

GRADE 10 PHYSICAL EDUCATION & HEALTH

First edition

5 units

10 lessons • one quarter

A video for every lesson

FIRST EDITION

COURSE GUIDE

This short course follows the same five strands every School Launch student meets each year (keeping active, water, food, strength, and the heart and lungs), now at a high-school level. Each lesson is built around a real person or study: Jerry Morris comparing the heart attacks of London bus drivers and conductors, Katharine Wells and Evelyn Dillon inventing the sit-and-reach test, Edward Adolph's soldiers sweating on desert marches, Friedlieb Runge isolating caffeine, Adolf Fick and Johannes Wislicenus climbing the Faulhorn to find what fuels muscle, the government chemists who tested Clark Stanley's Snake Oil Liniment, Dudley Sargent's Harvard gymnasium, Lev Matveyev's training year, Arthur Lydiard's marathon-mileage base, and Izumi Tabata's interval study.

Every lesson follows the same path: **the story**; **how they figured it out**, the question, the method and the measurements; **how your body works**, real physiology with worked numbers (MET-minutes, sweat rate, caffeine half-life, grams of protein per kilogram, sets × reps × load, the Karvonen formula); and **try it**, a real workout, test, kitchen task or experiment, recorded in a fitness journal and repeated to improve. The strength unit introduces light free weights, always with a knowledgeable adult present, a spotter for pressing lifts, technique before load, and no one-repetition-maximum testing.

God made the body good and gave it to us to care for. This course is about stewardship, strength, joy in movement and wise habits, never about size or looks: students are measured only against their own effort and improvement. The old Latin saying *Fabricando fit faber*, “by making, one becomes a maker,” fits training too: strength and endurance are built by practice, a little more each week. The quarter ends with a family fitness day that the student plans and leads.

Most videos come from children's hospitals, university and medical channels, TED-Ed, the Olympics and established coaching and

physical-therapy channels, chosen lesson by lesson. Every video was previewed for accuracy, for modest dress and for any product pitch. Some lifting and running videos show adults training with heavier loads or at higher volumes than this course asks of a tenth grader; the lesson notes say so. A few channels end with an invitation to subscribe or a mention of their own website; stop the video when the teaching ends.

Start with Lesson 1.1 →

WHO IT IS FOR

Written for students in grade 10 (about ages 15–16) who read independently, are comfortable with algebra and percentages, and can keep careful records. A parent or other knowledgeable adult supervises the activities, is present for every session that uses free weights, and helps in the kitchen. Nothing needs to be bought: every activity works with household things such as a sturdy step, a broom handle, water jugs, a backpack with books, a bathroom scale, measuring cups and a timer. Light dumbbells or a resistance band are optional.

HOW TO USE THIS COURSE

- 1. The weekly rhythm.** The quarter has 10 lessons, one a week, each with three sessions of 45–50 minutes. Session 1 is the warm-up, the video, the teaching, the worked examples and the picture study, with some movement. Session 2 is the activity (the workout, test, experiment or kitchen task) and the fitness journal. Session 3 repeats the activity and tries to improve on it. In the second week of each unit, use part of Session 3 for the unit review and begin the unit challenge. On the other days, aim for at least 60 minutes of moderate-to-vigorous activity in sport, chores, walking and play, with muscle- and bone-strengthening work on at least three days a week.
- 2. Check with your doctor first.** A parent should know about and supervise every activity. If the student has asthma, a heart condition, diabetes, a recent injury or any other health concern, check with your doctor before starting, and follow the doctor's advice about what to change. A sports physical is a good idea before the strength and interval units.
- 3. Story, then science, then doing.** The core ideas are written for the student to read, ideally aloud with a parent. The paragraphs marked *The story* and *How they figured*

it out tell what happened and how the evidence was gathered; *How your body works* and *Think it through* give the physiology and the worked numbers; *Try it* explains the activity. Ask the student to explain each worked example back in his or her own words and to redo it with his or her own numbers.

4. **Picture study.** Each lesson has one public-domain painting, print or historic photograph chosen for what it shows about work, movement, food, water or rest. Look at it quietly for two minutes, put it away and describe it from memory, then bring it back and work through the “look for” items and questions.
5. **The fitness journal.** Use one notebook (or a simple spreadsheet) for the whole quarter. Every activity is done, recorded and done again: sets, reps, loads, seconds, ounces, heart rates, ratings of effort. Date every page, write how it felt and what you will change next time. Honest records matter more than big numbers.
6. **Health, not looks.** In this course we talk about what bodies can do and how to care for them, never about size or shape. We do not count calories or call foods bad; calories appear only as a unit of food energy. Foods are “nutrient-dense” foods and “treat” foods, and feasts and treats are good gifts in their place. The one time a scale is used (the sweat-rate test in Lesson 2.1), the number recorded is the fluid lost, not body weight. Grades come from effort, consistency and personal improvement, never from comparing one student with another.
7. **No supplements, energy drinks or shortcuts.** This course teaches plainly why teenagers should skip energy drinks, caffeine pills, pre-workouts, protein powders and other supplements, and why ordinary food, water and sleep are enough for a growing athlete. Food allergies and medical diets belong to the family and their doctor.
8. **Optional books and gear.** Some units list a free government or hospital web page, or simple gear such as a resistance band or a jump rope. They are never required.
9. **Unit review and unit challenge.** Each unit ends with a review worth 100 points (with two or three worked calculations and a short written answer) and a unit challenge: an activity audit, a hydration plan built from your own sweat rate, a planned and cooked day of protein-rich meals, a six-week strength plan, or an aerobic training block. Keep the challenge pages in a folder.
10. **Safety.** Read the safety note before each activity. Warm up first and cool down after. Clear a space with a flat, non-slip floor and wear good shoes. Stop and tell an

adult right away at chest pain, dizziness, fainting, trouble breathing or sharp pain; tired muscles are normal, but joint pain is not. Free weights are used only with a knowledgeable adult present, with a spotter for any pressing lift, with technique practiced first on a broom handle, and never for a one-repetition maximum. Exercise and food are never used as a reward or a punishment.

11. **The family fitness day.** In the last week, the student plans and leads a family fitness day: a dynamic warm-up, stations from every unit, a water table, a protein-rich meal the student cooks, and a walk-run or interval relay in which everyone moves at his or her own pace.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–2

Keeping Active

How work moved from the farm to the desk and why activity must now be chosen, through Jerry Morris’s 1953 study of London bus drivers and conductors and a week-long MET-minute activity audit; and mobility and flexibility, from Wells and Dillon’s sit-and-reach test to a measured mobility routine.

1.1 From Farm to Desk: Jerry Morris and the London Buses

1.2 Mobility and Flexibility: Wells, Dillon and the Sit-and-Reach

UNIT 2 • WEEKS 3–4

Hydration

Measuring your own sweat rate, as Edward Adolph’s team did with soldiers in the desert, and building a drinking plan that avoids both dehydration and hyponatremia; and why to skip caffeine and energy drinks, from Runge’s discovery of caffeine to half-lives, sleep and the heart.

2.1 Measure Your Sweat Rate: Edward Adolph in the Desert

2.2 Caffeine and Energy Drinks: Why to Skip Them

UNIT 3 • WEEKS 5–6

Nutrition

Protein for growing athletes, from Fick and Wislicenus's climb of the Faulhorn to grams per kilogram and a day of real-food meals; and fads, myths and supplements, from Clark Stanley's Snake Oil Liniment to judging a health claim with a blinded test of your own.

3.1 Protein for Growing Athletes: The Climb of the Faulhorn

3.2 Fads, Myths and Supplements: The Snake Oil Test

UNIT 5 • WEEKS 9–10

Aerobic Training

Arthur Lydiard, his Olympic champions and the aerobic base, with easy runs in a heart-rate zone set by the Karvonen formula; and high-intensity intervals and the 1996 Tabata study, a safe interval session, heart-rate recovery and the family fitness day.

5.1 Arthur Lydiard and the Aerobic Base

5.2 High-Intensity Intervals: The Tabata Study and the Family Fitness Day

UNIT 4 • WEEKS 7–8

Strength

The five movement patterns (squat, hinge, push, pull and carry) with good form and light loads, through Dudley Sargent's Harvard gymnasium; and periodization, from Lev Matveyev's study of Olympic athletes to planning a six-week training cycle.

4.1 The Five Movement Patterns: Dudley Sargent's Gymnasium

4.2 Periodization: Lev Matveyev and the Training Year

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 From Farm to Desk: Jerry Morris and the London Buses: warm-up, video, teaching and picture study • Session 2: Lesson 1.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it <i>Three short sessions a week is the usual rhythm: one to learn, two to move. Keep moving every day, even on days with no lesson.</i>

WEEK	PLAN
2	• Session 1: Lesson 1.2 Mobility and Flexibility: Wells, Dillon and the Sit-and-Reach: warm-up, video, teaching and picture study • Session 2: Lesson 1.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 1 review and unit challenge
3	• Session 1: Lesson 2.1 Measure Your Sweat Rate: Edward Adolph in the Desert: warm-up, video, teaching and picture study • Session 2: Lesson 2.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
4	• Session 1: Lesson 2.2 Caffeine and Energy Drinks: Why to Skip Them: warm-up, video, teaching and picture study • Session 2: Lesson 2.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 2 review and unit challenge
5	• Session 1: Lesson 3.1 Protein for Growing Athletes: The Climb of the Faulhorn: warm-up, video, teaching and picture study • Session 2: Lesson 3.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
6	• Session 1: Lesson 3.2 Fads, Myths and Supplements: The Snake Oil Test: warm-up, video, teaching and picture study • Session 2: Lesson 3.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 3 review and unit challenge
7	• Session 1: Lesson 4.1 The Five Movement Patterns: Dudley Sargent's Gymnasium: warm-up, video, teaching and picture study • Session 2: Lesson 4.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
8	• Session 1: Lesson 4.2 Periodization: Lev Matveyev and the Training Year: warm-up, video, teaching and picture study • Session 2: Lesson 4.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 4 review and unit challenge

WEEK	PLAN
9	• Session 1: Lesson 5.1 Arthur Lydiard and the Aerobic Base: warm-up, video, teaching and picture study • Session 2: Lesson 5.1 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it
10	• Session 1: Lesson 5.2 High-Intensity Intervals: The Tabata Study and the Family Fitness Day: warm-up, video, teaching and picture study • Session 2: Lesson 5.2 activity and fitness journal • Session 3: Repeat the activity, try to improve, and log it • Session 3 (end of unit): Unit 5 review and unit challenge <i>Last week. Hold a family fitness day: the student leads the family through a warm-up, a favorite activity from each unit and a cool-down, serves a healthy snack and water, and shows the fitness journal.</i>

MATERIALS

Fitness journal (any notebook or a simple spreadsheet)

One for the quarter: activity audits, sweat-rate tables, food plans, training logs, heart-rate charts and reflections.

A timer or stopwatch (a phone timer works)

For intervals, rest periods, pulse counts and timed runs.

Good athletic shoes and comfortable, modest exercise clothes

Every activity lesson.

A towel or mat, a sturdy bench or step, a wall and a broom handle or length of dowel

For mobility work and for practicing lifting technique before any load is added.

Household loads: a backpack with books, gallon water jugs, a sturdy bag with handles

For goblet squats, hinges, rows and carries. Light dumbbells (5–25 lb) are optional and used only with a knowledgeable adult present.

A bathroom scale, a measuring cup and a water bottle with ounce marks (or a marked jug)

For the sweat-rate test in Lesson 2.1. The scale is used only to measure fluid lost.

A yardstick or tape measure and masking tape

For the sit-and-reach and ankle tests in Lesson 1.2 and the jump test in Lesson 3.2.

Food labels, measuring cups and spoons, and a kitchen

For the protein meal plan and cooking in Lesson 3.1. A parent supervises the stove and knives.

A safe running route or loop of known length

A track, a measured loop around the block or a park path, away from traffic, for Unit 5.

