OBESITY EXPERTISE

A first-principles curriculum in 196 books

BOOK 1 2nd of 196 in the series

Energy balance and dynamic weight-change modelling · Rung 1

Why energy balance is arithmetically true and practically insufficient

THE ACCOUNTING IDENTITY, ITS UNITS, AND WHY IT IS NOT A LEVER

Dr. Harsh Maheshwari

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drharshmaheshwari.com · version 1.2

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SERIES	Obesity Expertise: A first-principles curriculum in 196 books
BOOK	Book 1, Energy balance and dynamic weight-change modelling · Rung 1 (2nd of 196 in the series)
VERSION	1.2
LAST UPDATED	24 September 2026
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NEWEST VERSION	drharshmaheshwari.com

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NOT ADVICE

This book is for learning. It is not medical, legal or financial advice, and it does not replace a qualified professional who knows your situation.

About the author



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Harsh Maheshwari completed his MBBS at King George's Medical University (KGMU), Lucknow, and is a resident in MD Community Medicine at the All India Institute of Medical Sciences (AIIMS), Raipur. His MD thesis, on chrononutrition and obesity, was selected by the Indian Council of Medical Research (ICMR) for funding in 2026.

He learns best from first principles: rebuilding an idea from what came before it until the formula feels like the only reasonable answer. This series grew out of that habit.

His long-term aims are to reduce obesity in India and to help make India healthy.

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Introduction

Why this book exists

Every claim about body weight passes, sooner or later, through energy balance. This book teaches the one piece of physics that no argument about obesity is allowed to break: body fat is stored chemical energy, energy is conserved, so fat changes only when what comes in differs from what goes out. It also teaches why that true sentence is not an instruction: intake and expenditure are outputs of a regulated body, not dials you set.

How to read it

Read Book 0 first, or at least the sections this book names as it goes. Then read this one in order: each section assumes everything before it. Do every exercise before you read on.

Every section has the same shape. **Definition** states the idea exactly. **In plain terms** says it again in everyday words. **Illustration** works through one real case, usually with a source you can open yourself. **Where this picture breaks** says where the illustration stops being true. **Must-know points** are what should change what you do. Then come **exercises** and, in most sections, a graded **practice set**.

Do the exercises before you look anything up. The worked answers are in the appendix at the back, under the same numbers. The references for each Part follow that Part. The glossary lists every term of art in the plain words it was first given. The last pages list all 196 books in the series and show where this one sits.

If you are new to this

On a first reading, read each section's definition, plain-terms explanation, illustration and must-know points, and do the exercises. Worked derivations can be skimmed and revisited once the idea feels familiar. Keep a calculator beside you: every worked answer can be followed with pen, paper and a calculator. Anything beyond the stated prerequisites is explained where it first appears, or marked as beyond this book. The **Symbols used in this book** page lists every sign and Greek letter with how to read it and where it is first used.

How to send feedback

If something is wrong, unclear, or could be better, please write to **contact@drharshmaheshwari.com**. Put the book number, the version and the section in the subject line (for example: *Book 1, v1.2, section C5*). Say what the text says, what you think it should say, and, if you can, the source.

Corrections are made in new versions. The version number and the date of the last update are on the copyright page of every book, and the newest version of every book is at **drharshmaheshwari.com**.

WHERE THIS BOOK SITS

Book 1 of the series' 196 books (Book 0 and 195 rung books). Before it: Book 0, Ground floor. After it: Book 2, Mathematics for modelling and inference · Rung 1. The full list is at the back.

Symbols used in this book

Every sign and Greek letter this book prints, how to read it aloud, what it means in this series, and the section where it first appears. Each is also explained where it is first used.

Symbol	Read as	Meaning	First in
SIGNS			
Δ	delta, change in	A change or difference: Δt is a change in time	2 · How much energy a kilogram of body fat holds
$\times$	times	Multiplication	3 · A day of intake and a day of expenditure: the sizes
$\pm$	plus or minus	A range either side of a value: 11.8 ± 0.6 means 11.2 to 12.4	7 · Sizing an imbalance, and the static rule
MARKS ON LETTERS			
x^2, 10^{-3}	superscript	Small raised characters are powers: x^2 = x × x, and 10^{-3} = 0.001	Before you start
GREEK LETTERS			
ρ	rho	A correlation in a population, or a density	2 · How much energy a kilogram of body fat holds

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Before you start

This book uses the following Book 0 sections. Each is summarised where it is first needed; work through Book 0 itself if a summary is not enough.

- Book 0, A3 · Decimals, rounding, and significant figures
- Book 0, A4 · Percentages, and the percentage of a percentage
- Book 0, A5 · Ratios, rates and proportions
- Book 0, A6 · Powers, roots and scientific notation
- Book 0, A8 · Orders of magnitude and the back-of-envelope sanity check
- Book 0, B1 · What a unit is, and the SI base and derived units
- Book 0, B2 · Converting units as multiplication by one
- Book 0, B4 · Energy units: joule, kilojoule, calorie, kilocalorie
- Book 0, B6 · Body-size units: kg, m, cm and kg/m^2
- Book 0, C1 · Variables and algebra: what a letter stands for
- Book 0, C6 · Recognising shapes: linear, exponential, saturating
- Book 0, C7 · Rate of change, average and instantaneous, without the machinery
- Book 0, C8 · Accumulation, a running total, without the machinery
- Book 0, C9 · Stocks and flows
- Book 0, E1 · Atoms, molecules and bonds — enough to see where energy is stored
- Book 0, E2 · Chemical energy, combustion, and the bomb calorimeter
- Book 0, E3 · Conservation of energy, and a system with a boundary
- Book 0, E6 · Metabolism as chemistry happening in a body
- Book 0, E8 · Organs and systems that matter for metabolism
- Book 0, F4 · Argument: premise, inference, conclusion

Rung 1 — Introductory

1 · Body fat as stored chemical energy; fat mass and fat-free mass

DEFINITION. Fat is stored in the body as triglyceride, packed inside fat cells, adipocytes, which together make up adipose tissue.

Body weight is not one substance on a scale. Split it into two compartments. Fat mass is the body's fat, wherever it sits. Liver cells hold some of it too. Fat-free mass is everything else the body weighs. Some papers call it lean body mass, or lean mass.

Adipose tissue also holds fluid and protein. On this split, those count as fat-free mass.

Naming a change in body weight is not yet naming a change in fat. [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11]

IN PLAIN TERMS. Pack enough fat cells together and you have adipose tissue, the fatty layer and the pockets of fat scattered round a body. That is the store.

It is a large store. For most people, the fat sitting in adipose tissue holds more spare energy than anything else in the body does.

A person carrying more body fat is not simply carrying fat mass in place of fat-free mass. They generally carry more of both.

So weight on a scale is one number covering two different things. A kilogram gained or lost could be mostly fat, mostly the other compartment, or some mixture, and the scale alone cannot tell you which.

ILLUSTRATION. You are handed a weighing scale and a number: 90 kilograms.

Open the review, Hall and Guo, "Obesity energetics", *Gastroenterology* 2017, at https://pmc.ncbi.nlm.nih.gov/articles/PMC5568065/. Open your browser's find box and search for fat-free mass. Resting energy expenditure (REE) is the energy spent at rest. Metabolically active tissue is the tissue that spends most of it.

> *It has long been recognized that fat-free mass comprises the metabolically active tissues of the body and therefore contributes more to REE than body fat.*

Read on, in the same paragraph.

> *Fat-free mass is elevated in obesity, along with body fat, resulting in increased REE compared with lean subjects.*

Two people can carry the same 90 kilograms and split it differently between fat mass and fat-free mass. Neither split is visible in the number 90.

Now search the same page for vast majority.

> *Body fat represents the vast majority of energy stores in the body compared with the energy content of body protein and glycogen.*

Protein and glycogen are the other stores. When intake falls short, the body draws on all three.

WHERE THIS PICTURE BREAKS. It does not say how much of adipose tissue's own weight is fat, or how much energy either compartment holds for each kilogram. That is the next section.

MUST KNOW POINTS FOR YOU.

- A kilogram of body weight is not a kilogram of fat.
- A person carrying more body fat generally carries more fat-free mass too, not less.
- Ask how a fat-mass or fat-free-mass figure was measured before you accept it. A scale alone cannot give it.

2 · How much energy a kilogram of body fat holds

Checked against the sources as they stood on 2026-09-23.

DEFINITION. A kilojoule (kJ), from Book 0, B4, is a thousand joules; kilo means 10^3. The prefix this section adds is mega, meaning 10^6, a million. A megajoule (MJ) is a million joules.

The Atwater general factor for fat, from Book 0, E2, is 9.0 kilocalories (kcal) a gram. The Food and Agriculture Organization (FAO) prints 37 kilojoules beside it. That is a rounded value, and the two do not convert exactly. For a kilogram: 9,000 kilocalories, or 37 megajoules.

FAO's factors are corrected for energy lost in the faeces, and, for protein, in the urine. They describe fat eaten. Fat already stored in the body is not digested again. Hall (2008) gives fat in the body 39.5 megajoules a kilogram. For body fat, use 39.5.

Adipose tissue is not pure fat, section 1 already established. Counting only its fat, its energy per gram is its lipid fraction, the proportion of its mass that is fat, times fat's own energy per gram.

A deficit is expenditure larger than intake; a surplus is the reverse. The static rule, defined in section 7, says a deficit of 3,500 kilocalories removes a pound of weight. A pound is exactly 0.453 592 37 kilogram. Hall (2008) states that the rule "can be traced back to a calculation that assumes exclusive loss of adipose tissue consisting of 87% fat." That 87% is the rule's own assumption, not a measurement Hall reports.

A kilogram of lean mass lost or gained carries far less energy than a kilogram of fat. [12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27]

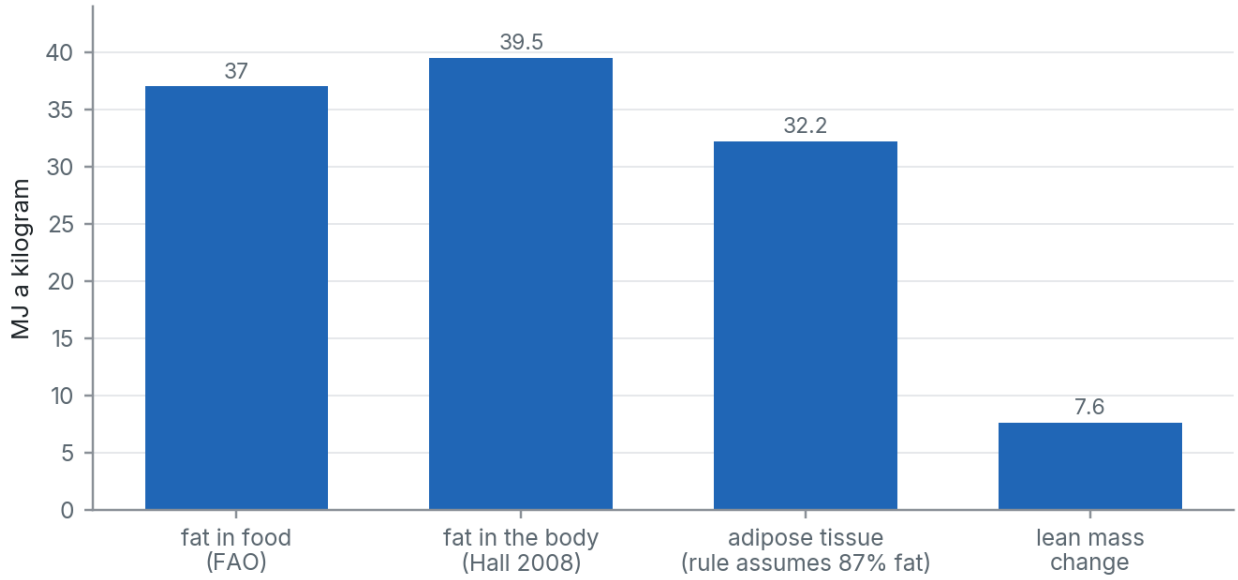
IN PLAIN TERMS. Ask a simple question: how much energy does a kilogram of "fat" gained or lost hold? There are two different honest answers, and mixing them up is the whole trap.

The first answer is about pure fat, the triglyceride itself. Fat in food carries about 9 kilocalories a gram, which is 9,000 a kilogram, or about 37 megajoules. Fat stored in the body carries 39.5 megajoules a kilogram.

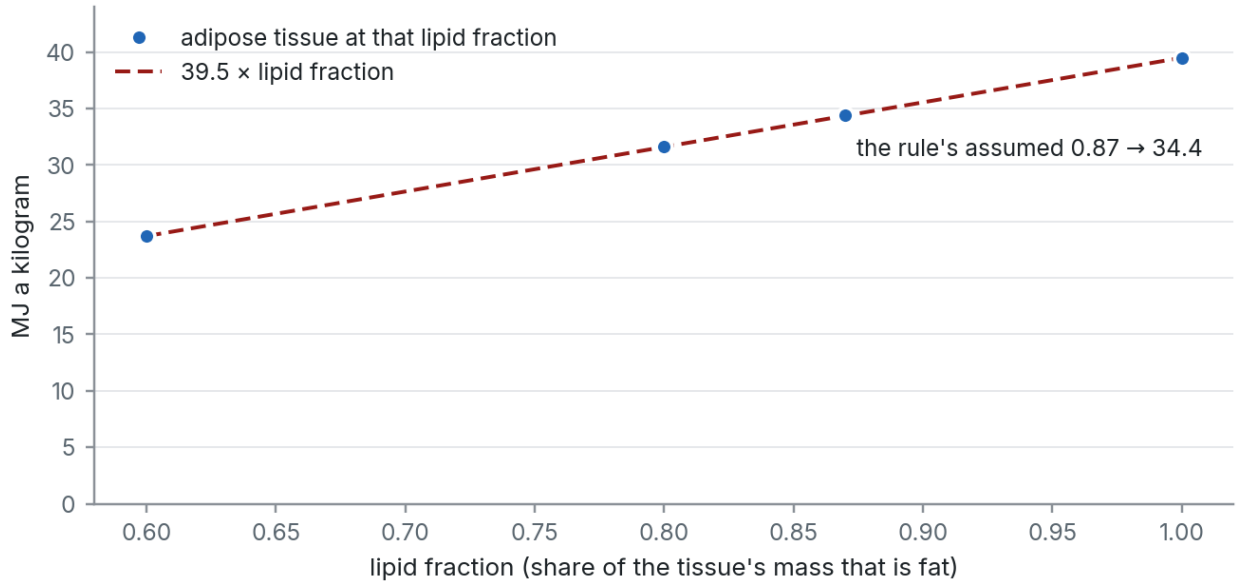
The second answer is about adipose tissue, the actual stuff that is gained or lost. It is not pure fat — section 1 already told you that. By how much depends on what fraction of it is fat, and here the honesty runs out: the only figure for that fraction in the sources this book cites is 87%, and it is not a measurement.

