical axis sets the scale for the y -values.
- Linear functions are defined by two numbers: their slope and their y -intercept. The slope of a linear function can be interpreted as the change in the y -value resulting from a one-unit increase in the x -value. The y -intercept is the y -value of the point where the graph crosses the y -axis.

- Multilinear functions have multiple independent variables, each of which has an associated slope.
- The graphs of linear functions are lines. The graphs of nonlinear polynomial functions are curvy.

NONMATHEMATICAL TAKEAWAYS

- Nutrition labels state that carbs and proteins yield 4 calories per gram and fats 9 calories per gram, but this is a simplification (the Atwater general factor system).
- Linear functions—and their big brother, multilinear functions—show up frequently in nutrition science. The slopes of these functions help us better understand many fundamental concepts in nutrition (like the Atwater general factor system and RMR).
- You have a 24-hour calorie-burning machine: your body. Every day it burns your resting metabolic rate (RMR) in calories, which you can estimate using (1.1)–(1.2) and your weight, height, and age. A one-unit change in these numbers has a quantifiable effect on your RMR (Table 1.1). If you're male, the RMR equations predict that your body requires 166 more calories a day than a female of your same weight, height, and age.
- You can increase your daily energy expenditure through aerobic exercise, the most effective way to burn off body fat [4]. The additional calories you burn depends on how much heavy breathing you're doing: you burn about 5 calories for each liter of oxygen consumed. You can estimate your per-minute aerobic caloric burn (ACB) using (1.4) and your weight, age, and heart rate. Don't exert yourself too much, though—make sure to stay well below your maximum heart rate (1.6).
- Macronutrients require different amounts of energy (calories) to be metabolized, and this is measured by a macronutrient's diet-induced thermogenesis (DIT). Protein has the highest DIT; metabolizing it requires between 20% and 35% of the protein calories ingested. Table 1.2 summarizes the DIT of the other macronutrients.
- The sum of your RMR, your 24-hour ACB, and your meals' total DIT gives a rough estimate of your total daily energy expenditure (TDEE);

see (1.7). If your activity level and/or diet varies from day to day, your TDEE will also vary day to day.

- You can estimate your TDEE by using (1.8); see Table 1.3 for the appropriate activity factor to use.
- In theory, eating your TDEE in calories will help you maintain your current weight. Eating fewer calories than your TDEE will create a caloric deficit and may lead to weight loss, whereas eating more than your TDEE will create a caloric surplus and may lead to weight gain.
- Nutrition science is not exact; see the bibliography for brief comments on the errors and limitations of some of the formulas presented in this chapter.

BONUS: A FEW PRACTICAL TIPS

- *Get a pedometer.* A basic pedometer is cheap. It'll do a good job of counting the number of steps you take, and glancing at it often might motivate you to take more steps than normal (and hence burn more calories).
- *Track your calories with a smartphone app.* Apps make it easy to track your food intake and exercise. Some also allow you to set targets for your daily caloric intake, making it easier to stay close to your TDEE, and/or input your weight and/or body fat percentage.
- *Get a "smart" scale.* These days you can buy scales that measure your weight and body fat percentage; some even email you the results! One tip: weigh yourself at the same time and under the same conditions (e.g., before breakfast); this will cut out the weight fluctuations caused by eating and/or the time of day.