Graph paper or a spreadsheet and colored pencils

For graphs of heart rate, sweat loss, training load and progress.

GRADING

Grades come mostly from the activities and the fitness journal, because fitness is learned by doing, measuring and doing again. A student who trains faithfully, records honestly, uses good form and improves on his or her own numbers earns full credit, whatever those numbers are.

PART	%
Activities (effort, participation, good form and safety)	40
Fitness journal (dated logs, calculations, graphs and reflections)	25
Unit reviews	15
Unit challenges	20

Scale: A 90–100, B 80–89, C 70–79, D 60–69. Below 60: redo the activity or review with help.

- Fitness marks reward effort, consistency, good form and improvement against the student’s own earlier numbers. They never depend on body size, body measurements or comparison with other students.
- A journal page earns full marks when it has a date, the numbers with units (reps, pounds, seconds, ounces, beats per minute), any calculation shown step by step, a sentence about how it felt and a sentence about what to change next time.

- In the unit reviews, calculations earn partial credit for correct setup and units even when the arithmetic slips.
- A student who finds sport hard, or who has a health condition that limits some activities, is graded on faithful effort within what the doctor allows. Every body can grow stronger; the goal is faithfulness, not being the best.

A NOTE TO PARENTS

You do not need to be a coach to teach this course, but you do need to be present. Read the story together, watch the video, check the worked examples, and then be the timer, the recorder and the safety officer. For the strength unit, a knowledgeable adult must be present whenever free weights are used: someone who has learned the movements, can see good and bad form, and can spot a pressing lift. If no one in the house fits that description, use household loads and bodyweight work only, or find a qualified coach or physical therapist for a session or two.

Keep the talk about bodies on what they can do and how to care for them. Teenagers hear a great deal of advice about food, supplements and appearance; this course gives them tools to judge it and points them back to ordinary food, water, sleep and steady work. Praise effort, good form and honest records. Exercise is good for the body, and Scripture says plainly that godliness is better still (1 Timothy 4:8). We move, eat, drink and rest to the glory of God.

Several stories are told honestly at a high-school level. Lesson 1.1 discusses heart attacks and death rates among middle-aged bus workers, and Lesson 2.1 explains that drinking far too much water during long events has caused deaths from hyponatremia. They are stated plainly and briefly, with the focus on what was learned.

UNIT 1

KEEPING ACTIVE

For most of history, people did not need to plan exercise. In 1900 about four in ten American workers farmed, and most other jobs meant walking, lifting and carrying. By 2000 fewer than two in a hundred worked on farms, and many of us now sit for most of the day at school, at desks and in cars. In this unit you will study the first great scientific test of what that change means: Jerry Morris's 1953 comparison of London bus drivers, who sat all day, with bus conductors, who climbed the stairs of double-decker buses hundreds of times a shift. You will learn to measure activity in MET-minutes and audit a week of your own life.

Then you will learn the difference between flexibility and mobility, how muscles and nerves control how far a joint can move, and when static and dynamic stretching help or hinder. You will meet Katharine Wells and Evelyn Dillon, two Wellesley College teachers who invented the sit-and-reach test in 1952, test yourself on four simple measures, and follow a mobility routine long enough to see your own numbers change.

PREREQUISITES

- Knows the youth activity guideline of at least 60 minutes a day and the difference between moderate and vigorous activity (earlier grades)
- Can take a pulse at the wrist or neck and convert a 15-second count to beats per minute
- Comfortable multiplying, adding columns of numbers and working with percentages

MASTERY CHECKLIST

- ☐ I can explain how work changed from farm to desk and why activity must now be chosen on purpose.
- ☐ I can describe Jerry Morris's bus study: the question, the two groups, what was measured, what was found and its limits.
- ☐ I can define a MET, sort activities into light, moderate and vigorous, and calculate MET-minutes for a day and a week.
- ☐ I can explain the difference between flexibility and mobility and the roles of muscle spindles and stretch tolerance.
- ☐ I can choose dynamic stretching before training and static stretching after it, and perform and measure a sit-and-reach and a knee-to-wall test.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Physical Activity Guidelines for Americans, 2nd edition (U.S. Department of Health and Human Services)**: Free. The 2018 guidelines on which Lesson 1.1 is based, with a chapter on children and adolescents and a table of moderate and vigorous activities.
- **A tape measure or yardstick and masking tape**: For the sit-and-reach, shoulder-reach and knee-to-wall tests in Lesson 1.2. A ruler taped to a step works too.
- **A pedometer or a phone step counter**: Optional, for the activity audit. Minutes and the talk test are enough.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

1.1 From Farm to Desk: Jerry Morris and the London Buses

3 sessions of 45–50 minutes

1.2 Mobility and Flexibility: Wells, Dillon and the Sit-and-Reach

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **8 pts**

How did American work change between 1900 and 2000, and why does that change mean activity must now be chosen deliberately?

2. **10 pts**

Describe Jerry Morris's 1953 bus study: the question, the two groups compared, and the main findings.

3. **8 pts**

What is a confounding factor? Give one possible confounding factor in the bus study and explain how Morris's later research addressed the question.

4. **8 pts**

State the Physical Activity Guidelines (2018) for people aged 6–17.

5. **10 pts**

Calculation. On Saturday you mow the lawn for 40 minutes (5.5 METs), walk the dog for 20 minutes (3 METs), and play 50 minutes of basketball (6.5 METs). Find the MET-minutes for each activity and the total. Did you meet the daily guideline?

6. **8 pts**

Calculation. Your audit shows moderate-to-vigorous minutes of 45, 70, 30, 85, 60, 20 and 95 over seven days. Find the weekly total and daily average, and the number of days you met the guideline.

7. **8 pts**

Explain the difference between flexibility and mobility, and give one example of each.

8. **8 pts**

What do muscle spindles do, and why does this make bouncing stretches a poor idea?

9. **8 pts**

When should you use dynamic stretching and when static stretching? State the ACSM guidance for static stretches.

10. **8 pts**

Calculation. Your sit-and-reach improved from 11.0 inches to 12.5 inches. Your left knee-to-wall is 8 cm and your right is 11 cm. Find the sit-and-reach percentage improvement and the left-right difference as a percentage of the right side.

11. **16 pts**

Short written answer. Write a paragraph explaining to a friend who sits most of the day why both daily exercise and breaking up long periods of sitting matter, using what you learned from Morris and from how muscles work. Include one specific plan for his or her school day.

ANSWER KEY

1. In 1900 about four in ten American workers farmed and most jobs were physical; by 2000 fewer than two in a hundred farmed and many jobs are done sitting. Because work no longer keeps most people active, we must plan activity into our days (sport, walking, chores, training) or we will sit most of the day.
2. Question: does physical activity at work affect heart disease? Groups: London bus drivers (seated all shift) and conductors (climbing the stairs of double-decker buses all day), similar men in the same city and company. Findings: conductors had less coronary heart disease; it came later and was milder; drivers' sudden-death rate from heart attack was about twice the conductors'. Postmen versus seated clerks and telephonists showed the same pattern.
3. A hidden difference between groups that could explain the result instead of the factor studied. Example: men who chose to be drivers might have differed in health or habits from conductors before they started. Morris later studied civil servants who all had desk jobs and compared those who took vigorous exercise in their free time with those who did not; the active men still had far fewer heart attacks, so activity itself mattered.
4. At least 60 minutes of moderate-to-vigorous physical activity every day, mostly aerobic, including vigorous activity on at least 3 days a week, muscle-strengthening activity on at least 3 days a week and bone-strengthening activity on at least 3 days a week.
5. Mowing: $5.5 \times 40 = 220$ MET-min. Walking: $3 \times 20 = 60$ MET-min. Basketball: $6.5 \times 50 = 325$ MET-min. Total = 605 MET-minutes. Moderate-to-vigorous minutes = $40 + 20 + 50 = 110$ minutes, so yes, the 60-minute guideline was met (and vigorous activity was included).
6. Total = $45 + 70 + 30 + 85 + 60 + 20 + 95 = 405$ minutes. Average = $405 \div 7 \approx 57.9$ minutes a day. Days at 60 or more: 70, 85, 60, 95 = 4 days. The goal is 60 every day, or seven hours a week.
7. Flexibility is the range a joint can be moved, often passively (e.g., how far a partner or gravity can stretch your hamstrings in a sit-and-reach). Mobility is how far you can move a joint actively with strength and control (e.g., lifting your leg high in a controlled leg swing or sitting into a deep squat with heels down and chest up).
8. Muscle spindles sense how far and how fast a muscle is stretched. A sudden stretch triggers the stretch reflex, making the muscle contract to resist.

Bouncing causes repeated sudden stretches, so the muscle tightens against you, the stretch is less effective, and tissue can be strained.

9. Dynamic stretching belongs in the warm-up before training or sport. Static stretching belongs after training or in a separate session, because long static holds just before sprinting or jumping can briefly reduce power. ACSM: hold 10–30 seconds at mild tension, repeat to about 60 seconds total per muscle group, at least 2–3 days a week (daily is most effective).
10. Sit-and-reach: $12.5 - 11.0 = 1.5$ in; $1.5 \div 11.0 \times 100 \approx 13.6\%$ improvement. Ankle: $11 - 8 = 3$ cm; $3 \div 11 \times 100 \approx 27\%$ less on the left.
11. Answers vary. A full answer explains that Morris found active workers had less and milder heart disease, and later that free-time exercise protected desk workers; that working muscles take up blood sugar and fat and train the heart, while long sitting leaves the large leg muscles idle; that 60 minutes of daily activity is the goal and short standing and walking breaks every 30–60 minutes help too; and gives a concrete plan (e.g., walk between classes, stand for 3 minutes each period, walk or bike to school, practice or train after school).

UNIT CHALLENGE: TWO-WEEK ACTIVE LIVING AUDIT AND MOBILITY PLAN

Continue your activity audit for two full weeks, keeping the one specific goal you set in Lesson 1.1, and do your 10-minute mobility routine every day. Record moderate-to-vigorous minutes, MET-minutes and sitting hours daily, and retest the four mobility tests at the end. Make two graphs (daily active minutes with a 60-minute line, and before-and-after mobility results) and write a one-page report on what changed, what was hard and what habit you will keep.

LOOK FOR	WHAT IT MEANS
Complete records	Fourteen dated days of audit entries with minutes, intensities, MET-minutes and sitting hours.
Calculations and graphs	Weekly totals, averages and MET-minutes calculated correctly; two clear, labeled graphs.
Faithful practice	Daily mobility routine logged; the personal goal kept on most days; tests repeated fairly.
Reflection	A thoughtful report naming specific changes, honest difficulties and a habit to keep. Effort and improvement count, not the size of the numbers.

1.1 FROM FARM TO DESK: JERRY MORRIS AND THE LONDON BUSES

OBJECTIVES

- Explain how work changed from farm to desk in the twentieth century and why activity must now be chosen deliberately.
- Describe Jerry Morris’s 1953 study of London busmen: the question, the comparison groups, the findings and the limits of the evidence.
- Define a MET and calculate MET-minutes for activities, a day and a week, and compare them with the Physical Activity Guidelines.
- Complete a stair-climb workout and a seven-day activity audit, and set one specific goal to sit less and move more.

Warm-up. Stair-conductor warm-up (5 minutes): march in place 1 minute; 10 slow step-ups on the bottom stair with each leg, standing tall at the top; 10 arm circles each way; 10 bodyweight squats; 1 minute of brisk walking up and down the hallway. Think about it: how many minutes have you sat today already? Write a guess before you check.

WATCH

What Sitting All Day Does to Your Brain and Body | Keith Diaz | TED

TED · 11:24

<https://www.youtube.com/watch?v=rKgtm81yi94>

WHEN TO WATCH

After “How your body works,” before the activity. Watch for what happens to blood sugar and mood when long sitting is broken up by short walks.

Note: A TED talk by an exercise scientist at Columbia University. One slide briefly shows an old cigarette advertisement as an example of the past; it is not an endorsement. Stop at the end of the talk.