Do the sum anyway, to see the size of the effect. Multiply 0.87 by fat's 37 kilojoules a gram. You get 32.19 megajoules a kilogram, near the famous rule's 32.2. That confirms nothing. Hall gives 32.2 as the same rule, 3,500 kilocalories a pound, written "equivalently" in megajoules a kilogram. He does not say which figure for fat the 87% calculation used. Start from 9,000 kilocalories instead and the same sum gives 7,830, not the rule's 7,700.

That is arithmetic on an assumption.



Energy in a kilogram, in megajoules: fat in food 37 (FAO); fat in the body 39.5 (Hall 2008); adipose tissue 32.2 only under the static rule's assumed 87% fat; a lean-mass change 7.6. Hall's body-fat figure is about 5.2 times the lean figure.



Counting only the fat in adipose tissue, its energy per kilogram is the lipid fraction times the 39.5 megajoules a kilogram of fat in the body. At the rule's assumed 0.87 that gives 34.4, above the rule's own 32.2. The points at 0.60 and 0.80 are arbitrary, drawn to show the line, not a measured range. Hall (2008) calls the real composition variable.

ILLUSTRATION. Open the table of prefixes kept by the International Bureau of Weights and Measures (BIPM), "The International System of Units (SI): Prefixes", at https://www.bipm.org/en/measurement-units/si-prefixes, and search the table for mega.

> *mega | M | 10⁶*

The page prints 10 with a small raised 6. Copied as plain text it can come out as 106. Read it as ten to the sixth, a million. A megajoule is a million joules, a thousand kilojoules.

Open FAO Food and Nutrition Paper 77, chapter 3, at https://www.fao.org/4/y5022e/y5022e04.htm, and search for the word Atwater.

> *The energy values are 17 kJ/g (4.0 kcal/g) for protein, 37 kJ/g (9.0 kcal/g) for fat and 17 kJ/g (4.0 kcal/g) for carbohydrates.*

Fat: 37 kilojoules a gram. Scale that to a kilogram.

```
37 kJ/g times 1000 g/kg = 37000 kJ/kg
37000 kJ/kg divided by 1000 kJ/MJ = 37 MJ/kg
```

37 megajoules a kilogram. The multiplication and the division cancel: a kilojoule-per-gram figure is already a megajoule-per-kilogram figure.

Open Hall, "What is the required energy deficit per unit weight loss?", *International Journal of Obesity* 2008, at https://pmc.ncbi.nlm.nih.gov/articles/PMC2376744/, and search for the word respectively.

> *the metabolizable energy densities of body glycogen, protein and fat are 17.6, 19.7, and 39.5 MJ/kg, respectively*

39.5 megajoules a kilogram for fat in the body, against FAO's 37 for fat in food.

Now search the same paper for 87%.

> *The origin of this rule can be traced back to a calculation that assumes exclusive loss of adipose tissue consisting of 87% fat*

It says a calculation assumes 87%. It does not say a measurement found 87%. Search on for the word variable.

> *the change of body fat,ΔF, is not equivalent to the loss adipose tissue, which includes a variable contribution of fluid and protein in addition to triglyceride*

Run the assumed fraction through the arithmetic once.

```
0.87 times 37 = 32.19
```

Search the same paper, near the start, for MJ per kg.

> *a cumulative energy deficit of 3500 kcal is required to lose 1 pound of body weight, or equivalently 32.2 MJ per kg*

"Equivalently": 32.2 is the rule itself, in megajoules a kilogram. 32.19 landing near it proves nothing. FAO's footnote gives fat's precise value as 37.4 kilojoules a gram; 37 is its rounding. Try 37.4, Hall's 39.5, and 9,000 kilocalories.

```
0.87 times 37.4 = 32.538
0.87 times 39.5 = 34.365
0.87 times 9000 = 7830
```

32.5, 34.4, and 7,830 kilocalories. The rule is 3,500 kilocalories a pound, about 7,700 a kilogram (section 7 works that out). Hall does not say which figure for fat the original calculation used. What the sum shows is the size of the effect an 87% assumption has, not how the rule was built.

Search the same paper for 7.6.

> *This results in a calculated energy density for lean body mass changes of ρL = 7.6 MJ/kg.*

ρL is the paper's symbol for it: the energy in a kilogram of lean mass lost or gained.

quantity	value	source
fat in food, FAO Atwater factor	9.0 kcal/g; 37 MJ/kg	FAO 2003
fat in the body	39.5 MJ/kg	Hall 2008
adipose tissue, the rule's assumption	32.2 MJ/kg (about 7,700 kcal/kg)	Hall 2008 (the rule, not a measurement)
lean mass change	7.6 MJ/kg	Hall 2008

WHERE THIS PICTURE BREAKS. The third row is different in kind, not just in size. It is one assumption, 87% fat, carried through one piece of arithmetic; the paper that reports the assumption also says the true figure is variable.

The closeness of 32.19 to Hall's 32.2 MJ/kg is not a confirmation. With 37.4 or 39.5 for fat, the same 87% lands elsewhere. And section 7's pound conversion restates the rule; it does not check the 87%.

The fourth row is named, not explained.

MUST KNOW POINTS FOR YOU.

- Pure fat holds about 9 kilocalories a gram (9,000 a kilogram), or 37 to 39.5 megajoules a kilogram: 37 for fat in food (FAO), 39.5 for fat stored in the body (Hall 2008).
- A kilogram of adipose tissue lost or gained is not a kilogram of pure fat. It is a mixture, and it holds less energy per kilogram than pure fat does. Never quote 9,000 kilocalories or 37-39.5 megajoules a kilogram for a kilogram of weight a patient has lost or gained.

- The figure of about 32 megajoules, or 7,700 kilocalories, for a kilogram of adipose tissue is the static rule's own number, which Hall (2008) traces to an assumed 87% lipid fraction that no source this book cites measures. Say "the rule assumes" when you use it, never "adipose tissue is".
- A sum that lands near the rule's 32.2, like 0.87 times 37, does not confirm the rule. Use 37.4 or 39.5 for fat and the same 87% lands elsewhere.
- A kilogram of lean mass lost or gained carries about 7.6 megajoules (Hall 2008), about a fifth of fat's figure. That is the energy of the change, not of lean tissue as a whole; Hall warns the two "are not equivalent".
- Because fat and lean tissue differ this much, and section 1 already showed a scale cannot tell you which compartment moved, no single kilocalories-per-kilogram figure is safe to apply to a patient's weight change without separately knowing, or reasonably assuming, what that change was made of.

PRACTICE. Ten problems on this technique, easiest first. Work them on paper before turning to the answers, which are in the appendix at the back under this section's name.

1. A tissue's energy per gram (counting only the fat) is found by multiplying its lipid fraction by 9.0. Work out the result for a lipid fraction of 0.80, and separately for a lipid fraction of 0.60.

2. Convert 34,000 kilojoules into megajoules. Then convert 2.5 megajoules into kilojoules.

3. Two energy densities are quoted for two different tissues: 39.5 and 7.6, in the same units. Work out how many times larger the first is than the second.

4. FAO Food and Nutrition Paper 77 gives the Atwater general factor for fat as 9.0 kilocalories a gram. Work out how many kilocalories that is for one kilogram of pure fat, then convert to megajoules using 1 kilocalorie = 0.004184 megajoules.

5. Hall (2008) gives the metabolizable energy density of body fat as 39.5 megajoules a kilogram. Convert this to kilocalories a kilogram, using 1 kilocalorie = 4.184 kilojoules.

6. Hall (2008) traces the static rule to a calculation assuming adipose tissue is 87% fat. Take FAO's 37 kilojoules a gram for fat and work out the adipose-tissue energy density in kilojoules a gram this assumption produces, and say how it compares with Hall's own statement of the rule as "32.2 MJ per kg".

7. Here is a worked answer. Find the step that broke.

```
pure fat holds 39.5 MJ/kg, Hall (2008)
a patient's weight falls by 4 kg over a diet
4 times 39.5 = 158
so the deficit responsible for the loss was 158 MJ
```

8. Here is a worked answer. Find the step that broke.

```
the static rule's adipose figure is about 7,700 kcal/kg
FAO's Atwater factor for fat is 9.0 kcal/g, or 9,000 kcal/kg
7,700 is close to 9,000
so the two figures confirm each other, and adipose tissue is essentially pure fat
```

9. A colleague says: "A kilogram of fat is worth about 9,000 kilocalories, so losing 5 kilograms needs a 45,000-kilocalorie deficit." Decide what to compute, compute it, and say what your answer does not establish.

10. A slimming clinic's brochure says: "Body fat holds 7,700 kilocalories per kilogram, a figure confirmed by peer-reviewed research (Hall, 2008)." Decide what to compute, compute it, and say what your answer does not establish.

3 · A day of intake and a day of expenditure: the sizes

Checked against the sources as they stood on 2026-09-23.

DEFINITION. An adult's daily energy intake and daily energy expenditure are both, for most people, somewhere in the low thousands of kilocalories: from about 7 to about 16 megajoules. Three kinds of number carry that claim, and they are not the same kind of number.

The first kind is a calculation of what a typical group would spend. The Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United Nations University (UNU) give worked examples in their 2004 report. Each multiplies a physical activity level (PAL), a multiplier for how active the group is, by a basal metabolic rate (BMR), the energy spent lying at rest after a fast. The product is total energy expenditure (TEE). The examples give 8.26 megajoules a day (1,975 kilocalories) for sedentary or lightly active 55 kg women, 9.86 megajoules (2,355 kilocalories) for active women, and 16.42 megajoules (3,925 kilocalories) for vigorously active men. None of these is a measurement. The method that would measure what a group actually spent is doubly labelled water.

The second kind is an adopted requirement: a number a body of experts has set, not measured in the person in front of you. India's Indian Council of Medical Research and National Institute of Nutrition (ICMR-NIN) set the adult energy requirement in 2020. It is 2,110 kilocalories a day for a sedentary man and 1,660 for a sedentary woman. It rises to 3,470 and 2,720 for heavy work. These are for a reference man of 65 kg and woman of 55 kg. They are calculated the same way, BMR times PAL.

The third kind is a survey estimate of consumption. India's National Sample Survey (NSS) takes the food each household recorded as consumed and converts it to energy with a conversion table, a table giving the energy in a unit of each food. It puts the all-India average at 2,212 kilocalories a person a day in rural areas and 2,240 in urban areas for 2023-24. The report warns that actual intake "depends on how these foods are processed and/or cooked". It calls its per consumer unit figures, which allow for age and sex, a sharper indicator of adequacy than the per person ones. [28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45]

IN PLAIN TERMS. How much energy does one adult eat and burn in a day?

The first question is what a typical group burns. Experts work it out: an activity multiplier times the energy spent at rest. For three example groups the answer came out between about 8 and 16 megajoules a day, roughly 2,000 to 4,000 kilocalories. That is a calculation, not a measurement.

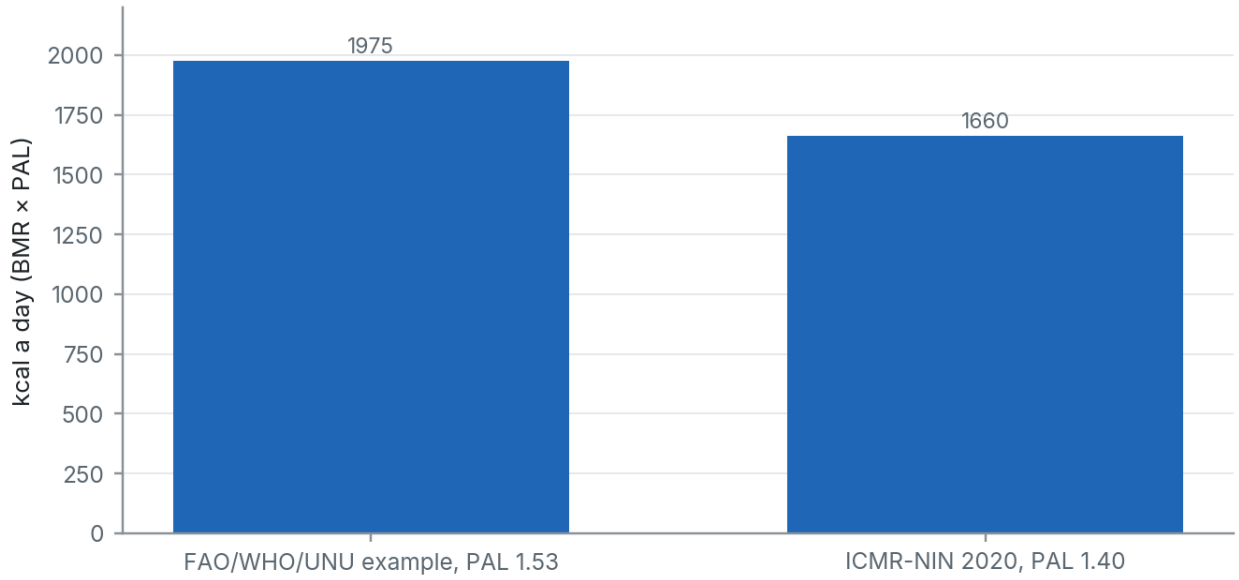
The method that measures it is called doubly labelled water. A person drinks water carrying rare, stable forms of hydrogen and oxygen. How fast they leave the body over the next 10 to 14 days gives the average energy spent.

The second question is what a committee recommends somebody eat. This is a target, set by experts as of a particular year, not a measurement of any one person on any one day.

The third question is what a household survey says people consume. India's National Sample Survey estimates that, on average, a person in the country gets a bit over 2,200 kilocalories a day. The figure is the food each household recorded as consumed, converted to energy with a conversion table.

There is a fourth thing worth knowing before you trust any number a person tells you themselves. Ask somebody to report what they ate and the answer is known to be unreliable.

So be careful when somebody says "an adult needs about 2,000 kilocalories a day." Keep the order of magnitude. Drop the idea that it is one fixed number.



The same sum for a sedentary 55 kg woman, with different inputs, in kilocalories a day. FAO/WHO/UNU's worked example multiplies its BMR by a PAL of 1.53 and gets 1,975. ICMR-NIN 2020 uses a PAL of 1.40 and a BMR set lower for Indians, and gets 1,660. Both are BMR times PAL; neither is a measurement.

ILLUSTRATION. A clinic in an Indian town sees a sedentary adult man and a sedentary adult woman on the same morning.

Open the ICMR-NIN Brief Note on Nutrient Requirements for Indians, 2020, at https://www.nin.res.in/rdabook/brief_note.pdf, and search for sedentary work.

> *Age group Category ICMR 2020 ICMR 2010 Difference Kcal/d Adult Men Sedentary work 2110 2320 -210 [...] Adult Women Sedentary work 1660 1900 -240*

The number under ICMR 2020 is the committee's figure for a 65 kg man and a 55 kg woman doing sedentary work: 2,110 kilocalories a day for him, 1,660 for her.