KEY TERMS

sedentary behavior

Any waking activity done sitting or lying with very low energy use (about 1.5 METs or less), such as sitting in class, riding in a car or watching a screen.

moderate and vigorous activity

Moderate activity is about 3.0–5.9 METs (you can talk but not sing); vigorous is 6 METs or more (you can say only a few words without pausing for breath).

epidemiology

The study of how often diseases happen in different groups of people and why: the science Morris used.

MET (metabolic equivalent)

A unit comparing the energy cost of an activity with sitting quietly at rest. 1 MET is resting; brisk walking is about 3.5 METs; running about 8–10 METs.

MET-minutes

METs × minutes. A way to add up the amount of activity across different kinds of exercise.

confounding factor

A hidden difference between groups that might explain a result instead of the factor being studied.

CORE IDEAS

The story. After the Second World War, heart attacks had become one of the leading causes of death among middle-aged men in Britain, and no one knew why. Jerry Morris, a doctor working for Britain’s Medical Research Council in London, looked for groups of men who did the same work in the same city but differed in one way. He found them on London’s red double-decker buses. Every bus had two men: a **driver**, who sat in his cab for the whole shift, and a **conductor**, who collected fares and climbed the narrow stairs to the top deck again and again, hundreds of times a day. In 1953 Morris and his colleagues published their results in the medical journal *The Lancet* under the title “Coronary Heart-Disease and Physical Activity of Work.”

How they figured it out. Morris’s team studied the health records of about 31,000 London Transport workers aged 35 to 64. The conductors had less coronary heart disease than the drivers. When conductors did develop it, it tended to come later in life and to be milder (more often chest pain, less often a sudden fatal attack), and the drivers’ rate of sudden death from heart attack was about twice the conductors’. The team found the same pattern in a second pair of jobs: postmen, who walked and

cycled their rounds, had less heart disease than government clerks and telephone operators who sat. Morris was careful. He knew the drivers and conductors might have differed in other ways (a **confounding factor**), so he kept testing the idea for decades. In the 1970s he followed thousands of British civil servants who all had desk jobs and found that those who took vigorous exercise in their free time had far fewer heart attacks. The answer held: being active protects the heart, even when your job does not require it. Morris himself kept walking, swimming and cycling into very old age and died in 2009 at 99.

How your body works. Your muscles are the largest tissue in your body, and when they work they pull sugar and fat out of the blood, help keep blood pressure healthy, and train the heart to pump more blood with each beat. When you sit for long stretches, the big leg muscles go almost silent, and the body handles sugar and fat in the blood less well. Scientists measure activity in **METs**. One MET is the energy you use sitting quietly. Light activity (slow walking, standing chores) is under 3 METs; moderate (brisk walking, raking leaves, easy cycling) is 3 to 5.9; vigorous (running, soccer, fast stair climbing, swimming laps) is 6 or more. The U.S. *Physical Activity Guidelines for Americans* (2nd edition, 2018) ask teenagers aged 6–17 to do at least 60 minutes of moderate-to-vigorous activity every day, including vigorous activity, muscle-strengthening and bone-strengthening activity on at least 3 days a week each. Fewer than one in four American teenagers do this.

Think it through. MET-minutes let you add different activities together. Suppose on Tuesday you walk briskly to and from practice for 30 minutes (3.5 METs) and play 50 minutes of soccer (7 METs). Walking: $3.5 \times 30 = 105$ MET-minutes. Soccer: $7 \times 50 = 350$ MET-minutes. Total: 455 MET-minutes, and 80 minutes of moderate-to-vigorous activity, so you met the daily guideline. Now count the sitting: 6 hours of classes and study, 1½ hours of homework, 1 hour in the car and 1½ hours of screens is 10 hours seated. Breaking that up matters too: standing and walking for 2–3 minutes every half hour wakes the leg muscles back up.

Try it. This week you will become your own epidemiologist. In Session 2 you will do a “conductor’s workout” on the stairs, measuring your heart rate and effort, and start a seven-day activity audit. In Session 3 you will repeat the stair workout, aiming for one more flight at the same effort, and plan the changes your audit shows you need. Exercise has real value for the heart, as Morris showed; Scripture adds that godliness

has more (1 Timothy 4:8). We care for the body because it is God's gift, not because it is the highest good.

PICTURE STUDY



Man with a Hoe, Jean-François Millet, 1860–1862 · Oil on canvas · J. Paul Getty Museum, Los Angeles

Image: [Wikimedia Commons](#), public domain

Jean-François Millet grew up on a farm in Normandy and spent his life painting the people who worked the land. Here a laborer pauses in a rough field he has been clearing with a heavy hoe. A century before Morris's study, almost all work looked like this: hard, long and physical. Millet wanted viewers to feel how tiring it was.

Look closely

- Find the hoe. How heavy do you think it is? Which muscles does swinging it all day use?
- Look at how the man stands. How can you tell he has been working for hours?
- Look at the ground. Find the stones and the thistles. What must the field have looked like before he started?
- Find the smoke rising in the distance and the small figure near it. What other work is going on in this field?

Talk about it

1. Farm work like this kept people active, but it was also exhausting. How is chosen exercise different from hard labor? What do we gain, and what do we lose, when work moves to a desk?

2. Estimate this man's MET level while hoeing (it is about 5 to 7). If he worked 8 hours, about how many MET-minutes would that be? Compare it with your day.
3. Ecclesiastes 9:10 says to do your work "with thy might." How can you bring that attitude to both your schoolwork and your training?

Safety first. Check with your doctor first if you have asthma, a heart condition, diabetes, a recent injury or any other health concern, and make sure a parent knows about every workout. Use a staircase with a handrail and good light, keep one hand near the rail, and wear shoes with grip; step down carefully rather than running down. Stop and tell an adult right away at chest pain, dizziness, fainting, trouble breathing or sharp pain.

ACTIVITY

The Conductor's Workout and a Seven-Day Activity Audit

Morris compared two kinds of workday. You will measure your own. First you will climb like a conductor and measure what it does to your heart rate. Then you will log every day for a week, sort your activity by intensity, calculate MET-minutes, and see how your week compares with the guidelines and with a conductor's shift.

You will need

- A staircase of at least 8–12 steps with a handrail (or a sturdy bottom step for step-ups)
- A timer, a pencil, and your fitness journal
- An audit table for 7 days: date, sitting hours, minutes of light, moderate and vigorous activity, what you did, MET-minutes
- A water bottle

Steps

1. **Resting heart rate.** Sit quietly for 3 minutes. Count your pulse for 30 seconds and double it. Record it.
2. **Warm up** with the stair-conductor warm-up above.
3. **The conductor's workout (Session 2).** For 8 minutes, walk up the full flight at a steady pace, touching the rail lightly, and walk back down carefully. Count every complete trip up as one flight. Keep a pace you could hold for the whole 8 minutes; this is not a race. (No staircase? Do step-ups on the bottom step: 20 steps leading with the right, 20 with the left, and count each 40 as one "flight.")
4. **Measure.** The moment you finish, count your pulse for 15 seconds and multiply by 4. Rate your effort from 1 (resting) to 10 (all-out). Then walk slowly for 2 minutes and check your pulse again.
5. **Record** flights, finishing heart rate, 2-minute heart rate and effort rating. Estimate the METs (steady stair climbing is about 4 to 8 METs depending on speed) and the MET-minutes.

6. **Start the audit.** Every evening for 7 days, fill in your audit table. Use the talk test to sort activity: light (can sing), moderate (can talk, not sing), vigorous (only a few words). Estimate sitting hours, including school, meals, homework, car and screens.
7. **Repeat (Session 3).** Warm up and do the conductor's workout again. Aim for one more flight in 8 minutes at the same effort rating, or the same flights at a lower finishing heart rate. Either is improvement.
8. **Analyze the week.** At the end of 7 days, total your moderate-to-vigorous minutes and MET-minutes. On how many days did you reach 60 minutes? How many days included vigorous, muscle-strengthening and bone-strengthening activity? What was your longest unbroken stretch of sitting?
9. **Set one goal.** Write one specific change, such as "I will stand and walk for 3 minutes at the end of every school period" or "I will walk to practice three days a week," and keep it for the unit challenge.

Tips

- Be honest in your audit. An accurate small number is more useful than a hopeful large one.
- Everyday tasks count: carrying groceries, mowing, shoveling snow and helping a neighbor move furniture are all real activity.
- If you play a sport, log practice by what you actually did, not by the time on the schedule; much of a two-hour practice may be standing.

Check your work

- ☐ I can explain what Morris compared, what he found and why he kept testing the idea.
- ☐ I can calculate MET-minutes for an activity, a day and a week.
- ☐ I completed the conductor's workout twice and a full seven-day audit, and wrote a specific goal.

FITNESS JOURNAL

1. Make a table of your two conductor's workouts: flights, finishing heart rate, 2-minute heart rate, effort rating. Circle what improved.
2. Draw a stacked bar graph of your audit: one bar per day, split into sitting hours, light, moderate and vigorous minutes. Draw a line at 60 minutes of moderate-to-

vigorous activity.

3. Show your MET-minute calculation for your most active and least active day.
4. Write a paragraph: What surprised you about your week? What is one confounding factor that could have affected Morris's bus study, and how did his later study of civil servants deal with it?

From history. Morris's bus study is often called the beginning of physical-activity epidemiology. In 1996 he and the American researcher Ralph Paffenbarger, who had found the same pattern among San Francisco dockworkers and Harvard graduates, were the first winners of the International Olympic Committee's Olympic Prize for sport science. The London "Routemaster" buses with an open platform at the back, where conductors hopped on and off, kept their conductors on some routes until 2005.

COMMON MISTAKES

- Thinking one workout cancels out a whole day of sitting. Daily exercise matters most, and breaking up long sitting also helps.
- Counting all of practice or gym class as vigorous. Log what you actually did; standing in line is light activity.
- Treating Morris's first study as final proof. It showed a strong pattern; it took decades of further studies to show that activity itself protects the heart.
- Running down stairs. Climb with energy, but always walk down holding the rail.

Make it a game • Confounder Hunt. Read the London busmen study as a skeptic. List three confounding factors that could have explained the results, such as age, diet or job choice. Your parent plays Jerry Morris and defends the study. Calculate MET-minutes for your week and compare to a target. Win by finding more flaws than she can answer.

Scripture. "Whatsoever thy hand findeth to do, do it with thy might" (Ecclesiastes 9:10, KJV)

The farm worker and the bus conductor did their work with their might. Whether our work is at a desk or in a field, we can do it wholeheartedly and choose to keep our bodies strong for it.

1.2 MOBILITY AND FLEXIBILITY: WELLS, DILLON AND THE SIT-AND-REACH

OBJECTIVES

- Tell how Katharine Wells and Evelyn Dillon designed the sit-and-reach test in 1952 and what it measures.
- Explain the difference between flexibility and mobility and the roles of muscles, tendons, joints, muscle spindles and stretch tolerance.
- Choose dynamic stretching before training and static stretching after, following the ACSM guidance on how long to hold a stretch.
- Measure four mobility tests, follow a daily routine, and retest to see personal improvement.

Warm-up. Dynamic warm-up (5 minutes): 1 minute of easy jogging in place; 10 leg swings forward-and-back and 10 side-to-side on each leg (hold a wall); 10 walking lunges with an overhead reach; 10 arm circles each way; 5 inchworms (bend, walk your hands out to a push-up position, walk your feet up to your hands). Think about it: did you feel looser after the warm-up? Why might that be?

WATCH

Workout Stretching and Easy Warm Up Exercises - Static and Dynamic Stretching

Saint Peter's Healthcare System · 3:16

<https://www.youtube.com/watch?v=f8knLSFeQ84>

WHEN TO WATCH

In Session 1, after “Good form.” Then do the dynamic stretches along with the video.

Note: A physical therapist from Saint Peter’s Sports Medicine Institute explains dynamic stretching, and an athlete in a T-shirt and shorts shows the moves.

BACKUP VIDEO

Sit and Reach Protocol Video

The Kenneth H. Cooper Institute · 2:13

<https://www.youtube.com/watch?v=T2LzgbHXbUI>

Before Test 1, to see exactly how a sit-and-reach is measured.

KEY TERMS

flexibility

The range of motion available at a joint, often measured passively (how far it can be moved, as in a stretch).

static stretching

Moving into a stretch and holding it still, usually for 10–30 seconds.

muscle spindle

A tiny sensor inside a muscle that detects stretch and triggers the stretch reflex, a quick contraction that resists sudden stretching.

mobility

The ability to move a joint actively and with control through its range of motion, using your own muscles.

dynamic stretching

Moving joints through their range in a controlled, repeated way, such as leg swings and walking lunges.

stretch tolerance

How much stretching your nervous system will allow before it signals discomfort. Early gains in flexibility come mostly from improved tolerance.

CORE IDEAS

The story. In the early 1950s, physical educators had a flexibility problem: their standard test was the standing toe touch, where students bent over and “bobbed” toward the floor. It was hard to measure fairly and bouncing into a stretch could strain the back. At Wellesley College in Massachusetts, Katharine Wells and Evelyn Dillon designed something simpler. The student sat on the floor with legs straight and feet flat against a box, reached forward slowly with both hands along a measuring scale, and held the farthest point. In 1952 they published “The Sit and Reach—A Test of Back and Leg Flexibility” in the *Research Quarterly*. Their test, with small changes, is still used in schools around the world, including the one-leg “back-saver” version in today’s FitnessGram.

How they figured it out. A good test must be **reliable** (it gives the same result when repeated) and **valid** (it measures what it claims to). Wells and Dillon tried their method on college students and reported that it gave consistent scores and was quick to give. Later researchers found that the sit-and-reach mainly measures the flexibility of the hamstrings (the muscles on the back of the thigh) and less of the lower back. That is a good lesson in science: every test measures something specific, and you must know what it is.

How your body works. How far a joint can move depends on three things: the shape of the bones and joint, the stiffness of the muscles, tendons and connective tissue that cross it, and the **nervous system**. Inside each muscle are **muscle spindles** that sense stretch; when a muscle is stretched quickly, they trigger a reflex that makes it tighten, which is why bouncing stretches backfire. Most of the improvement you notice in the first few weeks of stretching comes from greater **stretch tolerance**: your nervous system learns that the position is safe. Over months, the muscle-tendon unit itself becomes more extensible. **Flexibility** is how far a joint can be moved; **mobility** is how far you can move it yourself with strength and control, which is what sport and daily life need. During growth spurts, bones can lengthen faster than muscles adapt, so many teenagers feel tighter for a season; regular mobility work helps.

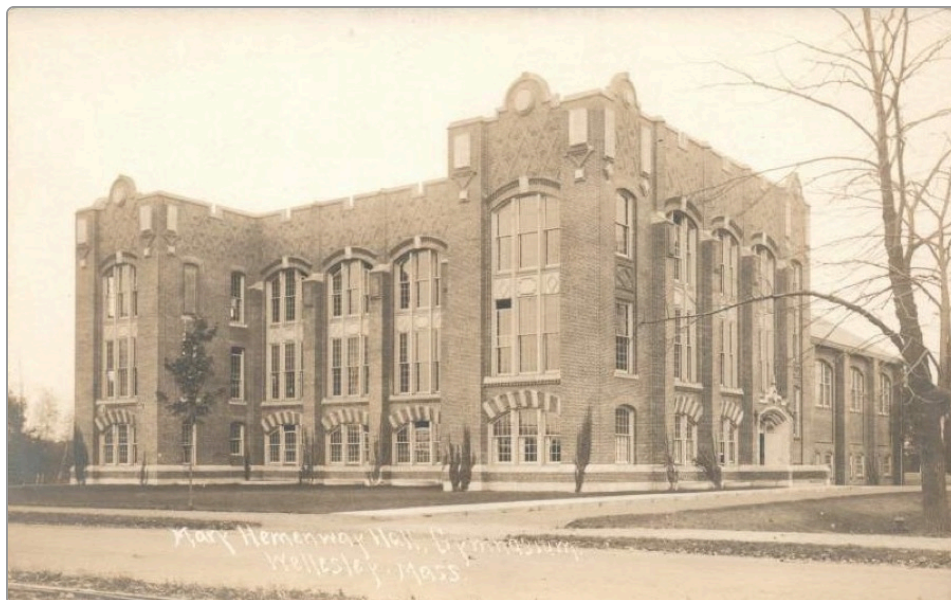
Good form. Before training, use a **dynamic warm-up**: light jogging, then movements through the ranges your sport uses. Long static holds (more than about 60 seconds per muscle) just before sprinting or jumping can briefly reduce power, so save them for later. After training, or as a separate session, use **static stretching**: the American

College of Sports Medicine advises holding each stretch for 10–30 seconds at a point of mild tension, not pain, repeating for a total of about 60 seconds per muscle group, on at least 2–3 days a week (daily works best). Breathe slowly, never bounce, and stretch both sides.

Think it through. Suppose your sit-and-reach is 8.5 inches today and 10.0 inches after three weeks. The gain is $10.0 - 8.5 = 1.5$ inches, and the percentage improvement is $1.5 \div 8.5 \times 100 \approx 17.6\%$. If your knee-to-wall test is 9 cm on the left and 12 cm on the right, the difference is 3 cm, or 25% less on the left ($3 \div 12$). A difference between sides is worth working on, because one stiff ankle can change how you land and run.

Try it. This week you will measure four mobility tests, learn a 10-minute daily mobility routine and a post-workout stretch routine, and retest at the end of the week. You will keep the routine going through the unit challenge.

PICTURE STUDY



Mary Hemenway Hall Gymnasium, Wellesley College, Unknown photographer (postcard), About 1910 · Photographic postcard · Wellesley College, Massachusetts
Image: [Wikimedia Commons](#), public domain

Wellesley College, a women's college near Boston, opened Mary Hemenway Hall as its gymnasium in 1909 and became a center for training teachers of physical education. Katharine Wells and Evelyn Dillon worked in Wellesley's physical education department when they designed the sit-and-reach test four decades after this postcard was made.

Look closely

- Look at the building. What clues tell you it was built for exercise and sport?
- Find the windows and doors. Why would a gymnasium need plenty of light and air?
- Look at the setting around the building. Where might students have walked, run or played outdoors?

Talk about it

1. Why would a college that trained teachers want a simple test that any teacher could give with a box and a ruler?
2. Wells and Dillon replaced a bouncing test with a slow, steady reach. Why is a slow reach both safer and more accurate?

3. What would make a fitness test fair to compare from one week to the next for the same student?

Safety first. Always warm up before testing or stretching. Move into each stretch slowly to mild tension, never to pain, and never bounce. If a test or stretch causes sharp pain, tingling or numbness, stop and tell an adult; anyone with a recent back, hip or knee injury should skip the related tests until a doctor says they are fine.

ACTIVITY

The Four-Test Mobility Check and a Daily Routine

You will build a homemade sit-and-reach box, measure four tests, learn a dynamic routine for before training and a static routine for after, and retest to see your own change.

You will need

- A sturdy bottom step or a box about 12 inches high, a yardstick or tape measure, and masking tape
- A wall, a towel or mat, and a helper to read the measurements
- A timer and your fitness journal with a test table: test, left, right, best, date

Steps

1. **Warm up** with the dynamic warm-up above. Never test cold.
2. **Test 1: sit-and-reach.** Sit on the floor with shoes off, legs straight, feet flat against the step or box. Tape the yardstick on top so that the 15-inch mark lines up with the front edge (where your feet are) and the low numbers point toward you. With one hand on top of the other, reach forward slowly along the yardstick and hold the farthest point for 2 seconds. Your helper reads the number. Do three reaches; record the best. (Past your toes scores more than 15.)
3. **Test 2: shoulder reach.** Reach your right hand over your right shoulder and down your back, and your left hand behind your lower back and up. Your helper measures the gap between the middle fingertips (a negative number) or the overlap (positive). Switch sides. Record both.
4. **Test 3: knee-to-wall ankle test.** Kneel facing a wall in a half-kneeling position, front foot flat. Keeping the heel down, push the front knee forward to touch the wall. Slide the foot back until you can just touch the wall with the heel still down. Measure from the big toe to the wall in centimeters. Test both ankles.
5. **Test 4: deep squat hold.** Feet shoulder-width, heels down, sit as deep as you can with chest up and arms forward. Hold for up to 30 seconds. Rate it: 1

(heels lift or you fall back), 2 (deep with effort), 3 (deep, heels down, chest up, comfortable).

6. **Learn the daily mobility routine (10 minutes).** 10 leg swings each direction each leg; 8 walking lunges with a twist toward the front knee; 8 “open-book” rotations on each side (lie on your side, knees bent, and rotate the top arm open to the floor behind you); 10 ankle rocks each side (the knee-to-wall motion, rocking in and out); 10 slow deep squats holding a doorframe; 10 arm circles and 10 wall slides (back to wall, slide arms up and down in a W-to-Y shape).
7. **Learn the after-training static routine.** Hold each stretch 30 seconds, twice per side: hamstring stretch (one leg straight on a low step, hinge forward with a flat back); kneeling hip stretch (one knee on a towel, shift hips forward); calf stretch against a wall (back knee straight, then bent); thigh stretch (hold a chair, pull heel toward seat); chest stretch in a doorway.
8. **Session 2:** do all four tests and record them, then do the mobility routine and the static routine. On days 3–6, do the 10-minute mobility routine once a day and the static routine after any training.
9. **Session 3 (end of the week):** warm up and retest all four tests exactly the same way. Calculate the change and percentage change for each. Keep going daily for the unit challenge and retest again in two weeks.

Tips

- Keep each test the same every time: same warm-up, same box, same helper, same time of day. Fair tests make your numbers trustworthy.
- Breathe out slowly as you ease into a stretch; your muscles relax more when you are calm.
- Compare only with yourself. Flexibility varies widely from person to person, and joint shape cannot be changed by stretching.

Check your work

- ☐ I can explain the difference between flexibility and mobility and why bouncing stretches backfire.
- ☐ I measured four tests fairly, did the routine daily and retested.
- ☐ I can choose the right kind of stretching before and after training.

FITNESS JOURNAL

1. Make a table of your four tests, left and right, on Day 1 and Day 7. Calculate the change and percentage change for each.
2. Draw a muscle with a muscle spindle inside and a tendon at each end. Label what happens in the stretch reflex when a muscle is stretched suddenly.
3. Write out your two routines (before training and after training) as a card you can keep in your gym bag.
4. Write a paragraph: Which test showed the biggest difference between your left and right sides? What might cause it, and what will you do about it?

From history. The sit-and-reach replaced the standing toe touch in many school fitness tests. Today's FitnessGram, developed by the Cooper Institute in Dallas, uses the back-saver sit-and-reach, which measures one leg at a time with the other knee bent, to put less strain on the lower back.

COMMON MISTAKES

- Bouncing to reach farther. It triggers the stretch reflex, strains tissue and gives an unfair score.
- Holding long static stretches right before a sprint or jump. Use a dynamic warm-up first; stretch statically afterward.
- Stretching to pain. Mild tension is enough; pain is a signal to ease off.
- Thinking more flexible is always better. Joints need strength and control through their range, not only looseness.

Make it a game • Four Test Mobility Day. Run four mobility tests such as sit-and-reach, shoulder reach, deep squat hold and ankle lunge. Record each and your parent checks form. Explain flexibility versus mobility, muscle spindles and stretch tolerance. Tell the 1952 sit-and-reach story. Retest after a week of a daily routine and aim for a bigger reach.

UNIT 1

KEEPING ACTIVE

For most of history, people did not need to plan exercise. In 1900 about four in ten American workers farmed, and most other jobs meant walking, lifting and carrying. By 2000 fewer than two in a hundred worked on farms, and many of us now sit for most of the day at school, at desks and in cars. In this unit you will study the first great scientific test of what that change means: Jerry Morris's 1953 comparison of London bus drivers, who sat all day, with bus conductors, who climbed the stairs of double-decker buses hundreds of times a shift. You will learn to measure activity in MET-minutes and audit a week of your own life.