Now open the FAO/WHO/UNU 2004 report's chapter 5 at https://www.fao.org/4/y5686e/y5686e07.htm and search for sedentary or light activity.

> *If this PAL was from a female population, 30 to 50 years old, with mean weight of 55 kg and mean BMR of 5.40 MJ/day (1 290 kcal/day), TEE = 1.53 × 5.40 = 8.26 MJ (1 975 kcal), or 150 kJ (36 kcal)/kg/d.*

Both figures are for 55 kg women. ICMR-NIN's is lower for two reasons. The committee lowered the sedentary PAL from 1.53, the value in this example, to 1.40. And it set the BMR for Indians 5% below the FAO/WHO/UNU equations, then another 5% below that. Both are BMR times PAL. Neither is a measurement.

Now open the NSS Report 594 highlight at https://www.mospi.gov.in/sites/default/files/publication_reports/Nutritional_Intake_in_India_L.pdf and search for the All-India row of Table 3.1.

> *2022-23 2023-24 2022-23 2023-24 Rural Urban Rural Urban Rural Urban Rural Urban [...] All-India 2233 2250 2212 2240 2407 2488 2383 2472*

The first four columns are per person, the last four per consumer unit. The third figure, 2,212 kilocalories a day, is rural, 2023-24: the food households recorded as consumed, converted to energy with a conversion table.

Three numbers, all near 2,000 kilocalories. The first two are the same sum with different inputs: one a worked example, one a country's adopted figure. The third counts food. None of them measures the patient in front of you. Before you use any one of them, say out loud which kind it is.

WHERE THIS PICTURE BREAKS. Every figure quoted here belongs to a specific group, at a specific activity level, in a specific year.

This section does not say how to reconcile the three kinds when they disagree. Nor does it say which one to trust for one patient.

MUST KNOW POINTS FOR YOU.

- "An adult needs 2,000 kilocalories a day" treats three different kinds of number as one. A daily energy figure is a calculated or measured spend, a committee's requirement, or a survey's estimate of consumption. Say which before you repeat it.
- India's adopted adult energy requirement is set by activity level and sex, as of 2020. A woman's runs from roughly 1,660 to 2,720 kilocalories a day, sedentary to heavy work. A man's runs from 2,110 to 3,470. These are for a reference man of 65 kg and woman of 55 kg.
- A patient's own account of what they ate is known to be unreliable.
- Do not use a population's figure as one patient's prescription: ICMR-NIN's own table says to adjust for actual weight and activity.

EXERCISE 1 (interpretation). Three sentences reach you in one week.

1. "An Indian woman needs 1,660 kilocalories a day."

2. “Urban Indians eat 2,240 kilocalories a day.”

3. “A sedentary woman burns 1,975 kilocalories a day.”

For each, say which kind of number it is and one thing it does not tell you.

4 · What expenditure is made of, and why a bigger body spends more

DEFINITION. Daily energy expenditure is made of three components, and they are not equal in size.

Resting energy expenditure (REE), from section 1, is the energy spent at rest. It is usually the largest of the three. The basal metabolic rate (BMR), from section 3, is not a fourth part. It is resting expenditure measured under set conditions: lying down, after a fast, in a room neither warm nor cold.

The thermic effect of food is the energy spent digesting, absorbing and processing what was eaten. Intake in this book is counted as metabolizable energy, not net metabolizable energy (Book 0, E2). So the cost of digestion is counted once, here, as expenditure.

Physical activity expenditure is the energy spent moving, whether as deliberate exercise or as the ordinary movement of a day.

Resting expenditure depends mainly on age, sex, body size and body composition. Physical activity expenditure depends on how much the body moves, in proportion to its weight. The thermic effect of food depends on what was eaten. [46, 47, 48, 49, 50, 51, 52, 53]

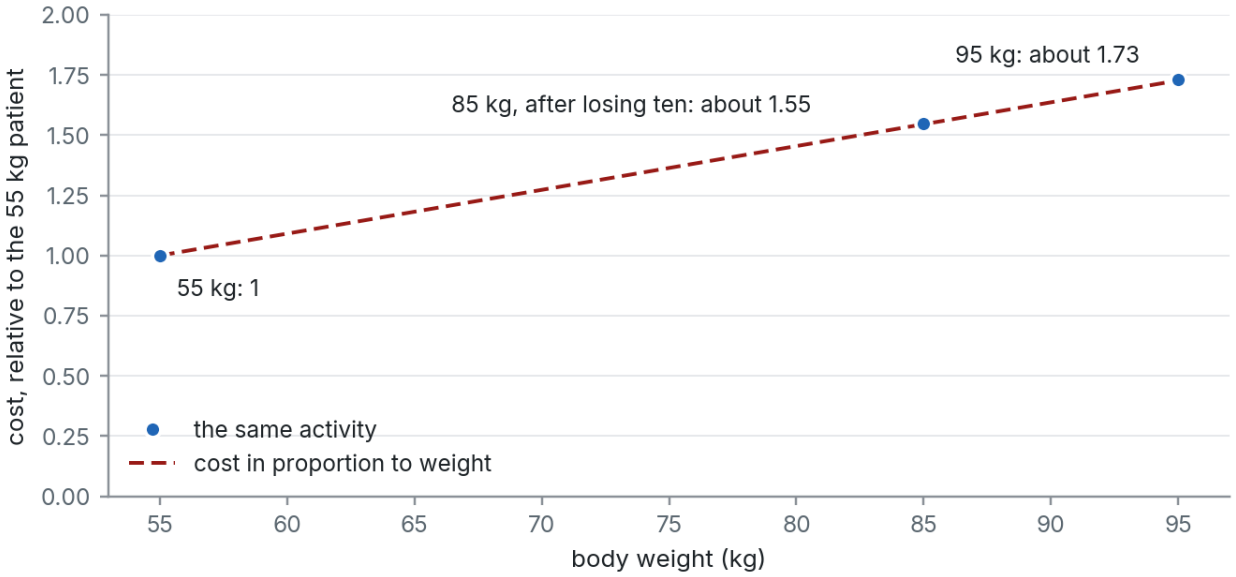
IN PLAIN TERMS. Every day, a body spends energy on three different kinds of work, and it does not spend the same amount on each.

Much of it goes on staying alive, doing nothing else. That is resting expenditure, and it is usually the biggest of the three. It is bigger in a bigger body, because more tissue means more of that background work. A person with more fat-free mass spends more at rest, whether or not they move at all that day.

A smaller share goes on the meal itself. Protein takes more effort to process than carbohydrate, and carbohydrate takes more than fat. This is the smallest of the three shares.

The rest goes on movement: everything from a deliberate workout to walking to the bus. Carry more weight through the same walk and it costs more.

A bigger body spends more, mostly because resting expenditure and movement both scale with size.



If the cost of an activity is in proportion to body weight, as Hall and Guo (2017) put it, the same walk, or any activity that carries the body, costs the 95 kg patient 95/55, about 1.73 times what it costs the 55 kg patient. After losing ten kilograms, at 85 kg, it costs about 1.55 times: less, for the same activity.

ILLUSTRATION. Two patients come to the same clinic on the same day, both adults, both sedentary. One weighs 55 kilograms. The other weighs 95 kilograms and carries more fat-free mass than the first.

Ask which of them has the higher daily energy expenditure, before checking anything.

Open the review, Hall and Guo 2017, at https://pmc.ncbi.nlm.nih.gov/articles/PMC5568065/, and search for linearly related.

> *Across a wide range of weights, REE is linearly related to both fat-free mass and body fat, such that the elevated REE with obesity is generally in line with what is expected for the body weight and composition.*

So the heavier patient's resting expenditure is expected to be higher. Fat-free mass counts for more of resting expenditure than body fat does, though both add to it.

Now search the same page for proportion to overall body weight.

> *The energy expended in physical activities is determined by their duration and intensity in proportion to overall body weight.*

Now imagine the heavier patient loses ten kilograms over the following year, some of it fat-free mass along with the fat. Search the same page for declines with weight loss.

> *physical activity energy expenditure declines with weight loss unless its quantity or intensity increases to compensate.*

A smaller body doing the same daily activities spends less doing them. That is not a failure of anything.

WHERE THIS PICTURE BREAKS. "Bigger body, more expenditure" holds for resting and activity expenditure. It does not hold for the thermic effect of food, which follows what was eaten.

The pattern describes what is generally expected for a given body weight and composition.

MUST KNOW POINTS FOR YOU.

- Daily expenditure is not one thing. It is resting expenditure, usually the largest share; the thermic effect of food, the smallest; and physical activity expenditure.
- Resting expenditure rises with both fat-free mass and body fat. A person with more body fat generally has more fat-free mass too. So do not assume a person with obesity has a slow metabolism. The source reports the opposite. Their resting expenditure is generally higher in total than a leaner person's, in line with their larger body.
- Both resting expenditure and physical activity expenditure scale with body size. The energy it takes to keep a person at a steady weight is their maintenance requirement. It is set by that weight. So it does not hold once their weight has changed, and their fat-free mass with it. Expect it to fall as their weight falls.
- Knowing the three components does not give you a patient's requirement. Use them to check what any computed requirement has left out.

EXERCISE 1 (interpretation). A colleague says a patient with obesity must have a slow metabolism. Open Hall and Guo 2017 at https://pmc.ncbi.nlm.nih.gov/articles/PMC5568065/ and search for Contrary to popular belief. Say what that paragraph shows, and what it does not.

5 · The accounting identity for a body

DEFINITION. A person's body energy stores are a stock, in the sense Book 0 gives that word.

Draw the boundary at the mouth and skin, as Book 0, E3 shows for a person, and count intake at the metabolizable line: the energy that crosses in after the losses in faeces, gas and urine have already left, which Book 0, E2 defines.

The change in body energy stores over an interval equals the energy intake minus the energy expenditure over that same interval.

Whenever the two sides are computed correctly for the same boundary and the same interval, they match, with no exception and no remainder. A day on which they appear not to match is a day on which a route was left off one side, not a day on which the identity failed.

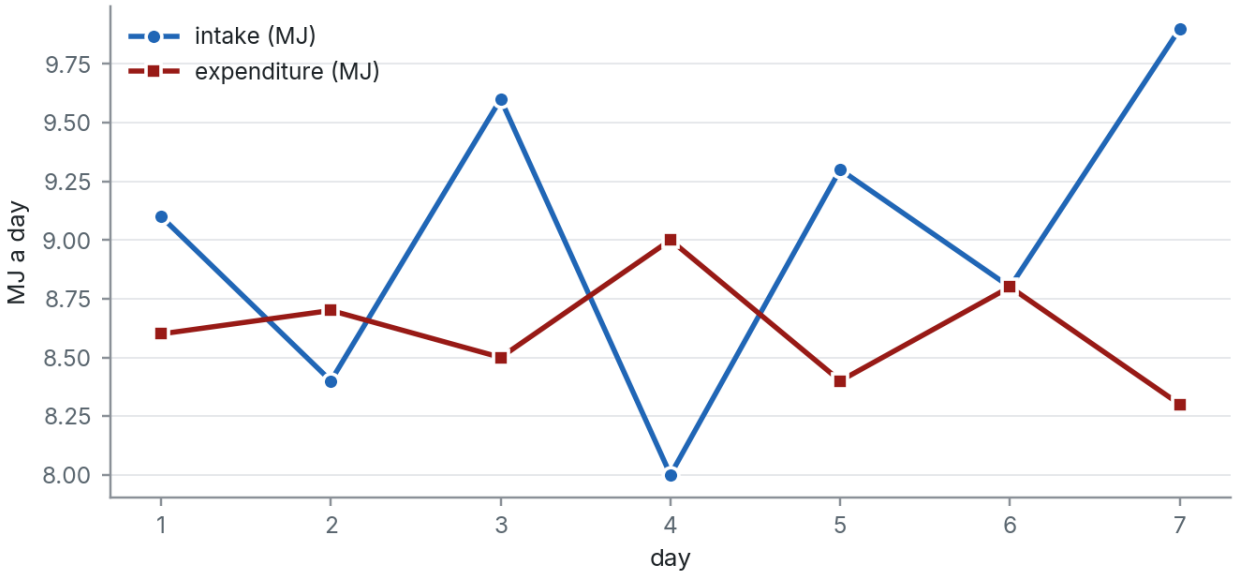
Because it is a balance line applied to one particular stock, the identity carries no direction and no cause. It says what the numbers must do. It does not say why intake or expenditure took the value it did. [54, 55, 56]

IN PLAIN TERMS. A body holds energy the way a bank account holds money. What you eat and drink is a deposit. Everything your body spends — moving, keeping warm, running your organs — is a withdrawal.

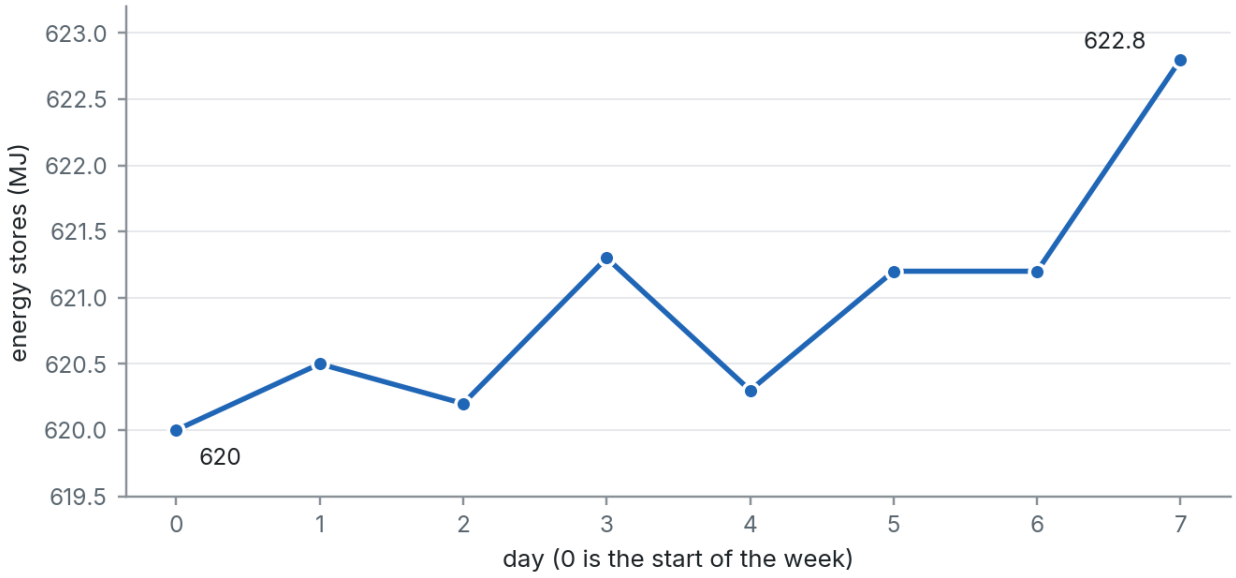
The balance changes only by deposits and withdrawals. Nothing else moves it.