Then you will learn the difference between flexibility and mobility, how muscles and nerves control how far a joint can move, and when static and dynamic stretching help or hinder. You will meet Katharine Wells and Evelyn Dillon, two Wellesley College teachers who invented the sit-and-reach test in 1952, test yourself on four simple measures, and follow a mobility routine long enough to see your own numbers change.

PREREQUISITES

- Knows the youth activity guideline of at least 60 minutes a day and the difference between moderate and vigorous activity (earlier grades)
- Can take a pulse at the wrist or neck and convert a 15-second count to beats per minute
- Comfortable multiplying, adding columns of numbers and working with percentages

MASTERY CHECKLIST

- ☐ I can explain how work changed from farm to desk and why activity must now be chosen on purpose.
- ☐ I can describe Jerry Morris's bus study: the question, the two groups, what was measured, what was found and its limits.
- ☐ I can define a MET, sort activities into light, moderate and vigorous, and calculate MET-minutes for a day and a week.
- ☐ I can explain the difference between flexibility and mobility and the roles of muscle spindles and stretch tolerance.
- ☐ I can choose dynamic stretching before training and static stretching after it, and perform and measure a sit-and-reach and a knee-to-wall test.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Physical Activity Guidelines for Americans, 2nd edition (U.S. Department of Health and Human Services)**: Free. The 2018 guidelines on which Lesson 1.1 is based, with a chapter on children and adolescents and a table of moderate and vigorous activities.
- **A tape measure or yardstick and masking tape**: For the sit-and-reach, shoulder-reach and knee-to-wall tests in Lesson 1.2. A ruler taped to a step works too.
- **A pedometer or a phone step counter**: Optional, for the activity audit. Minutes and the talk test are enough.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

1.1 From Farm to Desk: Jerry Morris and the London Buses

3 sessions of 45–50 minutes

1.2 Mobility and Flexibility: Wells, Dillon and the Sit-and-Reach

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **8 pts**

How did American work change between 1900 and 2000, and why does that change mean activity must now be chosen deliberately?

2. **10 pts**

Describe Jerry Morris's 1953 bus study: the question, the two groups compared, and the main findings.

3. **8 pts**

What is a confounding factor? Give one possible confounding factor in the bus study and explain how Morris's later research addressed the question.

4. **8 pts**

State the Physical Activity Guidelines (2018) for people aged 6–17.

5. **10 pts**

Calculation. On Saturday you mow the lawn for 40 minutes (5.5 METs), walk the dog for 20 minutes (3 METs), and play 50 minutes of basketball (6.5 METs). Find the MET-minutes for each activity and the total. Did you meet the daily guideline?

6. **8 pts**

Calculation. Your audit shows moderate-to-vigorous minutes of 45, 70, 30, 85, 60, 20 and 95 over seven days. Find the weekly total and daily average, and the number of days you met the guideline.

7. **8 pts**

Explain the difference between flexibility and mobility, and give one example of each.

8. **8 pts**

What do muscle spindles do, and why does this make bouncing stretches a poor idea?

9. **8 pts**

When should you use dynamic stretching and when static stretching? State the ACSM guidance for static stretches.

10. **8 pts**

Calculation. Your sit-and-reach improved from 11.0 inches to 12.5 inches. Your left knee-to-wall is 8 cm and your right is 11 cm. Find the sit-and-reach percentage improvement and the left-right difference as a percentage of the right side.

11. **16 pts**

Short written answer. Write a paragraph explaining to a friend who sits most of the day why both daily exercise and breaking up long periods of sitting matter, using what you learned from Morris and from how muscles work. Include one specific plan for his or her school day.

ANSWER KEY

1. In 1900 about four in ten American workers farmed and most jobs were physical; by 2000 fewer than two in a hundred farmed and many jobs are done sitting. Because work no longer keeps most people active, we must plan activity into our days (sport, walking, chores, training) or we will sit most of the day.
2. Question: does physical activity at work affect heart disease? Groups: London bus drivers (seated all shift) and conductors (climbing the stairs of double-decker buses all day), similar men in the same city and company. Findings: conductors had less coronary heart disease; it came later and was milder; drivers' sudden-death rate from heart attack was about twice the conductors'. Postmen versus seated clerks and telephonists showed the same pattern.
3. A hidden difference between groups that could explain the result instead of the factor studied. Example: men who chose to be drivers might have differed in health or habits from conductors before they started. Morris later studied civil servants who all had desk jobs and compared those who took vigorous exercise in their free time with those who did not; the active men still had far fewer heart attacks, so activity itself mattered.
4. At least 60 minutes of moderate-to-vigorous physical activity every day, mostly aerobic, including vigorous activity on at least 3 days a week, muscle-strengthening activity on at least 3 days a week and bone-strengthening activity on at least 3 days a week.
5. Mowing: $5.5 \times 40 = 220$ MET-min. Walking: $3 \times 20 = 60$ MET-min. Basketball: $6.5 \times 50 = 325$ MET-min. Total = 605 MET-minutes. Moderate-to-vigorous minutes = $40 + 20 + 50 = 110$ minutes, so yes, the 60-minute guideline was met (and vigorous activity was included).
6. Total = $45 + 70 + 30 + 85 + 60 + 20 + 95 = 405$ minutes. Average = $405 \div 7 \approx 57.9$ minutes a day. Days at 60 or more: 70, 85, 60, 95 = 4 days. The goal is 60 every day, or seven hours a week.
7. Flexibility is the range a joint can be moved, often passively (e.g., how far a partner or gravity can stretch your hamstrings in a sit-and-reach). Mobility is how far you can move a joint actively with strength and control (e.g., lifting your leg high in a controlled leg swing or sitting into a deep squat with heels down and chest up).
8. Muscle spindles sense how far and how fast a muscle is stretched. A sudden stretch triggers the stretch reflex, making the muscle contract to resist.

Bouncing causes repeated sudden stretches, so the muscle tightens against you, the stretch is less effective, and tissue can be strained.

9. Dynamic stretching belongs in the warm-up before training or sport. Static stretching belongs after training or in a separate session, because long static holds just before sprinting or jumping can briefly reduce power. ACSM: hold 10–30 seconds at mild tension, repeat to about 60 seconds total per muscle group, at least 2–3 days a week (daily is most effective).
10. Sit-and-reach: $12.5 - 11.0 = 1.5$ in; $1.5 \div 11.0 \times 100 \approx 13.6\%$ improvement. Ankle: $11 - 8 = 3$ cm; $3 \div 11 \times 100 \approx 27\%$ less on the left.
11. Answers vary. A full answer explains that Morris found active workers had less and milder heart disease, and later that free-time exercise protected desk workers; that working muscles take up blood sugar and fat and train the heart, while long sitting leaves the large leg muscles idle; that 60 minutes of daily activity is the goal and short standing and walking breaks every 30–60 minutes help too; and gives a concrete plan (e.g., walk between classes, stand for 3 minutes each period, walk or bike to school, practice or train after school).

UNIT CHALLENGE: TWO-WEEK ACTIVE LIVING AUDIT AND MOBILITY PLAN

Continue your activity audit for two full weeks, keeping the one specific goal you set in Lesson 1.1, and do your 10-minute mobility routine every day. Record moderate-to-vigorous minutes, MET-minutes and sitting hours daily, and retest the four mobility tests at the end. Make two graphs (daily active minutes with a 60-minute line, and before-and-after mobility results) and write a one-page report on what changed, what was hard and what habit you will keep.

LOOK FOR	WHAT IT MEANS
Complete records	Fourteen dated days of audit entries with minutes, intensities, MET-minutes and sitting hours.
Calculations and graphs	Weekly totals, averages and MET-minutes calculated correctly; two clear, labeled graphs.
Faithful practice	Daily mobility routine logged; the personal goal kept on most days; tests repeated fairly.
Reflection	A thoughtful report naming specific changes, honest difficulties and a habit to keep. Effort and improvement count, not the size of the numbers.

UNIT 2

HYDRATION

During the Second World War, the physiologist Edward Adolph and his team from the University of Rochester took soldiers and volunteers into the California desert to answer a life-and-death question: how much water does a person lose in the heat, and what happens when he does not replace it? They weighed men before and after desert walks, measured every drink, and turned the difference into a sweat rate. In this unit you will run the same test on yourself, calculate your own sweat rate, and use it to build a drinking plan for training and games. You will also learn the opposite danger, drinking far more than you sweat, which can dilute the sodium in the blood (hyponatremia).

Then you will look plainly at caffeine and energy drinks: what caffeine is (first isolated by the German chemist Friedlieb Runge in 1819), how it blocks the brain's sleep signal, how long it lingers in the body, what it does to the heart, sleep and recovery, and why pediatricians say energy drinks have no place in what teenagers drink. You will run your own experiment on sleep, water and morning energy.

PREREQUISITES

- Knows what water does in the body (cooling by sweat, carrying nutrients, cushioning joints) and the signs of dehydration (earlier grades)
- Knows that sweat contains salt and that sodium and potassium are electrolytes
- Can convert between ounces, cups, pounds and liters and calculate a percentage

MASTERY CHECKLIST

- ☐ I can explain how Adolph's desert studies measured sweat loss and what they learned.
- ☐ I can measure my own sweat rate and calculate it in ounces and liters per hour.
- ☐ I can build a drinking plan that limits fluid loss during exercise without over-drinking, and explain hyponatremia.
- ☐ I can explain how caffeine works on adenosine receptors, calculate how much remains after several half-lives, and describe its effects on sleep and the heart.
- ☐ I can give clear health reasons why teenagers should skip energy drinks.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **"Spilling the Beans: How Much Caffeine Is Too Much?" (U.S. Food and Drug Administration)**: Free. The FDA's plain-language page on caffeine amounts and risks, for Lesson 2.2.
- **A reusable water bottle with ounce marks**: Handy for the sweat-rate test and the water log; a measuring cup works too.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

2.1 Measure Your Sweat Rate: Edward Adolph in the Desert

3 sessions of 45–50 minutes

2.2 Caffeine and Energy Drinks: Why to Skip Them

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **8 pts**

How did Edward Adolph's team measure water loss in the desert, and what did they discover?

2. **8 pts**

Explain how sweat cools you and what sweat contains.

3. **10 pts**

Calculation. During a 75-minute soccer practice, a player's scale reading drops by 2.0 lb. He drank 20 oz and did not use the bathroom. Find his sweat loss and his sweat rate in ounces per hour and liters per hour.

4. **8 pts**

Calculation. Using the sweat rate from question 3, how much fluid would he lose in a 2-hour practice? If he drinks 8 oz every 15 minutes, what is his net loss?

5. **8 pts**

Describe how the brain and kidneys respond when you lose fluid in sweat.

6. **10 pts**

What is exercise-associated hyponatremia, what causes it, what are its symptoms, and what simple rule helps prevent it?

7. **8 pts**

How does caffeine make a person feel alert? Why is that alertness misleading?

8. **10 pts**

Calculation. A student drinks a 160 mg energy drink at 4:00 p.m. With a 5-hour half-life, how much caffeine remains at 9:00 p.m., 2:00 a.m. and 7:00 a.m.?

9. **8 pts**

Calculation. Using Health Canada's guideline of 2.5 mg per kilogram per day, what is the limit for a 60-kg teenager? What percentage of that limit is one 300 mg energy drink?

10. **6 pts**

What is the difference between a sports drink and an energy drink?

11. **16 pts**

Short written answer. A younger sibling says energy drinks help athletes play better. Write a paragraph explaining why teenagers should skip them, using what you learned about caffeine, sleep, the heart and sugar, and what to do instead.

ANSWER KEY

1. They weighed men before and after desert walks and work, measured all the water they drank, and calculated the water lost. Men could sweat about a liter an hour or more in desert heat; training did not reduce the need for water; men who drank freely did far better; and even with water available, men drank less than they lost during the march (voluntary dehydration).
2. Working muscles make heat; the body sends warm blood to the skin and releases sweat, and when sweat evaporates it carries heat away. Sweat is mostly water, with sodium, chloride and a little potassium.
3. Fluid lost from the body = $2.0 \times 16 = 32$ oz. Sweat loss = $32 + 20 = 52$ oz in 1.25 h. Sweat rate = $52 \div 1.25 = 41.6$ oz/h. In liters: $41.6 \times 30 \text{ mL} \approx 1,248 \text{ mL} \approx 1.25 \text{ L/h}$.
4. Loss = $41.6 \times 2 = 83.2$ oz. Drinking $8 \text{ oz} \times 8 \text{ times} = 64 \text{ oz}$. Net loss = $83.2 - 64 = 19.2$ oz (about 1.2 lb), a small loss he replaces afterward.
5. The blood becomes more concentrated; sensors in the brain detect it; you feel thirst; the pituitary releases antidiuretic hormone (ADH); the kidneys reabsorb more water and make less, darker urine.
6. Blood sodium below 135 mmol/L during or after exercise, usually from drinking far more fluid than is lost over hours, which dilutes blood sodium; water moves into cells and the brain swells. Symptoms: headache, nausea, vomiting, confusion, and in severe cases seizures or death. Rule: drink to a plan based on your sweat rate and never weigh more after exercise than before.
7. Adenosine builds up during waking hours and binds to receptors that make us sleepy. Caffeine resembles adenosine and blocks those receptors without activating them, so the sleepy signal is hidden. The body's need for sleep is still there; it is only masked.
8. 9:00 p.m.: $160 \div 2 = 80$ mg. 2:00 a.m.: $80 \div 2 = 40$ mg. 7:00 a.m.: $40 \div 2 = 20$ mg. There is still as much caffeine as in a cup of tea or most of a cola at bedtime.
9. $2.5 \times 60 = 150$ mg a day. $300 \div 150 \times 100 = 200$ percent of the limit.
10. A sports drink contains water, sugar and electrolytes to replace fluid and fuel during long, hard exercise. An energy drink is a caffeine product, often with large amounts of sugar and other stimulants; it does not hydrate better and is not recommended for teenagers.
11. Answers vary. A full answer explains that energy drinks contain large doses of caffeine (80–300 mg) and often 50 g or more of sugar; caffeine raises heart rate and blood pressure, can cause jitters, anxiety and irregular heartbeat, and stays

in the body for hours (half-life about 5 hours), stealing deep sleep when muscles recover and growth hormone is released; tolerance and withdrawal follow; the AAP says they have no place in teenagers' diets; emergency visits rose; and real performance comes from sleep, water, good food and training.

UNIT CHALLENGE: MY PERSONAL HYDRATION AND ENERGY PLAN

Using your two sweat-rate tests, write a one-page hydration plan for practices and games in cool and hot weather: what you drink before, how much and how often during, and what you drink and eat after, with the warning signs of both dehydration and hyponatremia. Keep a seven-day log of water intake, urine color and sleep (no caffeine), and finish with a short report and a graph showing how your sleep and energy related over the week.

LOOK FOR	WHAT IT MEANS
Sound plan	Drinking amounts based on your own measured sweat rate, with a small allowed loss and a clear rule against gaining weight.
Accurate calculations	Both sweat-rate tests calculated correctly with every step and unit shown.
Faithful log	Seven dated days of water, urine color, sleep and energy, kept honestly.
Reflection and graph	A clear graph and a thoughtful report on what you learned about water, sleep and energy. Effort and honesty count, not the numbers themselves.

2.1 MEASURE YOUR SWEAT RATE: EDWARD ADOLPH IN THE DESERT

OBJECTIVES

- Describe how Edward Adolph’s team measured water loss in the desert and what they discovered about thirst and performance.
- Measure your own sweat rate by the before-and-after method and calculate it in ounces and liters per hour.
- Explain how sweat cools the body, what it contains, and how the kidneys keep fluid in balance.
- Build a personal drinking plan that limits fluid loss and avoids over-drinking, and explain exercise-associated hyponatremia.

Warm-up. Heat-check warm-up (5 minutes): 1 minute of easy jogging in place, 10 jumping jacks, 10 bodyweight squats, 10 arm circles each way, 1 minute of skipping or high knees, then 1 minute of brisk walking. Think about it: where on your body did you feel warm first? Where would sweat appear first?

WATCH

Korey Stringer Institute Heat and Hydration

Korey Stringer (Korey Stringer Institute) • 10:42

<https://www.youtube.com/watch?v=lztHtCgjlwBM>

WHEN TO WATCH

After “Think it through,” before the sweat-rate test. Watch for the weight-change method and the urine color chart.

Note: From the Korey Stringer Institute at the University of Connecticut, which works to prevent sudden death in sport. It is made for coaches of football players and ends with the emergency treatment of heat stroke; that section is worth knowing.

BACKUP VIDEO

Sweat Rate Calculation

Drug Free Sport International • 1:40

<https://www.youtube.com/watch?v=NztTNSEvrYA>

Before you calculate your own sweat rate, for a quick worked example of the formula.

KEY TERMS

sweat rate

How much fluid you lose in sweat per hour of exercise, found from the change in body weight plus fluid drunk, minus urine.

voluntary dehydration

Adolph's name for the way people drink less than they sweat during exercise, even when water is available.

exercise-associated hyponatremia

A dangerously low level of sodium in the blood (below 135 millimoles per liter) during or after exercise, usually caused by drinking far more fluid than is lost.

evaporative cooling

Cooling that happens when sweat turns to vapor on the skin and carries heat away. Each liter of sweat that evaporates removes a large amount of heat.

antidiuretic hormone (ADH)

A hormone from the pituitary gland that tells the kidneys to hold on to water when the blood becomes too concentrated.

electrolyte

A mineral that carries an electric charge in body fluids, such as sodium, potassium and chloride.

CORE IDEAS

The story. When American soldiers began training for desert warfare in the early 1940s, the army needed to know how much water a man needed and whether men could be “trained” to need less. Edward F. Adolph, a physiologist at the University of Rochester in New York, led a team that spent long hot seasons in the California desert studying men walking, working and resting in the sun. They published their work after the war in a book, *Physiology of Man in the Desert* (1947).

How they figured it out. Adolph's team used a simple, powerful method: weigh a man before and after a walk, measure everything he drank, and the difference is the water he lost, mostly as sweat. They found that men marching in desert heat could sweat about a liter (roughly a quart) an hour or more. They found that no amount of training reduced the body's need for water; men who were allowed to drink as much as they wanted finished long marches in far better condition than men who were not. And they discovered something surprising: even with water at hand, men drank

less than they lost during the march and made up the difference later at meals. Adolph called this **voluntary dehydration**. Thirst alone, during hard work in the heat, lags behind real losses.

How your body works. Working muscles turn most of their fuel energy into heat. To keep your core near 98.6°F (37°C), your body sends warm blood to the skin and releases sweat; when sweat evaporates, it carries heat away. Sweat is mostly water with sodium, chloride and a little potassium; a liter of sweat often holds around a gram of sodium, though some people lose half that and others twice as much. Typical sweat rates in sport range from about half a liter to two liters an hour, depending on heat, humidity, effort, fitness and the person. When you lose fluid, your blood becomes more concentrated; the brain senses it, triggers thirst, and releases **ADH**, so the kidneys make less, darker urine. The American College of Sports Medicine notes that losing more than about 2 percent of body weight as fluid can reduce endurance and concentration, especially in heat.

Think it through. The sweat-rate formula is: *sweat loss = (weight before – weight after) + fluid drunk – urine*. One pound of body weight lost is about 16 fluid ounces of fluid (1 kilogram ≈ 1 liter). Example: a runner's scale reading drops by 1.6 lb during a 60-minute run; she drank 12 oz and did not use the bathroom. Fluid lost from the body: $1.6 \times 16 = 25.6$ oz. Sweat loss = $25.6 + 12 = 37.6$ oz in one hour, a sweat rate of about 37.6 oz/h, or $37.6 \times 30 \text{ mL} \approx 1.1 \text{ L/h}$. If she drinks 8 oz every 20 minutes (24 oz/h) in a 90-minute practice, she loses $37.6 \times 1.5 = 56.4$ oz and replaces 36 oz, a net loss of about 20 oz (about 1¼ lb): a small, safe loss. Afterward she replaces the rest with water and her next meal.

Too much is dangerous too. If you drink much more than you sweat for hours, the extra water dilutes the sodium in your blood. Water then moves into cells, which swell; in the brain this causes headache, nausea, confusion, vomiting and, in severe cases, seizures and death. In a study of 488 runners in the 2002 Boston Marathon, 13 percent finished with hyponatremia; the strongest warning sign was *gaining* weight during the race. The rule: you should never weigh more after exercise than before. Drink to a plan built from your sweat rate, and let thirst guide you in ordinary activity.

Try it. This week you will measure your sweat rate in two different conditions and use your numbers to build a personal drinking plan. Only the change on the scale

matters; you will record fluid lost, not body weight.

PICTURE STUDY



Haymaking, Winslow Homer, 1864 · Oil on canvas · Columbus Museum of Art, Ohio

Image: [Wikimedia Commons](#), public domain

Winslow Homer painted this young farmhand turning hay on a hot summer day in 1864. Haying had to be done in the hottest, driest weeks of summer, so that the cut grass would dry before it was stored. Farm families knew a great deal about working in heat long before scientists measured sweat.

Look closely

- Find the straw hat. What does it do for the worker in the sun?
- Look at his shirt sleeves and clothing. How might they help or hurt him in the heat?
- Find the shade trees. When would a sensible haymaker rest under them?
- Look for any water jug or drink. Homer does not show one: where might the worker keep his water, and how often should he drink?

Talk about it

1. Turning hay with a fork is moderate-to-vigorous work. Using a sweat rate of about 1 liter (34 oz) an hour, how much might he lose in a 4-hour morning?
2. Adolph found that workers drink less than they lose. What plan would you give this young man for his water during a hot afternoon?
3. Why did farm families start work early in the morning during haying season?

Safety first. Do the sweat-rate test on a moderate session, not an all-out effort, and not in extreme heat; drink normally during it. Stop and tell an adult at dizziness, headache with confusion, nausea, chills or goose bumps in the heat, or if you stop sweating. Never try to lose fluid on purpose, and never force down large amounts of water; you should never weigh more after exercise than before.

ACTIVITY

The Sweat-Rate Test and Your Drinking Plan

You will do what Adolph's team did: measure fluid lost during a real workout. Then you will repeat the test in different conditions (hotter or cooler, harder or easier) and use your numbers to build a drinking plan for practices and games.

You will need

- A bathroom scale (digital is best) on a hard, level floor
- A water bottle with ounce marks, or a measuring cup to fill a bottle
- A towel, a timer, a thermometer or weather app for the temperature and humidity
- Fitness journal with a sweat-rate table: date, conditions, workout, minutes, change on scale, fluid drunk, sweat loss, sweat rate

Steps

1. **Prepare.** Drink normally through the day. An hour before the test, use the bathroom.
2. **Before.** In the same light, dry exercise clothes you will wear for the workout (no shoes), step on the scale. A parent may read the scale and write the number privately; the only number you need is the change.
3. **Fill your bottle** to a known amount (for example, 24 oz) and record the temperature, humidity and whether you are in sun or shade.
4. **Exercise for 60 minutes** at a steady moderate effort: an easy run, a bike ride, or a circuit of brisk step-ups, squats, jumping jacks and walking. Drink whenever you like, but do not use the bathroom.
5. **After.** Towel off thoroughly (sweat on the skin or soaked clothing adds weight), change into the same dry clothes if they are soaked, and weigh again on the same scale.
6. **Calculate.** Fluid drunk = starting amount – amount left. Fluid lost from the body = change on the scale $\times$ 16 oz per pound. Sweat loss = fluid lost + fluid drunk. Sweat rate = sweat loss $\div$ hours. Convert to liters (oz $\times$ 30 mL $\div$ 1,000).