How much your stores changed today equals what went in today, minus what went out today.

```
the change in body energy stores over the day = energy intake for the day minus energy expenditure for the day
```



The made-up week's two sides of the identity, in megajoules a day. On days where intake is above expenditure stores rose, where it is below they fell; the seven gaps add to 2.8 megajoules.



The same week as a stock. Stores start at 620 megajoules and each day move by that day's intake minus expenditure, ending at 622.8, 2.8 higher. A day of zero change, day 6, leaves the line flat. The axis does not start at zero, so small daily changes look large.

ILLUSTRATION. Take a made-up week, seven days, to see the identity used forwards and then checked backwards.

Suppose this person's energy stores stand at 620 megajoules at the start of the week. Each day their intake and expenditure, in megajoules, are recorded.

day	intake (MJ)	expenditure (MJ)
1	9.1	8.6
2	8.4	8.7

day	intake (MJ)	expenditure (MJ)
3	9.6	8.5
4	8.0	9.0
5	9.3	8.4
6	8.8	8.8
7	9.9	8.3

The change on each day is intake minus expenditure.

```
day 1: 9.1 minus 8.6 = 0.5
day 2: 8.4 minus 8.7 = -0.3
day 3: 9.6 minus 8.5 = 1.1
day 4: 8.0 minus 9.0 = -1.0
day 5: 9.3 minus 8.4 = 0.9
day 6: 8.8 minus 8.8 = 0
day 7: 9.9 minus 8.3 = 1.6
```

Sum the seven daily changes to get the change over the week.

```
0.5 plus -0.3 plus 1.1 plus -1.0 plus 0.9 plus 0 plus 1.6 = 2.8
```

Stores rose by 2.8 megajoules over the week. Add that to the starting figure.

```
620 plus 2.8 = 622.8
```

Stores stand at 622.8 megajoules at the end of the week.

Now check it the other way, the way an auditor would: sum all seven days' intake, sum all seven days' expenditure, and subtract the totals once, rather than day by day.

```
intake total: 9.1 plus 8.4 plus 9.6 plus 8.0 plus 9.3 plus 8.8 plus 9.9 = 63.1
expenditure total: 8.6 plus 8.7 plus 8.5 plus 9.0 plus 8.4 plus 8.8 plus 8.3 = 60.3
63.1 minus 60.3 = 2.8
```

Same 2.8 megajoules. It has to be: the identity holds on any interval, a day or a week, as long as intake and expenditure are counted over exactly that interval and nothing else changes the boundary.

Day 6 is worth a second look. Intake and expenditure matched exactly, and stores did not move that day. That is not a day on which nothing was happening in the body — catabolism and anabolism were both still running, as Book 0, E6 teaches. It is a day on which the two flows through the stock happened to be equal.

WHERE THIS PICTURE BREAKS. Not everything you eat is deposited. Part of it leaves in faeces, gas and urine before it reaches the account.

Body energy stores are not measured directly day to day; what gets measured is body mass, and turning a mass change into an energy change needs a further fact about what the mass is made of, which this record does not supply.

MUST KNOW POINTS FOR YOU.

- Write the day down. State the day, or the stretch of days, before you accept or quote a figure built from this identity.
- Intake in this identity is metabolizable intake, the figure that survives the losses Book 0, E2 names, not the gross energy a bomb calorimeter reports. A label's figure is already an estimate of metabolizable energy, for an average person, not for this one.
- A day when intake equals expenditure is still a day when the body is breaking down and building up. Zero change means the two matched, not that nothing happened.
- The identity holds on any interval you choose, provided intake and expenditure are both counted over exactly that interval. A day on which the scale seems to disagree with the identity usually reflects food still in the gut and water shifts, which move mass without moving stored energy.
- This identity fixes the arithmetic and answers no question about cause.

EXERCISE 1 (calculation). A patient's energy stores are 540 megajoules on the morning you first see them. Over the next ten days their average daily intake is 8.9 megajoules and their average daily expenditure is 9.4 megajoules.

Work out their energy stores at the end of the ten days. Then say in words what has to be true of their body mass for that change to show up on a scale.

PRACTICE. Eight problems on this technique, easiest first. Work them on paper before turning to the answers, which are in the appendix at the back under this section's name.

1. On a given day, energy intake is 380 and energy expenditure is 410, in the same units.

Work out the change in energy stores for that day.

2. Each row is one day. Two of the three numbers are given each time. Work out the missing one.

intake	expenditure	change in stores
500	470	
500		-20
	460	35
500	500	

3. Three United Nations bodies wrote a report together. They are the Food and Agriculture Organization (FAO), the World Health Organization (WHO) and the United Nations University

(UNU). The report gives a worked example. It puts a woman's total energy expenditure at 8.26 megajoules a day. That is for a woman who sits a lot or is lightly active (FAO/WHO/UNU 2004).

Take one made-up day. A woman with that expenditure takes in 8.80 megajoules. Count all of it as metabolizable energy. Work out the change in her energy stores that day, in megajoules. Say whether her stores rose or fell.

4. Take the same 8.26 megajoules a day as her expenditure (FAO/WHO/UNU 2004). Over a made-up run of 14 days at that same expenditure, her energy stores fall by 9.8 megajoules in total.

Work out her average daily metabolizable intake over those 14 days.

5. Here is a worked answer. Find the step that broke.

```
a laboratory reports that a sample of a snack holds 1,800 kilojoules, measured by
burning it in a bomb calorimeter
a person eats that snack and nothing else that day, so 1,800 kilojoules crosses into
their energy stores
their expenditure that day is 9,500 kilojoules
1,800 minus 9,500 = -7,700
so their stores fell by 7,700 kilojoules that day
```

6. Here is a worked answer. Find the step that broke.

```
on Monday, a patient's stores change by -0.4 megajoules
on Tuesday, their stores change by -0.6 megajoules
change over the two days = -0.4 minus -0.6 = 0.2
so their stores rose by 0.2 megajoules over the two days
```

7. A fitness app tells a user: "Your weight hasn't moved in three months, so your calories in and calories out are perfectly matched every single day."

Decide what to compute, compute it, and say what your answer does not establish.

8. A colleague in a meeting says this.

> *We put her on a diet supplying exactly 8.0 megajoules a day, and her measured expenditure is 8.5 megajoules a day. So her stores must be falling by 0.5 megajoules every single day of the diet.*

The figures are made up for this problem. Decide what to compute, compute it, and say what your answer does not establish.

6 · The first law for a body in one sentence, without a lever

DEFINITION. The one-sentence statement: a person's energy stores change only by the energy that crosses the boundary drawn round them, and the rate of that change equals energy intake minus energy expenditure. It is conservation of energy, the rule Book 0, E3 teaches, applied to a person. That rule says energy is never made or destroyed, only changed in form. Physicists call one version of it the first law of thermodynamics.

An identity of this kind constrains the numbers on either side of it and names nothing else. The inference most often attached to it — that eating less will therefore make a person's stores fall — does not follow from the identity alone. It needs a further premise, about what happens to expenditure and appetite when intake changes. The identity is silent on that. A lever is a handle you pull to get a result, and the identity gives you none. [55, 57]

IN PLAIN TERMS. Here is the whole identity again, in one line.

```
the change in a person's energy stores = energy intake minus energy expenditure
```

Read it as a rule about arithmetic, because that is all it is. It says the two sides have to match.

A step people take next, all the time, sounds almost like it follows from the line above. "So if you want your stores to stop rising, eat less." That step is a separate claim. It needs something the identity never supplied. Cutting intake has to lower the left-hand side, instead of expenditure falling just as far.

Whatever the true answer is, it has to come from evidence about bodies, not from the accounting line.

ILLUSTRATION. Lay the "eat less" step out the way Book 0, F4 teaches: premise, inference, conclusion. Then test the inference before you ask whether the premise is true.

Premise: the change in a person's energy stores equals energy intake minus energy expenditure.

Conclusion: if this person eats less, their energy stores will fall.

Now ask the inference test's question: does the conclusion follow?

It does not, not on the premise alone. The premise says nothing about what happens to expenditure if intake is reduced. If expenditure stayed exactly where it was, the conclusion would follow. If expenditure fell by the same amount intake fell, the difference would stay where it was. The conclusion would fail, while the identity held exactly as before.

Picture the missing premise written out loud, the way Book 0, F4's own illustration does it: "and expenditure does not fall by as much as intake did." A second premise hides behind it too: that the cut in intake can be held, whatever appetite does. People who make the "eat less" argument rarely say either sentence. Both premises do the work anyway, hidden. Both are claims about physiology, not consequences of the accounting line above them.

WHERE THIS PICTURE BREAKS. This illustration tests one inference, from one premise, and it does not settle whether "eat less" works as an instruction.

The inference that fails is the one that treats the identity as a lever.

MUST KNOW POINTS FOR YOU.

- When someone offers "energy in minus energy out" as the reason for an instruction, treat it as one premise of the argument. Then ask what has been assumed about expenditure that was never stated.
- The identity is consistent with every serious account of why energy stores, and with them weight, change. Every one of them can be written so the two sides balance.
- Say what changed, in energy terms, if you know it. Do not let the identity stand in for an account of why it changed, which you may not have.
- A trainee who has just learned this identity will reach for it. Asked why a patient's weight moved, they will answer "energy in, energy out". Watch for the sentence doing the work of an inference nobody has actually made.
- When a journalist repeats "it's just calories in, calories out", the accurate short reply is that the arithmetic is real and settles nothing about cause.

EXERCISE 1 (critique). A clinic pamphlet says: "Energy balance is simple physics: calories in minus calories out equals weight change. So weight change is entirely under a person's control."

Lay the argument out as a premise and a conclusion, in the style of Book 0, F4, and say whether the inference holds.

7 · Sizing an imbalance, and the static rule

DEFINITION. A kilogram of body fat is proposed to hold a fixed number of kilocalories. A surplus or a deficit of energy intake, summed over time, then converts into a change in fat mass at that fixed rate. Every other quantity is held constant for the interval this is applied to: the day's intake, the day's expenditure, and the energy content of a kilogram of fat itself. This is the static rule.

Its common English form is 3,500 kilocalories removed or added for each pound of body weight changed. The rule is stated for body weight, and it assumes every kilogram of that weight is fat tissue. The sources this book cites trace it to Wishnofsky (1958), cited by Thomas (2013) and Hall (2008). Hall and colleagues (2011) say it was "derived by estimation of the energy content of weight lost". Wishnofsky's estimate is the calculation section 2 describes: tissue taken to be 87% fat, times fat's energy per gram.

```
3500 divided by 0.45359237 = 7716.18
```

About 7,716 kilocalories per kilogram.

Given a daily surplus or deficit of D kilocalories, held at the same size for n days, the static rule predicts a change in fat mass of D times n, divided by 7,716, in kilograms. Because D is held fixed, the predicted change is a straight line against time: the same daily D always predicts the same rate of change, on day one and on day one thousand.

The rule fails for two separate reasons, and this section covers the second. First, real tissue lost is not all fat tissue, so no single kilocalories-per-kilogram figure holds for every kilogram lost; section 2 covers that. Second, and the reason a straight line is the wrong shape, intake and expenditure are not constant through a period of weight loss: both respond to the loss itself. [58, 59, 60, 12, 61]

IN PLAIN TERMS. Say a kilogram of fat is worth a fixed number of kilocalories. Eat that many fewer than you burn, and a kilogram should come off. That is the whole idea, and the number everybody has heard is 3,500 kilocalories for a pound.

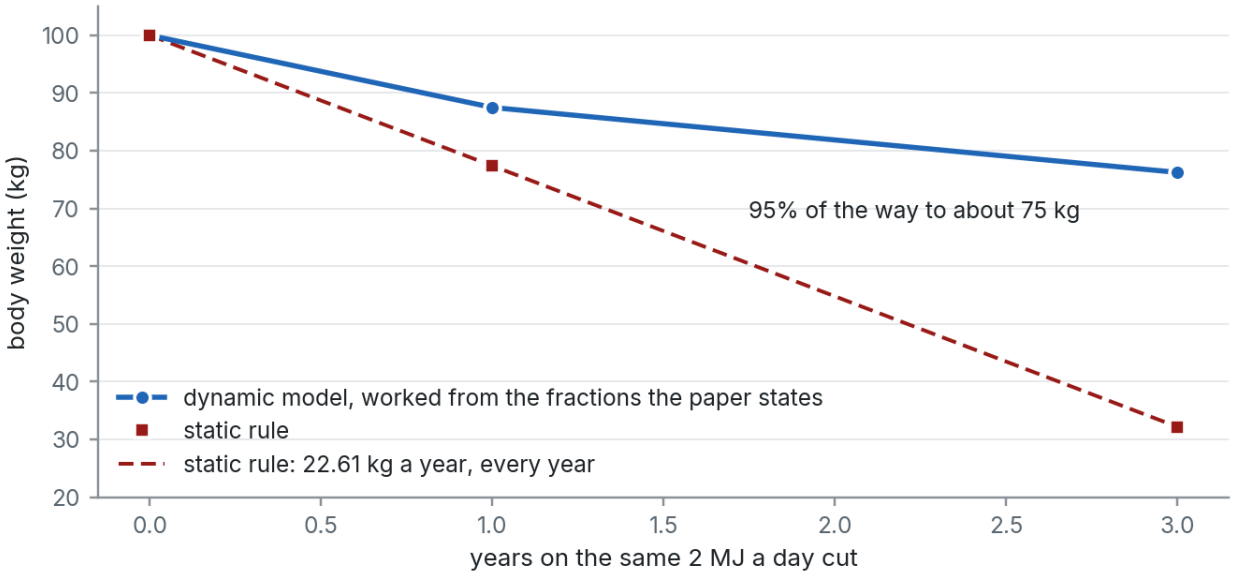
A pound is not the unit this course uses, so turn it into kilograms first. One pound is exactly 0.453 592 37 kilogram. Divide the 3,500 by that.

```
3500 divided by 0.45359237 = 7716.18
```

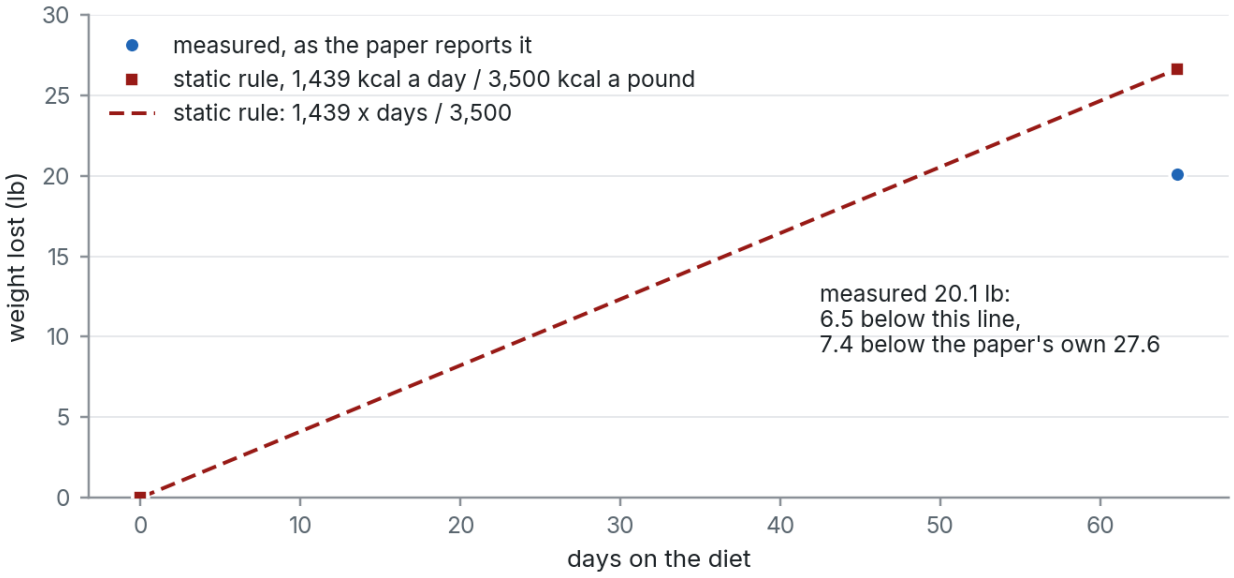
About 7,716 kilocalories for a kilogram. It is a calculation, not something anybody measured.

Pick a daily surplus or deficit, and hold it the same size every day. Multiply it by the number of days, and divide by 7,716.

Plot that against time and you get a straight line, because the daily amount never changes in the sum. Nobody's daily intake and daily expenditure sit still while they lose weight. A smaller body spends less.



Hall's 100 kg man cutting 2 MJ a day: the static rule's straight line loses about 22.61 kg every year. The dynamic model loses half of its 25 kg in year 1 and is 95% of the way to about 75 kg by year 3.



Thomas's cohort: 1,439 kcal a day for 64.8 days gives 26.64 lb on the static rule. Measured loss was 20.1 lb, 7.4 lb less than the paper's own 27.6 lb prediction.

ILLUSTRATION. Take the scenario Hall and colleagues (2011) use in the *Lancet* to make this point. A sedentary man weighing 100 kilograms cuts his energy intake by 2 megajoules a day and keeps it cut. One kilocalorie is 0.004184 megajoules, so divide by that.

```
2 divided by 0.004184 = 478.01
```

About 478 kilocalories a day. Run the static rule forward for one year.

```
478.01 times 365 = 174473.65
174473.65 divided by 7716.18 = 22.61
```

About 22.6 kilograms in the first year.

Now the failure. The paper's own dynamic model is built on energy balance, with expenditure allowed to change. For the same man on the same cut, it predicts weight levelling off towards about 75 kilograms. The model takes "roughly 1 year to reach half of the maximum weight loss". It is 95% of the way there after about three years.

model	weight change after one year
the static rule	about 22.6 kg
the dynamic model	roughly 11 to 12.5 kg (the paper: the static rule's 22 kg is about double)

The static rule is not merely optimistic here. It has the wrong shape. It says every year should look like the first, for as long as the deficit is kept up. The dynamic model says the loss slows and levels off. The man's expenditure falls as his body gets smaller. That shrinks the real deficit, even though his intake has not changed again.

Thomas and colleagues (2013) pooled 103 adults whose diets were supervised or whose intake was measured. Their prescribed deficit averaged 1,439 kcal a day. Work out what the static rule predicts they should lose over their average 64.8 days on the diet.

```
1439 times 64.8 = 93247.2
93247.2 divided by 3500 = 26.64
```

About 26.6 pounds. The paper's own figure is 27.6 pounds. The paper worked the rule out person by person and averaged. Multiplying two averages gives a slightly different number.

What they actually lost was 20.1 pounds: "Subjects lost 20.1±11.3 lbs, 7.4±12.6 lb less than the 27.6±16.0 lbs predicted by the 3500 kcal rule." The number after ± shows how widely people varied around the average. (27.6 minus 7.4 is 20.2. The 0.1 is rounding in the paper's figures.)

Figures quoted in this illustration are from [62, 63, 64].

WHERE THIS PICTURE BREAKS. The straight line holds only until intake and expenditure respond to the loss. No source here gives an interval over which it is safe. The Hall model puts half the eventual loss in the first year. Thomas's dieters already fell about a quarter short of the rule within about nine weeks.

MUST KNOW POINTS FOR YOU.

- Convert the unit before you argue about the number.
- A rule that holds a daily amount fixed and multiplies it by time always draws a straight line, whatever the real quantity does.
- The static rule's assumption that expenditure stays put is closest to true in the first days. Its assumption that the loss is fat is furthest from true then. Trust it for neither the first week nor the long run.
- When you tell a patient a target using this rule, say that it over-predicts from the first weeks.

- At the rule's 7,716 kcal, a kilogram of fat is two to four whole days of a person's total expenditure. That uses section 3's 8 to 16 megajoules a day.
- A figure like 3,500 kcal per pound being widely printed, including in textbooks, does not make it a measured property of fat.

EXERCISE 1 (calculation). A person keeps to a deficit of 600 kcal a day for 40 days. Using the static rule, work out the predicted loss in kilograms.

EXERCISE 2 (teaching). A health secretary has one page and wants an answer first. They have asked: "Is the 3,500-calorie rule good enough to put in a public information leaflet?"

PRACTICE. Eight problems on this technique, easiest first. Work them on paper before turning to the answers, which are in the appendix at the back under this section's name.

1. A rule says 3,500 kcal removes one pound. One pound is 0.45359237 kilogram. How many kcal per kilogram is that?

2. Using a rate of 3,500 for one unit, work out the total for 5 units, and separately for 12 units.

3. Thomas and colleagues' pooled dieters were prescribed an average deficit of 1,439 kcal a day. They were on the diet for an average of 64.8 days. Use the static rule's 3,500 kcal a pound to work out the predicted loss in pounds. Then convert it to kilograms. One pound is exactly 0.45359237 kg.

4. Hall and colleagues model a 100 kg sedentary man. He cuts his intake by 2 megajoules a day and holds that cut for a year. One kilocalorie is 0.004184 megajoules. Use that to turn the daily cut into kilocalories. Then run the static rule forward for 365 days at 7,716.18 kcal per kilogram. Compare your figure with the paper's static-rule prediction of "22 kg lost in the first year".

5. A textbook states: "The accumulation of an extra 3500 calories adds one pound of weight. If an excess of 200 calories per day is ingested, one extra pound of body weight will be gained every 18 days. At that rate, an extra 20 pounds can be gained over the course of a year." A student extends the reasoning. "So anyone eating 200 calories over their needs, every day, for the rest of their life, will gain 20 pounds a year, every year, forever." Find the step that broke.

6. Here is a worked answer. Find the step that broke.

```
a clinic wants a target for 8 kilograms of fat loss
the static rule gives 3,500 for a unit of weight change
8 times 3500 = 28,000
so the patient needs a total deficit of 28,000 kcal
```

7. A slimming programme's leaflet says: "Cut 500 calories a day and you will lose about a pound a week — in six months, that is 26 pounds off." Decide what to compute, compute it, and say what your answer does not establish.

8. A dietitian tells a patient: "Keep to 500 kcal under your target and you'll reliably lose a pound a week — do the maths yourself if you don't believe me." Decide what to compute, compute it, and say what your answer does not establish.

8 · Spotting a claim that breaks conservation

DEFINITION. A weight-loss claim breaks conservation when the fat change it asserts could not have happened, given the energy that could plausibly have crossed the boundary drawn round the person over the stated time.

First, draw the boundary and list the routes energy can cross it: in, as food and drink; out, as heat, as work done on things around the person, and in whatever is not absorbed.

Second, put a number on the claimed fat change. Use the static rule's conversion from section 7: 3,500 kilocalories (kcal) for each pound, about 7,716 for each kilogram (kg). Use it here because it is kind to the claim. Pure fat holds more, 39.5 megajoules a kilogram, about 9,440 kilocalories (section 2). So a claim that fails at 7,716 fails at 9,440 too.

Third, compare that amount with the largest deficit the person could plausibly have run over that time. A claim that needs more than the person's whole expenditure over the interval is impossible. One that needs more than any deficit people are known to manage is implausible. Neither verdict depends on the method claimed.

One case looks alarming and does not fail this test. The body stores some energy as glycogen (Book 0, E6). Hall and colleagues note that the energy stored per unit mass "varies considerably, especially when accounting for the intracellular water associated with stored glycogen and protein". Glycogen holds 17.6 megajoules a kilogram, less than half of fat's 39.5. The water stored with it holds none. Cutting carbohydrate also changes how much salt, and so fluid, the kidneys let go.

So fast early loss, especially when carbohydrate is cut, can be largely glycogen, its water and that fluid. Glycogen's share comes in the first week. None of this is a violation. It is a different substance leaving, at a far lower energy cost per kilogram than fat. [65, 66, 67, 18, 68, 69, 70, 71, 72, 73]

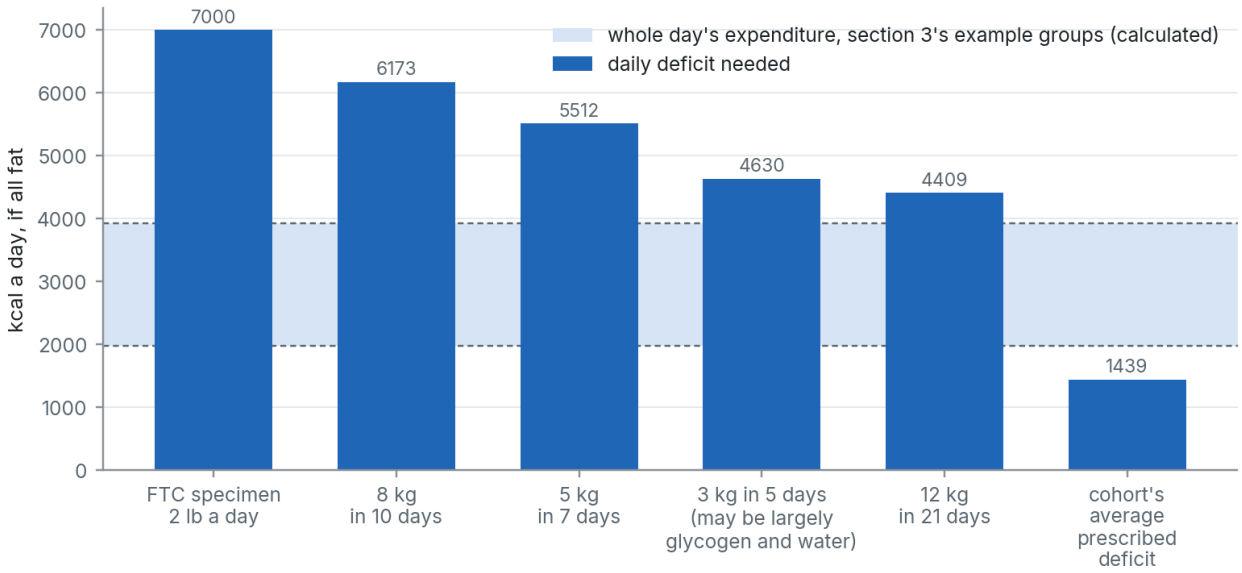
IN PLAIN TERMS. You do not need to know anything about the diet to check. You need three things: a boundary, a number, and a limit.

Draw the boundary round the person.

Turn the claimed fat change into an energy number. Use the rate from the previous section: 3,500 kilocalories for a pound, about 7,716 for a kilogram.

Now the limit. Over any stretch of time, the biggest deficit a person can run is their whole expenditure for that stretch. You cannot eat less than nothing. If a claim needs more than that, it is impossible. If it needs more than any deficit people are known to manage, it is implausible.

One thing looks like a violation and is not. The body stores some energy as glycogen, and stores it with water. Cut carbohydrate, and glycogen, its water and some extra fluid can leave fast. Glycogen's part comes in the first week. Fast is not the same as impossible.



Daily deficit each claim needs if every kilogram lost were fat. The shaded band is the whole day's expenditure section 3's worked examples calculate for their groups, 1,975 to 3,925 kcal, not a measurement. Every claim needs more, so for anyone like those groups none can be all fat. The US Federal Trade Commission (FTC) specimen needs about 4.9 times the 1,439 kcal a day average prescribed deficit of Thomas's cohort.

ILLUSTRATION. Open the US Federal Trade Commission's (FTC) "Gut Check" guide to spotting false weight-loss claims, at https://www.ftc.gov/business-guidance/resources/gut-check-reference-guide-media-spotting-false-weight-loss-claims. Its examples are the FTC's own specimens of a claim type. They are not real advertisements. Treat each one as a specimen handed to you to test, never as proof that a real product said it.

Claim 1's own example reads: "Lose up to 2 pounds a day without diet or exercise."

Turn 2 pounds a day into an energy requirement using the static rule.

```
2 times 3500 = 7000
```

7,000 kilocalories a day, every day, as fat alone.

Now the hard ceiling. Even eating nothing, your deficit cannot beat your whole expenditure. The worked examples in section 3 put a whole day's expenditure at 1,975 to 3,925 kilocalories for their example groups. These are calculated, not measured. 7,000 is more than that. So for anyone like them, the claim is impossible as fat.

It is also far past what people manage. Thomas and colleagues pooled 103 adults whose intake was supervised or measured. Their average prescribed deficit was 1,439 kilocalories a day. The claim needs roughly five times that. And it says this happens "without diet or exercise", naming no route for the energy at all.

Take a made-up case. A person starting a low-carbohydrate diet loses 3 kilograms in the first five days. Using the static rule, that would require:

```
3 times 7716.18 = 23148.54
23148.54 divided by 5 = 4629.71
```

About 4,630 kilocalories a day. That is also above that range, so for anyone like them it is impossible as fat. But the loss need not be fat. Much of it can be glycogen, its water, and fluid the kidneys let go. The fat rate does not apply to those.

Figures quoted in this illustration are from [74, 75, 62].

WHERE THIS PICTURE BREAKS. This test rules claims out; it does not rule anything in.

MUST KNOW POINTS FOR YOU.

- A deficit is bounded above by total expenditure for the period, because intake cannot go below zero.
- A claim that names no route — "without diet or exercise" is the common wording — has not said which crossing changed. Ask: did intake fall, and how? Did output rise, and how? If the answer is "neither", conservation (Book 0, E3) rules it out.
- Fast early weight loss, especially when carbohydrate is cut sharply, is often real. It can be largely glycogen, the water stored with it, and fluid the kidneys let go. It is not all fat.
- When a journalist brings you a headline figure, ask for the time period before doing anything else.
- This check clears a claim of one specific defect, an energy impossibility. Say what the check did and did not do, every time you report its result.