7. **Check your urine color** for the rest of the day (pale straw is the goal) and drink with your next meal to replace what you lost.
8. **Repeat (Session 3)** in different conditions: a warmer or cooler day, indoors versus outdoors, or a harder session of the same length. Compare the two sweat rates.
9. **Build your plan.** Using your higher sweat rate, write how much and how often you will drink during a 90-minute practice (for example, 6–8 oz every 15–20 minutes) so that you lose only a little and never gain. Add what you will drink and eat afterward.

Tips

- A scale that reads to 0.2 lb or 0.1 kg gives the best results. Weigh both times on exactly the same spot.
- If you must use the bathroom, measure the urine in a disposable cup and subtract it, or simply note it and redo the test another day.
- Your sweat rate is yours. Never copy someone else's plan; heavy sweaters need more, light sweaters less.

Check your work

- ☐ I can explain how Adolph measured sweat and what voluntary dehydration means.
- ☐ I measured and calculated my sweat rate in two conditions.
- ☐ I wrote a drinking plan that limits loss and avoids over-drinking.

FITNESS JOURNAL

1. Copy your sweat-rate table for both tests, showing every step of the calculation.
2. Make a bar graph comparing your two sweat rates, labeled with the conditions. Explain the difference.
3. Draw a flow chart of fluid balance: sweating → blood becomes concentrated → brain senses it → thirst and ADH → kidneys save water → darker urine.
4. Write your drinking plan on a card for your gym bag, with the warning signs of both dehydration and hyponatremia.

From history. Adolph's team also showed that men in the desert could not get used to doing without water, a belief some officers held at the time. Their work led to the simple rule still used by armies, outdoor workers and coaches: plan your water by the heat and the work, and drink it.

COMMON MISTAKES

- Waiting until you are very thirsty during long, hot exercise. Adolph showed thirst lags behind losses in hard work.
- Drinking huge amounts “to be safe.” Over-drinking can cause hyponatremia; never gain weight during exercise.
- Forgetting to towel off before the second weigh-in, which makes your sweat loss look smaller.
- Using the scale to judge your body. In this test the only number that matters is the fluid lost.

Make it a game • Sweat Rate Calculator. Take sample numbers your parent invents: starting mass, ending mass, fluid drunk and exercise minutes. Calculate sweat rate in ounces and liters per hour. Race to finish first and double-check your unit conversion. Then explain voluntary dehydration and Adolph's desert findings. Design your own drinking plan from the answer.

2.2 CAFFEINE AND ENERGY DRINKS: WHY TO SKIP THEM

OBJECTIVES

- Tell how Friedlieb Runge first isolated caffeine in 1819 and explain how caffeine blocks adenosine in the brain.
- Calculate how much caffeine remains in the body after several half-lives and explain its effects on sleep, heart rate and recovery.
- Explain why pediatricians and the American Academy of Pediatrics say teenagers should not drink energy drinks.
- Run a one-week experiment on sleep, water and morning energy, and plan natural sources of energy.

Warm-up. Wake-up warm-up (5 minutes): 30 seconds each of marching, arm circles, jumping jacks, high knees, bodyweight squats, butt kicks, side shuffles and brisk walking, then 3 slow deep breaths. Think about it: how awake do you feel now compared with before the warm-up? What gave you that energy?

WATCH

How does caffeine keep us awake? - Hanan Qasim

TED-Ed • 5:15

<https://www.youtube.com/watch?v=foLf5Bi9qXs>

WHEN TO WATCH

After “How they figured it out.” Watch for how caffeine fits into adenosine receptors.

Note: An animated TED-Ed lesson. It explains caffeine for a general audience, including adults who drink coffee; this lesson adds why teenagers should skip energy drinks.

KEY TERMS

caffeine

A stimulant drug found naturally in coffee, tea, cacao and guarana, and added to sodas and energy drinks.

adenosine

A chemical that builds up in the brain while you are awake and makes you feel sleepy by binding to adenosine receptors.

half-life

The time it takes for the amount of a drug in the body to fall by half. Caffeine's half-life is about 5 hours in a healthy adult, but it varies widely.

stimulant

A substance that speeds up the nervous system, raising alertness, heart rate and blood pressure.

tolerance and withdrawal

Tolerance: needing more of a drug for the same effect. Withdrawal: headaches, tiredness and irritability when a regular user stops.

energy drink

A drink sold for “energy” that contains large amounts of caffeine (often 80–300 mg a can), usually with added sugar and other stimulants. It is not the same as a sports drink.

CORE IDEAS

The story. In 1819 a young German chemist, Friedlieb Ferdinand Runge, showed the famous poet Johann Wolfgang von Goethe how an extract of deadly nightshade could make a cat's pupils widen. Goethe was impressed and handed Runge a box of coffee beans, asking him to find out what was in them. Runge soon isolated a bitter white substance from the beans: caffeine. Today it is the most widely used drug in the world. Most adults who drink coffee or tea take it in modest amounts. But in recent years caffeine has been packaged for young people in a new way: cans and powders sold as “energy.”

How they figured it out. Scientists later learned exactly how caffeine works. During the day, a chemical called **adenosine** builds up in your brain as your cells use energy. It fits into adenosine receptors like a key in a lock and slows brain activity, so you feel sleepy by evening; sleep clears it away. Caffeine is shaped enough like adenosine to sit in the lock without turning it. The sleepy signal is blocked, so you feel alert, but the tiredness has not gone away; it is only hidden. In a 2013 study, adults who took a strong dose of caffeine even six hours before bedtime lost about an hour of sleep, often without noticing.

How your body works. Caffeine reaches its peak in the blood within about an hour and has a **half-life** of roughly 5 hours. It raises heart rate and blood pressure, can cause jitteriness, anxiety, an upset stomach and a racing or irregular heartbeat, and delays and lightens sleep. Teenagers need 8 to 10 hours of sleep a night, and deep sleep is when growth hormone is released and muscles recover from training;

caffeine steals exactly that. Regular use builds **tolerance**, and stopping brings **withdrawal** headaches and fatigue for several days, which is why people feel they “need” it. The FDA says about 400 mg a day is a limit for healthy adults; Health Canada advises teenagers to take no more than 2.5 mg per kilogram of body weight a day; and the American Academy of Pediatrics says energy drinks have no place in the diets of children and adolescents.

Why energy drinks are worse. One can can hold anywhere from about 80 to 300 mg of caffeine, plus guarana (another caffeine source) and other stimulants, and many 16-ounce cans carry about 50 grams or more of added sugar, the Daily Value for a whole day. They are easy to drink fast and cold, often more than one, sometimes with coffee or soda. U.S. emergency-room visits involving energy drinks roughly doubled between 2007 and 2011, to more than 20,000 a year. For an athlete, they offer nothing that sleep, water and food do not do better, and they can be dangerous for anyone with an unknown heart rhythm problem. Pre-workout powders and caffeine pills carry the same risks in concentrated form.

Think it through. Suppose a student drinks a can with 200 mg of caffeine at 3:30 p.m. With a 5-hour half-life, about 100 mg remain at 8:30 p.m., 50 mg at 1:30 a.m. and 25 mg at 6:30 a.m. At bedtime there is still as much caffeine in the body as in a cup of coffee. For a 55-kilogram (121-pound) teenager, Health Canada’s limit would be $2.5 \times 55 = 137.5$ mg a day, so that one can is already $200 \div 137.5 \approx 145$ percent of the limit.

Try it. This week you will be a caffeine detective, finding where caffeine hides in ordinary drinks and foods, and you will run a one-week experiment to see what sleep, water and morning movement do for your energy. Paul wrote, “All things are lawful for me, but I will not be brought under the power of any” (1 Corinthians 6:12). Real energy comes from rest, food, water and work, God’s ordinary gifts.

PICTURE STUDY



The Sleeping Spinner, Gustave Courbet, 1853 · Oil on canvas · Musée Fabre, Montpellier, France

Image: [Wikimedia Commons](#), public domain

Gustave Courbet painted ordinary people at their ordinary work. Here a young woman has been spinning wool into thread for so long that she has drifted off to sleep in her chair, the wool still in her hand. Her body has simply insisted on rest.

Look closely

- Look at her head, hands and shoulders. How can you tell she is deeply asleep, not just resting her eyes?
- Find the spinning wheel and the wool. What work was she doing, and how long might she have been at it?
- Look at the light and the colors. Does the painting feel calm or anxious? Why?

Talk about it

1. Adenosine builds up the longer we are awake and work. What did her body do when it had built up enough?
2. If she drank a strong caffeinated drink to keep spinning, would her body's need for sleep go away? What would happen instead?

3. Psalm 127:2 says God “giveth his beloved sleep.” Why might sleep be seen as a gift rather than a waste of time?

Safety first. Do not test caffeine on yourself; this lesson studies it with labels and calculations only. If you regularly drink caffeine and decide to stop, cut down gradually to avoid withdrawal headaches, and tell a parent. Anyone who has felt a racing or pounding heartbeat, chest pain or fainting after caffeine should tell a parent and see a doctor.

ACTIVITY

Caffeine Detective and the Natural-Energy Experiment

First you will find where caffeine hides and calculate how long it would linger. Then, for one week, you will skip caffeine entirely and track sleep, water, a quick morning movement routine and how alert you feel, to learn what really gives you energy.

You will need

- Labels from drinks and foods in your home or store (sodas, iced tea, chocolate, coffee drinks); the FDA page in the kit list
- A ruler (12-inch) and a helper for the reaction test
- Fitness journal with an energy log: date, bedtime, wake time, hours slept, water by noon, morning routine done, reaction score, energy rating 1–10

Steps

1. **Caffeine detective (Session 2).** Find the caffeine content of at least six drinks or foods from labels or the FDA page (a 12-oz cola has about 30–40 mg; an 8-oz cup of coffee about 80–100 mg; black tea about 40–50 mg; an energy drink 80–300 mg). Make a table and rank them.
2. **Half-life graph.** For a 200 mg dose at 3:30 p.m., calculate the amount left every 5 hours until 50 mg or less remains, and graph it. Mark your bedtime on the graph.
3. **Learn the morning routine (5 minutes):** drink a glass of water (8 oz), open the curtains or step outside for daylight, then do 20 jumping jacks, 10 squats, 10 push-ups (any level), 30 seconds of high knees and 1 minute of brisk walking.
4. **Learn the ruler-drop reaction test.** Your helper holds a ruler vertically with the zero mark between your open thumb and finger. Without warning, the helper drops it; you catch it as fast as you can. Record the centimeters (or inches) where you caught it. Do 5 drops and average them. Smaller is faster.
5. **Start the experiment.** For 7 days, take no caffeine at all. Set a fixed bedtime that gives you at least 8½ hours in bed. Each morning, do the routine, then the reaction test, and rate your energy from 1 to 10 at mid-morning.

6. **Repeat (Session 3).** Halfway through the week, redo the reaction test and compare it with Day 1. Note any withdrawal headache if you used caffeine before.
7. **Analyze.** At the end of the week, graph hours slept and energy rating by day. Do the nights with more sleep line up with better reaction scores or higher energy?
8. **Write your natural-energy plan:** your bedtime, a no-screens time before bed, water through the day, breakfast with protein, daylight and movement in the morning, and what you will say if a friend offers you an energy drink.

Tips

- Caffeine is often hidden. Iced teas, some flavored waters, chocolate, and drinks labeled “focus” or “boost” may contain it; caffeine amounts are not always listed.
- Sports drinks and energy drinks are different. A sports drink is fluid, sugar and salt for long, hard exercise; an energy drink is a caffeine product.
- If you are tired all the time even with good sleep, tell a parent; it can be a sign of a health problem worth checking.