EXERCISE 1 (critique). Here is a magazine advertisement, invented for this exercise. It reads: "Our patch helped users lose 1 pound a day for 10 days — with no change to diet or exercise." Say what is wrong with the claim, and what you would ask the advertiser for.

EXERCISE 2 (teaching). A first-year resident has ten minutes and a whiteboard. They ask: "A patient tells me they lost 5 kilograms of pure fat in one week eating normally. How do I know if that's even physically possible before I ask about their diet?"

PRACTICE. Eight problems on this technique, easiest first. Work them on paper before turning to the answers, which are in the appendix at the back under this section's name.

1. A claimed weight change is 6 units of mass, said to be entirely fat. Using a rate of 3,500 for each unit, work out the total energy the claim requires.

2. A claimed energy crossing totals 24,500. The rate is 3,500 for each unit of mass. Work out how many units of mass that could account for, if the crossing were entirely fat.

3. The FTC's own Claim 1 specimen wording reads "Lose up to 2 pounds a day without diet or exercise." This is the regulator's illustration of a false claim type, not a real advertisement. Using the static rule, work out the daily energy requirement the specimen implies, in kilocalories, treating the claimed loss as entirely fat.

4. Thomas and colleagues' pooled cohort was prescribed an average deficit of 1,439 kcal a day, with intake supervised or measured. Work out what multiple of that deficit the 7,000 kcal a day figure from the previous problem represents, to one decimal place.

5. Here is a worked answer. Find the step that broke.

```
a claim says a person lost 4 kg of fat in a week eating nothing but water
the body obeys the laws of physics, and energy is conserved
so wherever the 4 kg's worth of energy went, it had to come from somewhere
therefore the claim must be true, because energy cannot simply vanish
```

6. Here is a worked answer. Find the step that broke.

```
a person starts a strict low-carbohydrate diet and loses 2.5 kg in the first four
days
the static rule needs 7716.18 kcal per kg
2.5 times 7716.18 = 19290.45
19290.45 divided by 4 = 4822.61 kcal/day required
nobody can run a deficit that size for four days, so the reported loss must be fab-
ricated
```

7. An invented social media post says: "I lost 8 kg of pure fat in 10 days on this new plan. That proves calories don't matter, only what you eat does." Decide what to compute, compute it, and say what your answer does not establish.

8. A colleague at a conference says: "A patient of mine dropped 12 kg in the first three weeks after weight-loss (bariatric) surgery. With the tiny amount they're eating, that's clearly just calories in versus calories out. Nothing else is going on." The patient weighed 140 kg before surgery (a made-up figure). Decide what to compute, compute it, and say what your answer does not establish.

9 · Intake and expenditure are outputs of a regulated system

DEFINITION. Energy intake and energy expenditure are not two independent dials a person sets and then leaves alone. They are outputs of a system that senses body weight, or a signal that tracks it, and pushes back when weight falls. Cut intake, and two things move against the cut.

Expenditure falls by more than the loss of fat and lean mass alone accounts for. After a person sustains a loss of 10% or more of body weight, 24-hour energy expenditure falls by about 20% to 25%, and expenditure ends up about 10% to 15% lower than the change in fat and lean mass alone would predict. The extra fall is the adaptive part: a formerly heavier person now needs roughly 300 to 400 fewer kilocalories (kcal) a day than a person of the same weight and composition who was never heavier. How long this lasts is still disputed.

Appetite rises. Per kilogram lost, eating rises by about 100 kcal a day, more than three times the fall of about 30 kcal a day in expenditure. So the appetite response, not the metabolic one, is the larger of the two.

Both responses run in the direction that returns stored energy toward where it was. [76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88]

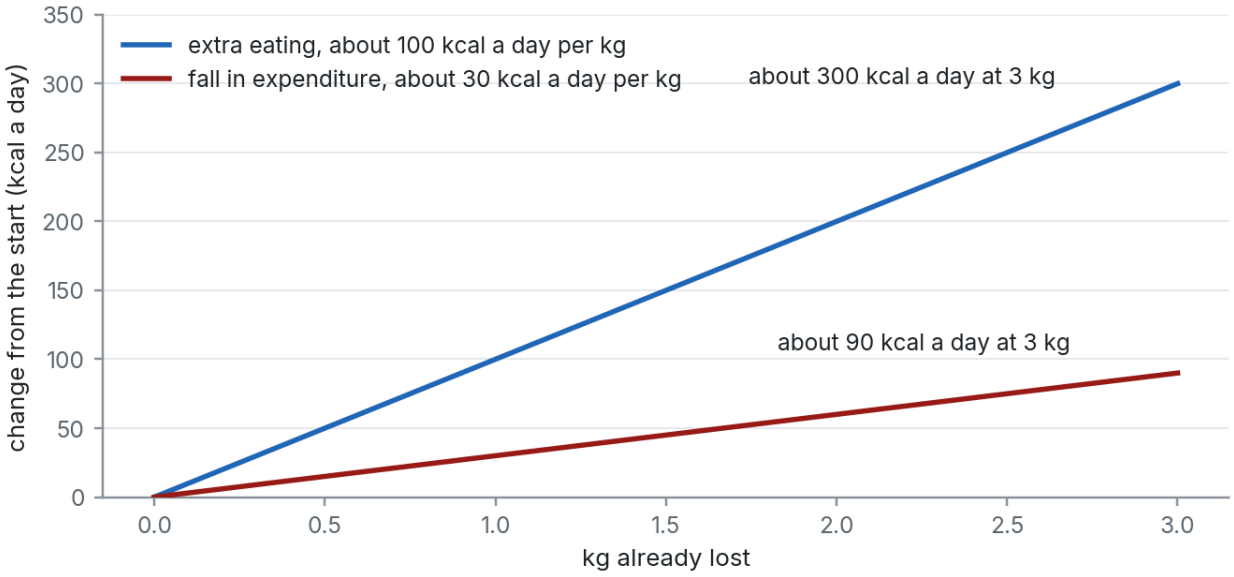
IN PLAIN TERMS. Cut what you eat, and two things start moving against you.

Lose a tenth of your body weight and keep it off, and your daily expenditure drops by about a fifth to a quarter. Some of that drop is exactly what a smaller body should cost to run. The rest is extra: expenditure ends up about 10 to 15% lower than a body of that new size would need.

At the same time your appetite rises. Appetite, not metabolism, does most of the pushing back.

Neither of these is the person's character failing.

How large the pushback is probably varies between people. The trial behind the appetite estimate reported only a group average.



Per kilogram lost, extra eating rises by about 100 kcal a day and expenditure falls by about 30 kcal a day. For the made-up person 3 kg lighter, that is about 300 against about 90 kcal a day. Both lines are fitted slopes, not measurements of one person.

ILLUSTRATION. Take the trial behind the 100 kcal figure, analysed by Polidori and colleagues (2016). It ran for 52 weeks, in 153 people with type 2 diabetes, a condition in which blood glucose runs high. Each took a drug that makes the kidneys pass glucose out in the urine instead of keeping it.

Body weight was measured repeatedly over the year. The researchers worked back, from how weight actually moved, to how much people must have been eating. They found intake climbing as weight fell: close to 100 kcal a day of extra eating for every kilogram already lost.

In the studies Rosenbaum and Leibel review, people holding a loss of a tenth or more of their body weight needed 300 to 400 fewer kcal a day than someone who had always weighed that much. That is the expenditure side of the same loop.

Now compare the two, kilogram for kilogram. Take a made-up person 3 kg lighter than they started, within the several kilograms the trial's average loss reached. Before any loss, both changes are 0. At 3 kg, extra eating is 3 times 100 kcal, about 300 kcal a day. The fall in expenditure, at about 30 kcal a day per kilogram, is 3 times 30, about 90 kcal a day. Eating has moved more than three times as far.

Figures quoted in this illustration are from [89, 90, 91].

WHERE THIS PICTURE BREAKS. The 100 kcal per kg figure is a slope fitted to one trial's group average, in adults with type 2 diabetes losing weight slowly over a year through glucose loss in urine, not from dieting. The trial did not measure expenditure: the 30 kcal per kg comes from oth-

er studies, of losses of 10 to 20%. Its authors do not yet know whether the slope holds over a range of weight losses, so the worked case stays within the several kilograms the trial saw.

MUST KNOW POINTS FOR YOU.

- "Cut intake and weight keeps falling at the same rate" is incomplete. Treat a plateau in weight loss as the expected output of this loop, not as proof the patient has stopped trying.
- A conversation about "slower metabolism" that never mentions rising hunger is describing the smaller half of what the patient is fighting.
- A formerly heavier person needs roughly 300 to 400 fewer kcal a day than someone who was always that weight, to hold the same weight. How long that lasts is still disputed.
- Do not quote the 100 kcal per kg or the 300-400 kcal figures to a patient as what will happen to them.

EXERCISE 1 (critique). A colleague says: "This patient's weight loss has stalled because they've stopped sticking to the diet. The arithmetic hasn't changed, so the only thing that can have changed is their behaviour." Using this section, say what is wrong with that inference.

10 · Arithmetically true, practically insufficient

DEFINITION. "Eat less, move more" is usually offered as an argument with an unstated premise. Written out in full, its eat-less half runs like this. Premise one: the rate of change of stored energy equals intake minus expenditure. Premise two, unstated: once intake is cut, expenditure and appetite stay where they were. Premise three: a fall in stored energy shows up as a fall in weight. Conclusion: cutting intake is a sufficient instruction for losing weight.

The inference holds: grant every premise and the conclusion follows. What fails is premise two, which is false. Once a person acts on the instruction, expenditure and appetite move. They move in response to the fall in body weight, or a signal that tracks it, in the direction that opposes it, as section 9 shows.

This is not a claim that the accounting is wrong. [92, 93, 94, 76, 95]

IN PLAIN TERMS. Stores go up when intake is bigger than expenditure, and down when it is smaller. So cut intake, with expenditure unchanged, and stores must fall.

But the instruction says more than the arithmetic does. It quietly assumes expenditure does stay unchanged. Cut intake, and expenditure itself falls, further than the lost weight alone explains. Appetite rises, and pulls harder than expenditure falls.

ILLUSTRATION. Suppose a newspaper runs a quote like this from a doctor: "Weight loss is just maths. Calories in, calories out. If someone isn't losing weight, they aren't sticking to the plan."

Premise one: stored energy changes at a rate equal to intake minus expenditure. True; it is the identity.

Premise two, left unsaid: once intake is cut, expenditure and appetite stay where they were.

Premise three, also unsaid: a fall in stored energy shows up as a fall in weight. True; the stores are body tissue (section 1).

Conclusion: a person not losing weight has not really cut intake.

The evidence in this book says premise two is false. Expenditure falls as weight falls, and further than the lost mass explains. So a held cut produces a loss that slows and stops. Appetite rises as well. That is why the cut is so hard to hold, and why a stall is no evidence about effort.

The doctor's quote does not misstate the arithmetic. It misstates what follows from it, by adding a premise that was never checked and is not true.

WHERE THIS PICTURE BREAKS. This section shows the instruction rests on a false premise; it does not say the instruction never works. Some people do lose weight and keep it off this way, with long-term, sustained effort.

MUST KNOW POINTS FOR YOU.

- The identity is never in dispute and is never what breaks. State the identity and the instruction as two separate claims, every time, so the second one can be checked rather than assumed.
- "They must not be sticking to it" is the same unlicensed move as the instruction itself: an observation (the scale has stalled) explained by inventing a premise (lack of effort) instead of checking the one already shown to be false.
- You can give this whole argument to a non-specialist in about three minutes, using no mechanism and no moral claim: the accounting is true, the instruction adds an assumption, the assumption is false, and the difficulty that follows is physiological.
- Do not turn this argument into advice for a patient; it says what the arithmetic cannot license, not what to do instead.

EXERCISE 1 (teaching). A health secretary has one page and wants the one paragraph they can put in front of a minister who has just said "obesity is simple, it's calories in versus calories out." Write it. No methods section, answer first.

EXERCISE 2 (build). Write a one-page explanation of why energy balance is arithmetically true and practically insufficient. State the identity, name the instruction people draw from it, name the unstated premise, and say what the evidence in this book shows about that premise. No mechanism, no verdict on any individual's effort. Then read it to a non-medical reader and note where they stopped you to ask a question. You should be able to give the same explanation from memory in about three minutes.

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Appendix · Worked answers

2 · How much energy a kilogram of body fat holds

1. Multiply each fraction by 9.0.

```
0.80 times 9.0 = 7.2
0.60 times 9.0 = 5.4
```

7.2 and 5.4.

2. A megajoule is a thousand kilojoules, so kilojoules to megajoules means dividing by 1,000.

```
34000 divided by 1000 = 34
```

34 megajoules.

Megajoules to kilojoules means multiplying by 1,000.

```
2.5 times 1000 = 2500
```

2,500 kilojoules.

3. Divide the larger by the smaller.

```
39.5 divided by 7.6 = 5.197368421
```

Round once, at the end: about 5.2 times larger.

4. Scale the gram figure to a kilogram first.

```
9.0 times 1000 = 9000
```

9,000 kilocalories a kilogram. Convert to megajoules.

```
9000 times 0.004184 = 37.656
```

37.656 megajoules a kilogram. That is close to the 37 FAO prints, not equal: 9.0 and 37 are rounded separately.

5. Put both figures in kilojoules first. 39.5 megajoules is 39,500 kilojoules.

```
39.5 times 1000 = 39500
```

Divide by the size of one kilocalorie in kilojoules.

```
39500 divided by 4.184 = 9440.73
```

About 9,440.7 kilocalories a kilogram, close to but not the same as FAO's 9,000. The two describe different fat: FAO's is fat eaten, corrected for what digestion loses; Hall's is fat already stored in the body.

6. Multiply the assumed fraction by the energy per gram.

```
0.87 times 37 = 32.19
```

32.19 kilojoules a gram, which is the same number in megajoules a kilogram: 32.19 MJ/kg.

Hall's 32.2 MJ per kg is the rule itself in megajoules ("equivalently"). 32.19 lands near it, but that confirms nothing. Try FAO's precise 37.4, and Hall's 39.5.

```
0.87 times 37.4 = 32.538
0.87 times 39.5 = 34.365
```

32.5 and 34.4. Hall does not say which figure for fat the original calculation used. The sum shows the size of the effect an 87% assumption has, not how the rule was built.

7. The step that broke is the third. 39.5 megajoules a kilogram is pure fat's own energy density, from Hall (2008). The 4 kilograms the patient lost is not 4 kilograms of pure fat. It is adipose tissue plus some lean mass; Hall (2008) notes that lean mass is lost alongside fat. Even the adipose tissue is diluted by whatever part of it is not triglyceride.

Using 39.5 on a figure that is not pure fat overstates the deficit. Even taking the rule's own assumed adipose figure, 32.2 MJ/kg, instead:

```
4 times 32.2 = 128.8
```

128.8 megajoules, noticeably below 158 — and this second number still rests on an unverified 87% assumption, so neither figure should be reported as if it were exact.

Why the wrong answer looks reasonable. 39.5 is a real, correctly quoted figure from a cited source, and the multiplication is arithmetically correct. What is missing is the check this whole section turns on: which kilogram, pure fat's or adipose tissue's, the 4 kilograms lost actually refers to.

8. The step that broke is the last. Closeness between the two figures is not confirmation, and the direction of the gap says the opposite of the conclusion.

7,700 is lower than 9,000 because the rule assumes adipose tissue is less than 100% fat.

```
9000 minus 7700 = 1300
```

That 1,300 kilocalories a kilogram is roughly the dilution the rule assumes, not evidence that there is none. 7,700 is the rule's own figure, which Hall traces to an assumed 87% fat.

```
0.87 times 9000 = 7830
```

0.87 times 9,000 gives 7,830, the same neighbourhood.

Why the wrong answer looks reasonable. Both figures are real and correctly quoted, and "close, so consistent" is a reasonable-sounding move in other settings. Here it inverts the relationship: the two numbers are close because the rule assumes a fraction near 1, not because two separate measurements agree.

9. What to compute: the arithmetic as stated, and then which of the two things "a kilogram of fat" could mean in it.

```
9000 times 5 = 45000
```

45,000 kilocalories, exactly the colleague's figure — if 9,000 is the right rate to use for the 5 kilograms in question.

9,000 kilocalories a kilogram is FAO's figure for fat in food. It is not the figure for adipose tissue, which the static rule puts at about 7,700. Using the adipose figure instead:

```
7700 times 5 = 38500
```

38,500, noticeably below 45,000.

What this does not establish. It does not establish which of the two figures, or some other one entirely, is right for this patient's 5 kilograms, because that depends on whether the 5 kilograms is being treated as pure triglyceride or as adipose tissue, and on how much of it is fat-free mass at all — a question this section does not answer and section 1 says a scale cannot answer either. It does not establish that 7,700 is a measured figure either: it carries the same unverified 87% assumption this section has flagged throughout.

What to say to the colleague: name which kilogram, pure fat's or adipose tissue's, before quoting either number.

10. What to compute: whether Hall (2008) reports 7,700 kcal/kg (about 32.2 MJ/kg) as a confirmed finding, or as something else, and whether the arithmetic behind it is a measurement.

Check the figure against the paper's own words. Hall (2008) states the static rule "can be traced back to a calculation that assumes exclusive loss of adipose tissue consisting of 87% fat." Run that assumption through FAO's fat factor, and through Hall's.

```
0.87 times 37 = 32.19
0.87 times 39.5 = 34.365
```

32.19 megajoules a kilogram lands near the paper's "32.2 MJ per kg", which is the rule itself in megajoules. That confirms nothing: with Hall's 39.5 the same sum gives 34.4, and Hall does not say which figure for fat the original calculation used. The sum shows the size of the effect an 87% assumption has, not how the rule was built.

The word "traced" is doing the opposite of the word "confirmed". Hall (2008) is explaining where an existing rule's number came from, an assumed 87%, and then goes on to warn that the change in body fat "is not equivalent to the loss adipose tissue, which includes a variable contribution of fluid and protein in addition to triglyceride." A paper that calls a composition variable, right after naming the fixed figure a rule assumes, is not confirming that figure.

What this does not establish. It does not establish that 87% is wrong for any particular patient. Nor that the paper rejects the rule. Hall does compare the rule with weight-loss studies. The rule roughly fits people with obesity and more than 30 kg of body fat, and overstates the deficit for leaner people. And it does not tell you what a real, measured lipid fraction for adipose tissue would be, because no source this book cites reports one.

What to say about the brochure: "confirmed" is wrong. The paper traces the number to an assumption and calls the real composition variable. "Roughly right for some patients, by comparison with data" is what the paper says.

3 · A day of intake and a day of expenditure: the sizes

EXERCISE 1. (a) An adopted requirement: ICMR-NIN 2020, for a 55 kg reference woman doing sedentary work, calculated as BMR times PAL. It does not tell you what a particular woman needs. The committee's own table says to adjust for actual weight and activity, and the sentence has dropped "sedentary" as well.

1. A survey estimate of consumption: NSS Report 594, all-India urban, per person, 2023-24. It is the food households recorded as consumed, converted to energy with a conversion table. It

does not tell you what any one person ate, and the report says actual intake depends on how the food is processed and cooked. It is also per person, not per consumer unit, so it does not allow for age and sex.

2. A calculated spend: the FAO/WHO/UNU worked example. It multiplies a PAL of 1.53 by a BMR of 5.40 megajoules, for a hypothetical group of 55 kg women aged 30 to 50. It is not a measurement, and it is a group's average, not one woman's day. Measuring it would take doubly labelled water.

4 · What expenditure is made of, and why a bigger body spends more

EXERCISE 1. It shows the colleague has the direction wrong. People with obesity generally have a higher absolute REE, not a lower one. Fat-free mass is elevated in obesity along with body fat, and REE is linearly related to both.

It does not show that metabolism is fast for the body's size. The paragraph says the elevated REE is "generally in line with what is expected for the body weight and composition". So it is higher because the body is bigger, not because it spends more than its size predicts.

It also says "generally". It does not tell you this patient's REE. Only a measurement would.

5 · The accounting identity for a body

EXERCISE 1. Find the average daily change first, then multiply by the number of days, the accumulation move from Book 0, C8.

```
8.9 minus 9.4 = -0.5
-0.5 times 10 = -5
```

Stores fall by 5 megajoules over the ten days.

```
540 minus 5 = 535
```

535 megajoules at the end of the ten days.

To see this on a scale, the 5 megajoules must have come out of tissue the scale weighs. You would also need to know how many megajoules a kilogram of that tissue holds before converting. That figure is in section 2.

1. Apply the identity: change equals intake minus expenditure.

```
380 minus 410 = -30
```

Minus 30 for the day. Stores fell by 30 units.

2. Use the identity in whichever direction the missing number sits.

Row 1. Intake minus expenditure.

```
500 minus 470 = 30
```

Row 2. Change equals intake minus expenditure, so expenditure equals intake minus change.

```
500 minus -20 = 520
```

Row 3. Intake equals change plus expenditure.

```
35 plus 460 = 495
```

Row 4. Equal intake and expenditure.

```
500 minus 500 = 0
```

Zero change. Notice that the row 4 answer says nothing about whether either flow was large or small, only that they matched.

3. Apply the identity in megajoules.

```
8.80 minus 8.26 = 0.54
```

Her stores rose by 0.54 megajoules that day.

4. Find the average daily change first.

```
9.8 divided by 14 = 0.7
```

Her stores fell by an average of 0.7 megajoules a day, so the daily change is minus 0.7.

Rearrange the identity for intake: intake equals change plus expenditure.

```
-0.7 plus 8.26 = 7.56
```

Her average daily intake was 7.56 megajoules.

5. The second step broke. The bomb-calorimeter figure is not what crossed into this person's stores.

Book 0, E2 draws a line between two kinds of energy. One is gross energy, what a calorimeter reports for the food. The other is metabolizable energy, what actually reaches the body. In between, some is lost in faeces, gases and urine. The identity takes intake at the metabolizable line. So some of the 1,800 kilojoules left the body unused. It never reached the stores.

So the third and fourth lines do a correct sum on the wrong number. The subtraction is fine. The 1,800 was never the right figure to subtract from.

What the correct working needs: how much of the 1,800 kilojoules the body took up. The laboratory's figure does not say. Without it, you cannot work out the change in stores that day. You can only set an upper limit on it.

Why the wrong answer looks reasonable. Every step after the second is correct. The units match all the way through. A real energy figure sits at the top. The fault is a line nobody wrote: which boundary the "1,800 kilojoules" was measured across.

6. The step that broke is the third. Two daily changes are accumulated by adding them, the move from Book 0, C8, not by subtracting one from the other.

```
-0.4 plus -0.6 = -1.0
```

Stores fell by 1.0 megajoules over the two days, not rose by 0.2.

The fourth line compounds the error by reading a positive number off an arithmetic slip and reporting it as a rise, when both individual days were already falls. A change over an interval cannot be a rise if every day inside that interval was itself a fall. That alone is a reason to have gone back and checked the third line before trusting the fourth.

Why the wrong answer looks reasonable. Both daily figures are correctly signed, and the working has the shape of a calculation with a "minus" sign in it, which reads as careful. But it is not the identity's own move. To total a run of changes, you add them, as in Book 0, C8. You never subtract one day's change from another's.

7. What to compute: whether a steady total over three months requires every day inside it to balance individually. The identity accumulates day by day, Book 0, C8's move, so the question is whether a zero sum forces every term to be zero.

It does not. Take three made-up months as 90 days. Suppose, generously, that a steady weight means the sum of the 90 daily changes is zero, or close enough to it that no change is detectable on a scale.

```
the sum of 90 daily changes = 0
```

That sum can be reached by 90 days each near enough to zero. It can also be reached by 45 days each up by 0.3 megajoules and 45 days each down by 0.3 megajoules. Or a large early rise can be cancelled by a later fall. All three give the same three-month total.

What this does not establish. It does not establish that any single day balanced, only that the 90 days added to roughly zero. It does not even establish that stores were steady. A steady weight can hide fat lost and lean tissue gained, which hold different energy per kilogram (section 2).

It does not establish that intake and expenditure were each steady either. Both could have moved together and kept their difference near zero throughout. And it says nothing at all about what caused the total to land near zero. That is exactly the question this section's definition says the identity cannot answer.

What to say instead of the app's sentence: a steady weight over three months suggests, at most, that the account roughly balanced over three months. It is not a day-by-day claim, and it is not a claim about why.

8. What to compute: are the two figures the ones the identity needs? They must be on the same boundary and for the same day.

Run the identity with both figures at face value.

```
8.0 minus 8.5 = -0.5
```

You get minus 0.5 megajoules a day. That is the colleague's figure, if both numbers are what the identity needs.

Now check what each number is. "Supplying 8.0 megajoules" is very likely what the diet plan gives her. That is not always the metabolizable energy that reaches her stores. Some food served is not eaten. Some food eaten is not absorbed.

Then the "measured expenditure" of 8.5 megajoules a day. If it comes from a method like doubly labelled water, it is an average over several days. It is not a figure for one day. Neither gap makes the sum wrong. Both mean the 0.5 megajoules a day is a model's guess dressed up as a daily measurement.

What this does not establish. It does not show that her stores fall by exactly 0.5 megajoules on every day of the diet. This section's illustration shows daily changes from -1.0 to 1.6 megajoules within one week. It does not show that 0.5 megajoules a day goes on once her weight has changed. The 8.5 megajoules is unlikely to stay fixed, because a smaller body spends less (section 4). And it shows nothing about where the shortfall came from, or why intake and expenditure took the values they did.

What to say in the meeting: the sum is fine as a same-day estimate. "Every single day" and "must be" are claims the two numbers do not support.

6 · The first law for a body in one sentence, without a lever

EXERCISE 1. Premise: the change in energy stores equals intake minus expenditure. Conclusion: weight change is entirely under a person's control.

The inference does not hold. Granting the premise fully changes nothing about whether either side of it is under anyone's control. Expenditure includes resting expenditure (section 4), which is not chosen. Nothing in the identity says the two sides move independently. "The two sides must balance" and "a person can freely set either side" are different claims. Only the first follows from physics.

The pamphlet needed a further premise — that intake and expenditure each respond only and fully to choice — and did not state it. Stated aloud, it is the premise a reader can actually check.

The pamphlet also writes "weight change" where the identity says "change in energy stores". Getting from one to the other means knowing what the lost or gained tissue is made of (section 1, section 2).

7 · Sizing an imbalance, and the static rule

EXERCISE 1. Total the deficit, then divide by the per-kilogram rate.

```
600 times 40 = 24000
24000 divided by 7716.18 = 3.11
```

About 3.1 kilograms predicted, on the static rule's own terms.

EXERCISE 2. Answer first: not as a bare rule. If it goes in at all, it needs a warning that it promises too much.

Why. The rule is simple arithmetic, and it is printed widely, including in nutrition textbooks. Even over the first two months it over-predicts: dieters whose intake was checked lost about three-quarters of what it promised. Past the first year it is further off. The rule assumes intake and expenditure never change. A published model built on energy balance predicts a loss that slows and levels off. In that model's worked example, the rule's first-year number is about double the model's.

What to print instead of the bare rule. Real loss falls short of the rule from the start. It slows over time. A smaller body needs less to maintain itself. Quote no week-fifty-two number from this rule at all.

1. Divide the kilocalories by the kilograms.

```
3500 divided by 0.45359237 = 7716.18
```

7,716.18 kcal per kilogram, to two decimal places.

2. Multiply the rate by the count each time.

```
3500 times 5 = 17500
3500 times 12 = 42000
```

17,500 and 42,000.

3. Total the deficit over the days, then divide by 3,500.

```
1439 times 64.8 = 93247.2
93247.2 divided by 3500 = 26.64
```

26.64 pounds predicted. Convert to kilograms by multiplying by the exact factor.

```
26.64 times 0.45359237 = 12.08
```

About 12.08 kilograms.

4. Divide the megajoules by the size of one kilocalorie in megajoules.

```
2 divided by 0.004184 = 478.01
```

About 478.01 kcal a day. Total it over the year and divide by the per-kilogram rate.

```
478.01 times 365 = 174473.65
174473.65 divided by 7716.18 = 22.61
```

About 22.6 kilograms, against the paper's 22 kilograms. The two are close. The small gap is rounding, in the conversion and in the paper's own figures. So this arithmetic reproduces the paper's static-rule prediction. It is not the figure the paper's dynamic model gives.

5. The textbook's own arithmetic is not the broken step; check it first.

```
3500 divided by 200 = 17.5
365 divided by 17.5 = 20.86
```

About 21 pounds a year on 200 extra kilocalories a day, matching the textbook's rounded "20 pounds" closely enough. The arithmetic holds.

The first break is the textbook's own step to a whole year. The body starts to respond well inside a year. "Forever" repeats the same mistake. The rule was run forward on a fixed daily surplus. It never asked whether a heavier body needs more each day. A heavier body spends more at rest and more to move itself. So the same 200-calorie habit gives a shrinking surplus as the weight comes on.

Why the wrong answer looks reasonable. The arithmetic for one year is correct, and repeating a correct calculation feels safe. What breaks is an assumption carried silently past the point where it stops holding.

6. The step that broke is the second-to-last one. It is a unit swap, not a wrong multiplication. The static rule's 3,500 is a rate for one pound, not one kilogram. Multiplying kilograms by the pound rate treats a kilogram as a pound. That understates the deficit by a factor of about 2.2, since one kilogram is about 2.2 pounds.

The correct version uses the rate per kilogram.

```
8 times 7716.18 = 61729.44
```

About 61,730 kcal, not 28,000: more than double the wrong figure.

Why the wrong answer looks reasonable. 8 times 3,500 is correct multiplication, and 28,000 looks like a plausible target. Nothing in the arithmetic signals an error. The mistake is which rate got attached to which unit. Problem 1 trains exactly that check.

7. What to compute: whether the leaflet's numbers fit the static rule it quietly uses. Then, over what interval that rule is being trusted.

Check the weekly figure first.

```
500 times 7 = 3500
3500 divided by 3500 = 1
```

One pound a week is exactly what 500 kcal a day gives under the static rule; that part is arithmetically sound. Now the six-month figure.

```
1 times 26 = 26
```

Six months is about 26 weeks, so 26 pounds is what a straight line through the weekly figure gives. The leaflet's arithmetic is internally consistent.

What this does not establish. It does not show that a person on the diet for six months actually loses 26 pounds. The static rule assumes the same 500-kcal deficit keeps giving the same weekly loss. The data in this section's illustration show that failing within about nine weeks.

It does not show that 500 kcal a day can be kept up for 26 weeks. That is a question about behaviour, which this arithmetic cannot touch. And it says nothing about whether the pounds lost are fat. The rule fixes a rate per pound without asking what the pound is made of.

8. What to compute: how the promised rate compares with a real cohort on a bigger deficit. That is the closest real check among the sources this book cites.

The patient's promised deficit, in the same terms Thomas and colleagues report.

```
500 times 7 = 3500
```

3,500 kcal a week, or exactly one pound a week by the static rule, before the body responds. Thomas and colleagues' dieters were prescribed a bigger deficit: 1,439 kcal a day. In a week, that is:

```
1439 times 7 = 10073
```

Their intake was supervised or measured. Their loss still fell short of the rule's prediction for their own deficit. On average they lost 7.4 pounds less than the predicted 27.6.

What this does not establish. It does not show that this patient will do better, relative to prediction, than that cohort. The patient has a smaller deficit and less control over intake. Nor does it give a number for how far this patient will fall short. It shows only that "reliably" is not a word the static rule has earned.

8 · Spotting a claim that breaks conservation

EXERCISE 1. Two separate things are wrong. The same three-step check finds both.

First, put a number on it. Ten pounds in ten days, on the static rule, is 3,500 kilocalories a day as fat, for ten days straight. That is nearly the whole day's expenditure section 3's worked examples calculate for their most active group, 3,925 kilocalories. It is far more than the 1,975 they calculate for the least active.

Second, ask what route supplies that. The ad says no change to diet and no change to exercise. Read that way, intake did not fall and output did not rise. A boundary drawn round a person has only two kinds of route, in and out. The ad has claimed neither moved.

What to ask the advertiser for: what, physically, changed at the boundary? What let 3,500 kilocalories a day leave the person while intake and expenditure stayed the same? No answer keeps the ad's own wording true. The FTC says so directly about products like this: "Nothing you wear or apply to the skin can cause substantial weight loss."

EXERCISE 2. Draw a circle on the board and call it the patient. Write in, for food and drink, and out, for heat, work, and what is not absorbed. Nothing else crosses.

Turn 5 kilograms of fat into an energy figure using the rate from the previous section, about 7,716 kilocalories a kilogram.

```
5 times 7716.18 = 38580.9
```

About 38,600 kilocalories, over seven days.

```
38580.9 divided by 7 = 5511.6
```

About 5,512 kilocalories a day, as a deficit, if every gram of the five kilograms was fat.

Now compare that with a whole day's expenditure. Section 3's worked examples calculate 1,975 to 3,925 kilocalories a day for their example groups. If "eating normally" means intake stayed about the same, all 5,512 must come from extra output. Output would then be several times an ordinary day, for a week. Be skeptical of that number before you ask a single question about the diet. Either the weight lost was not five kilograms of fat, or the week was not really a week, or the history is incomplete.

1. Multiply the count by the rate.

```
6 times 3500 = 21000
```

21,000.

2. Divide the total by the rate.

```
24500 divided by 3500 = 7
```

7 units.

3. Multiply the claimed pounds a day by the rate.

```
2 times 3500 = 7000
```

7,000 kilocalories a day.

4. Divide the larger figure by the smaller.

```
7000 divided by 1439 = 4.864489229
```

About 4.9 times the cohort's average prescribed deficit.

5. The step that broke is the last one. The word doing the damage is "therefore".

Conservation does say the energy had to come from somewhere. For a person eating nothing, that somewhere is the body's own stores. That much is right. It does not follow that the claim is true. Conservation fixes what the numbers must add up to. It says nothing about whether the numbers given are the real ones.

The missing step is the one this section teaches. Put a figure on the fat, and check it against a ceiling.

```
4 times 7716.18 = 30864.72
30864.72 divided by 7 = 4409.25
```

About 4,409 kilocalories a day. Eating nothing, the deficit is at most a whole day's expenditure. Section 3's worked examples calculate that at 1,975 to 3,925 kilocalories a day for their example groups. The claim needs more, so for anyone like them it is impossible as fat.

Why the wrong answer looks reasonable. It invokes a true law. It rightly says that law rules out energy vanishing. Then it slides from "not impossible in principle" to "true", which conservation could never establish.

6. The step that broke is the last one. The arithmetic to 4,822.61 kcal a day is correct. But it silently assumes every kilogram lost was fat. This section names the case where that fails: the first days of a diet that cuts carbohydrate sharply. Glycogen is stored with water, and using it up releases both. Cutting carbohydrate also makes the kidneys let go of fluid. Water carries no energy, so this loss costs far less than 7,716 kcal a kilogram.

So the verdict "fabricated" does not follow. The energy check was run on the wrong substance. First ask whether 2.5 kilograms in four days, at the start of a low-carbohydrate diet, could be glycogen, water and fluid. This check alone cannot rule that out.

Why the wrong answer looks reasonable. Every line of arithmetic is correct. The verdict sounds like the kind of impossibility this section trains you to catch. But the catch depends on asking what the lost mass was made of, before running the fat rate on it. That question was skipped.

7. What to compute: the daily energy the claim needs, if the 8 kilograms were all fat. Compare it with a ceiling before asking anything about what the person ate.

```
8 times 7716.18 = 61729.44
61729.44 divided by 10 = 6172.94
```

About 6,173 kilocalories a day. That is over four times the cohort's average prescribed deficit, 1,439 kcal a day. It is also more than the whole day's expenditure section 3's worked examples calculate for any of their groups, 1,975 to 3,925.

What this does establish. For anyone like those groups, the 8 kg was not pure fat. That would need more than a whole day's expenditure, every day for 10 days.

What it does not establish. It does not say how much was fat. On a plan that cuts carbohydrate, some could be glycogen, water and fluid. It says nothing about whether "what you eat" matters apart from the energy it supplies. That needs a different kind of evidence from an arithmetic bound.

8. What to compute: the daily energy 12 kilograms in three weeks would need as fat. Then check it against a whole day's expenditure.

```
12 times 7716.18 = 92594.16
92594.16 divided by 21 = 4409.25
```

About 4,409 kilocalories a day, for three straight weeks. That is roughly three times the cohort's average prescribed deficit, 1,439 kcal a day. It is also more than section 3's worked examples calculate for any of their groups. But those groups weighed 55 to 70 kg. This patient weighed 140.

Do not scale their per-kilogram rate up to 140 kg. Body fat adds less to resting expenditure than fat-free mass does (section 1). Use an equation in weight instead. The report section 3 drew on gives Schofield's equations for basal metabolic rate, in its Table 5.2. Age and sex are not given, so take the adult row that gives the most, men 18 to 30. Multiply by section 3's sedentary multiplier, 1.53. Let intake be zero.

```
15.057 times 140 plus 692.2 = 2800.18
2800.18 times 1.53 = 4284.2754
21 times 4284.2754 = 89969.7834
89969.7834 divided by 7716.18 = 11.66
```

At most about 11.7 kilograms of fat. The other adult rows, ages 18 to 60, give less, down to women 30 to 60:

```
8.126 times 140 plus 845.6 = 1983.24
```

So even the most generous row falls just short of 12 kilograms of fat. The margin is small. The table also lists 153 kcal a day beside that row, the usual spread of real people around the equation. Add it once:

```
2800.18 plus 153 = 2953.18
2953.18 times 1.53 = 4518.3654
21 times 4518.3654 = 94885.6734
94885.6734 divided by 7716.18 = 12.30
```

About 12.3 kilograms, just over 12. So the check makes 12 kilograms of pure fat unlikely, not impossible: intake above zero after surgery makes it less likely, a more active patient more. Check one assumption too: that Schofield's equations still hold at 140 kg. Nothing here shows they do.

What this does not establish. It does not show the colleague is right or wrong about the mechanism. Surgery is meant to cut intake, so a large real deficit is plausible. But early in a sharp cut, glycogen, its water and fluid can leave too. So "nothing else is going on" is an assumption, not a result. The check cannot say how much of the 12 kilograms was fat.

9 · Intake and expenditure are outputs of a regulated system

EXERCISE 1. The arithmetic - intake minus expenditure - still holds, but the colleague has assumed both sides are still what they were at the start. As weight falls, expenditure falls with it, so even a fixed intake gives a loss that slows and levels off. Appetite rises at the same time, which makes the prescribed intake harder and harder to hold. A stall therefore cannot tell "stopped trying" apart from either effect. Concluding "stopped sticking to the diet" needs a check on intake, and self-report is a poor check.

10 · Arithmetically true, practically insufficient

EXERCISE 1. The accounting is correct: stored energy changes at a rate equal to intake minus expenditure, and that is always true. What is not correct is the instruction built on it - "eat less, move more, and the rest follows" - because it assumes expenditure and appetite hold still once a person acts on it. They do not. Cutting intake makes the body burn somewhat less and want to eat somewhat more, automatically. So the accounting supports the direction of the policy and does not support the assumption that the arithmetic alone will carry a person the rest of the way. A policy built only on the arithmetic will under-predict how much support people need to keep the change going.

EXERCISE 2. There is no single correct page; the answer is judged against the four things the prompt names. A page that states the identity without also stating that it is an identity - always true by the way stores are defined - has not done the first job. A page that names the instruction but not the unstated premise (once intake is cut, expenditure and appetite stay where they were) has not done the second. A page that cites evidence without naming a number (the 20-25% fall in expenditure, and the rise in intake of about 100 kcal a day per kg lost, as the reason a cut is hard to hold, both from section 9) has not done the third. A page that slides into "so it isn't the patient's fault" as a moral verdict, rather than stopping at the physiological explanation, has broken the prompt's no-verdict condition.

Glossary

Every term of art this book teaches, in the plain words it gets where it is first used, and the section that teaches it.

Term	Plain words	Section
accounting identity (for a body)	the change in body energy stores over an interval equals the energy intake minus the energy expenditure over that same interval	5
adaptive part (of the fall in expenditure)	the extra fall in expenditure after a weight loss, beyond what the loss of fat and lean mass alone accounts for	9
adipocyte	a fat cell	1
adopted requirement	a number a body of experts has set, not measured in the person in front of you	3
basal metabolic rate (BMR)	the energy spent lying at rest after a fast	3
breaks conservation (of a claim)	asserts a fat change that could not have happened, given the energy that could plausibly have crossed the boundary drawn round the person over the stated time	8
consumer unit	the survey's per-head measure that allows for age and sex, as against a plain count per person	3
conversion table	a table giving the energy in a unit of each food	3
deficit (of energy)	expenditure larger than intake; a surplus is the reverse	2
doubly labelled water	the method that measures what was actually spent: a person drinks water carrying rare, stable forms of hydrogen and oxygen, and how fast they leave the body over the next 10 to 14 days gives the average energy spent	3
dynamic model	a model built on energy balance, with expenditure allowed to change	7
energy expenditure	the energy a body burns, or spends, in a day	3
energy intake	the energy a person eats in a day	3
fat mass	the triglyceride held in adipose tissue	1
fat-free mass	everything else the body weighs; some papers call it lean body mass, or lean mass	1
first law of thermodynamics	the physicists' name for one version of conservation of energy: energy is never made or destroyed, only changed in form	6
implausible (of a weight-loss claim)	needs more than any deficit people are known to manage	8
impossible (of a weight-loss claim)	needs more than the person's whole expenditure over the interval	8
lean body mass	what some papers call fat-free mass	1
lever	a handle you pull to get a result; the identity gives you none	6
lipid fraction	the proportion of a tissue's mass that is fat	2

Term	Plain words	Section
maintenance requirement	the energy it takes to keep a person at a steady weight	4
megajoule	a million joules, a thousand kilojoules; mega means 10^6, a million	2
metabolically active tissue	the tissue that spends most of the energy spent at rest	1
physical activity expenditure	the energy spent moving, whether as deliberate exercise or as the ordinary movement of a day	4
physical activity level (PAL)	a multiplier for how active the group is	3
pound	a unit this course does not use; exactly 0.453 592 37 kilogram	2
regulated system	a system that senses body weight, or a signal that tracks it, and pushes back when weight falls	9
resting energy expenditure (REE)	the energy spent at rest	1
static rule	a kilogram of body fat is taken to hold a fixed number of kilocalories, so a surplus or deficit summed over time converts into fat at that fixed rate, every other quantity held constant; commonly 3,500 kilocalories a pound	7
thermic effect of food	the energy spent digesting, absorbing and processing what was eaten	4
total energy expenditure (TEE)	the product of physical activity level and basal metabolic rate: what a group spends in a day	3
type 2 diabetes	a condition in which blood glucose runs high	9

The series: all 196 books

In build order: Book 0 first, then every Introductory rung, then every Intermediate rung, and so on; within a level, a subject comes after the subjects it depends on. "done" means that book's version 1 is finished. This is Book 1.

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1	**Energy balance and dynamic weight-change modelling · Rung 1 ◀ you are here**	**done**
2	Mathematics for modelling and inference · Rung 1	done
3	Qualitative and mixed methods · Rung 1	done
4	Food systems, value chains and Indian food policy · Rung 1	done
5	Policy process, framing and advocacy craft · Rung 1	done
6	R, reproducibility engineering and data management · Rung 1	
7	Question selection and research strategy · Rung 1	done
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OBESITY EXPERTISE · BOOK 1

Energy balance and dynamic weight-change modelling · Rung 1

A short book on the first law of thermodynamics as it applies to a human body: what a kilocalorie is, how large a day of eating, a day of spending and a kilogram of fat are, how to spot a claim that breaks conservation of energy, and why "eat less" does not follow from "energy is conserved".

Book 1 of the series' 196 books, free to read at drharshmaheshwari.com.



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Version 1.2 · 24 September 2026

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