Check your work

- ☐ I can explain how caffeine blocks adenosine and calculate how much remains after several half-lives.
- ☐ I can give at least three health reasons for teenagers to skip energy drinks.
- ☐ I completed the seven-day experiment and wrote a natural-energy plan.

FITNESS JOURNAL

1. Copy your caffeine table and your half-life graph with your bedtime marked.
2. Draw a simple diagram of an adenosine receptor with adenosine fitting in, then caffeine blocking it. Label what each one does to alertness.
3. Graph your week: hours slept (bars) and energy rating (line) for each day. Add your reaction-test averages.
4. Write a short, kind reply you could give a teammate who says, “You need an energy drink before the game.”

From history. Runge went on to make other discoveries, including some of the first chemicals obtained from coal tar and early experiments with paper chromatography. He spent most of his career as a chemist in a factory in Oranienburg, near Berlin.

COMMON MISTAKES

- Thinking caffeine gives energy. It hides tiredness by blocking a signal; only sleep, food and rest restore you.
- Assuming an afternoon drink will be gone by bedtime. Half of it can still be there five hours later.
- Confusing sports drinks with energy drinks, or thinking energy drinks are safe because they are sold to teenagers.
- Using caffeine to make up for staying up late, which starts a cycle of poor sleep and more caffeine.

Make it a game • Half-Life Drill. Starting with two hundred milligrams of caffeine and a half-life of five hours, calculate how much remains after five, ten and fifteen hours. Race the clock to do it on paper. Then explain adenosine blocking in the brain and what caffeine does to sleep and recovery. Tell Runge's 1819 story. Suggest three natural energy swaps.

Scripture. “All things are lawful unto me, but all things are not expedient: all things are lawful for me, but I will not be brought under the power of any.” (1 Corinthians 6:12, KJV)

A habit that a person feels he cannot do without has a kind of power over him. Choosing sleep, water and food over stimulants keeps us free and clear-headed.

HYDRATION

During the Second World War, the physiologist Edward Adolph and his team from the University of Rochester took soldiers and volunteers into the California desert to answer a life-and-death question: how much water does a person lose in the heat, and what happens when he does not replace it? They weighed men before and after desert walks, measured every drink, and turned the difference into a sweat rate. In this unit you will run the same test on yourself, calculate your own sweat rate, and use it to build a drinking plan for training and games. You will also learn the opposite danger, drinking far more than you sweat, which can dilute the sodium in the blood (hyponatremia).

Then you will look plainly at caffeine and energy drinks: what caffeine is (first isolated by the German chemist Friedlieb Runge in 1819), how it blocks the brain's sleep signal, how long it lingers in the body, what it does to the heart, sleep and recovery, and why pediatricians say energy drinks have no place in what teenagers drink. You will run your own experiment on sleep, water and morning energy.

PREREQUISITES

- Knows what water does in the body (cooling by sweat, carrying nutrients, cushioning joints) and the signs of dehydration (earlier grades)
- Knows that sweat contains salt and that sodium and potassium are electrolytes
- Can convert between ounces, cups, pounds and liters and calculate a percentage

MASTERY CHECKLIST

- ☐ I can explain how Adolph's desert studies measured sweat loss and what they learned.
- ☐ I can measure my own sweat rate and calculate it in ounces and liters per hour.
- ☐ I can build a drinking plan that limits fluid loss during exercise without over-drinking, and explain hyponatremia.
- ☐ I can explain how caffeine works on adenosine receptors, calculate how much remains after several half-lives, and describe its effects on sleep and the heart.
- ☐ I can give clear health reasons why teenagers should skip energy drinks.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **"Spilling the Beans: How Much Caffeine Is Too Much?" (U.S. Food and Drug Administration)**: Free. The FDA's plain-language page on caffeine amounts and risks, for Lesson 2.2.
- **A reusable water bottle with ounce marks**: Handy for the sweat-rate test and the water log; a measuring cup works too.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

2.1 Measure Your Sweat Rate: Edward Adolph in the Desert

3 sessions of 45–50 minutes

2.2 Caffeine and Energy Drinks: Why to Skip Them

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. (8 pts)

How did Edward Adolph's team measure water loss in the desert, and what did they discover?

2. (8 pts)

Explain how sweat cools you and what sweat contains.

3. (10 pts)

Calculation. During a 75-minute soccer practice, a player's scale reading drops by 2.0 lb. He drank 20 oz and did not use the bathroom. Find his sweat loss and his sweat rate in ounces per hour and liters per hour.

4. (8 pts)

Calculation. Using the sweat rate from question 3, how much fluid would he lose in a 2-hour practice? If he drinks 8 oz every 15 minutes, what is his net loss?

5. (8 pts)

Describe how the brain and kidneys respond when you lose fluid in sweat.

6. (10 pts)

What is exercise-associated hyponatremia, what causes it, what are its symptoms, and what simple rule helps prevent it?

7. (8 pts)

How does caffeine make a person feel alert? Why is that alertness misleading?

8. (10 pts)

Calculation. A student drinks a 160 mg energy drink at 4:00 p.m. With a 5-hour half-life, how much caffeine remains at 9:00 p.m., 2:00 a.m. and 7:00 a.m.?

9. **8 pts**

Calculation. Using Health Canada's guideline of 2.5 mg per kilogram per day, what is the limit for a 60-kg teenager? What percentage of that limit is one 300 mg energy drink?

10. **6 pts**

What is the difference between a sports drink and an energy drink?

11. **16 pts**

Short written answer. A younger sibling says energy drinks help athletes play better. Write a paragraph explaining why teenagers should skip them, using what you learned about caffeine, sleep, the heart and sugar, and what to do instead.

ANSWER KEY

1. They weighed men before and after desert walks and work, measured all the water they drank, and calculated the water lost. Men could sweat about a liter an hour or more in desert heat; training did not reduce the need for water; men who drank freely did far better; and even with water available, men drank less than they lost during the march (voluntary dehydration).
2. Working muscles make heat; the body sends warm blood to the skin and releases sweat, and when sweat evaporates it carries heat away. Sweat is mostly water, with sodium, chloride and a little potassium.
3. Fluid lost from the body = $2.0 \times 16 = 32$ oz. Sweat loss = $32 + 20 = 52$ oz in 1.25 h. Sweat rate = $52 \div 1.25 = 41.6$ oz/h. In liters: $41.6 \times 30 \text{ mL} \approx 1,248 \text{ mL} \approx 1.25 \text{ L/h}$.
4. Loss = $41.6 \times 2 = 83.2$ oz. Drinking $8 \text{ oz} \times 8 \text{ times} = 64$ oz. Net loss = $83.2 - 64 = 19.2$ oz (about 1.2 lb), a small loss he replaces afterward.
5. The blood becomes more concentrated; sensors in the brain detect it; you feel thirst; the pituitary releases antidiuretic hormone (ADH); the kidneys reabsorb more water and make less, darker urine.
6. Blood sodium below 135 mmol/L during or after exercise, usually from drinking far more fluid than is lost over hours, which dilutes blood sodium; water moves into cells and the brain swells. Symptoms: headache, nausea, vomiting, confusion, and in severe cases seizures or death. Rule: drink to a plan based on your sweat rate and never weigh more after exercise than before.
7. Adenosine builds up during waking hours and binds to receptors that make us sleepy. Caffeine resembles adenosine and blocks those receptors without activating them, so the sleepy signal is hidden. The body's need for sleep is still there; it is only masked.
8. 9:00 p.m.: $160 \div 2 = 80$ mg. 2:00 a.m.: $80 \div 2 = 40$ mg. 7:00 a.m.: $40 \div 2 = 20$ mg. There is still as much caffeine as in a cup of tea or most of a cola at bedtime.
9. $2.5 \times 60 = 150$ mg a day. $300 \div 150 \times 100 = 200$ percent of the limit.
10. A sports drink contains water, sugar and electrolytes to replace fluid and fuel during long, hard exercise. An energy drink is a caffeine product, often with large amounts of sugar and other stimulants; it does not hydrate better and is not recommended for teenagers.
11. Answers vary. A full answer explains that energy drinks contain large doses of caffeine (80–300 mg) and often 50 g or more of sugar; caffeine raises heart rate and blood pressure, can cause jitters, anxiety and irregular heartbeat, and stays

in the body for hours (half-life about 5 hours), stealing deep sleep when muscles recover and growth hormone is released; tolerance and withdrawal follow; the AAP says they have no place in teenagers' diets; emergency visits rose; and real performance comes from sleep, water, good food and training.

UNIT CHALLENGE: MY PERSONAL HYDRATION AND ENERGY PLAN

Using your two sweat-rate tests, write a one-page hydration plan for practices and games in cool and hot weather: what you drink before, how much and how often during, and what you drink and eat after, with the warning signs of both dehydration and hyponatremia. Keep a seven-day log of water intake, urine color and sleep (no caffeine), and finish with a short report and a graph showing how your sleep and energy related over the week.

LOOK FOR	WHAT IT MEANS
Sound plan	Drinking amounts based on your own measured sweat rate, with a small allowed loss and a clear rule against gaining weight.
Accurate calculations	Both sweat-rate tests calculated correctly with every step and unit shown.
Faithful log	Seven dated days of water, urine color, sleep and energy, kept honestly.
Reflection and graph	A clear graph and a thoughtful report on what you learned about water, sleep and energy. Effort and honesty count, not the numbers themselves.

NUTRITION

In the 1840s the most famous chemist in Europe, Justus von Liebig, taught that muscles burn their own protein for energy, so hard workers and athletes needed great quantities of meat. In 1865 two professors in Zurich, Adolf Fick and Johannes Wislicenus, tested the idea by climbing a mountain while eating almost no protein and measuring what their bodies broke down. Their answer still shapes sports nutrition: carbohydrate and fat are the main fuels, and protein is the building material. In this unit you will learn how much protein a growing athlete really needs, calculate it from ordinary food, and plan and cook protein-rich meals.

Then you will learn to judge the flood of claims about food, supplements and quick fixes. You will hear how government chemists tested Clark Stanley's Snake Oil Liniment and found no snake in it, learn why dietary supplements are not checked by the FDA before they are sold, and design a blinded test of a "performance" claim of your own.

PREREQUISITES

- Knows the food groups and what carbohydrate, protein and fat do (earlier grades)
- Can read a Nutrition Facts label, including serving size and grams of protein
- Knows that calories are a unit of food energy: about 4 per gram of carbohydrate or protein and 9 per gram of fat

MASTERY CHECKLIST

- ☐ I can tell how Fick and Wislicenus tested Liebig's idea on the Faulhorn and what they concluded.
- ☐ I can explain what protein does in the body, what amino acids are and why nine are essential.
- ☐ I can calculate protein needs in grams per kilogram and total the protein in a day of meals from labels.
- ☐ I can explain how dietary supplements are regulated and why teenagers should not use them.
- ☐ I can judge a health claim with clear questions and design a fair, blinded test.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Dietary Guidelines for Americans (U.S. Departments of Agriculture and Health and Human Services)**: Free. The official guidelines, with food-group amounts and protein foods for teenagers, for planning the meals in Lesson 3.1.
- **Dietary Supplements (U.S. Food and Drug Administration)**: Free. The FDA's own explanation of how supplements are regulated and what it does not review before sale, for Lesson 3.2.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

3.1 Protein for Growing Athletes: The Climb of the Faulhorn

3 sessions of 45–50 minutes

3.2 Fads, Myths and Supplements: The Snake Oil Test

3 sessions of 45–50 minutes

UNIT 3 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **10 pts**

What did Liebig claim, and how did Fick and Wislicenus test it on the Faulhorn? What did they conclude?

2. **8 pts**

Name four jobs of protein in the body and explain what essential amino acids are.

3. **10 pts**

Calculation. For a 55-kg teenage athlete, find the RDA for protein (0.85 g/kg) and the athletic range (1.2–2.0 g/kg).

4. **10 pts**

Calculation. A day's meals: 2 eggs (6 g each), 1 cup of milk (8 g), a peanut butter sandwich (2 tbsp peanut butter, 7 g; 2 slices bread, 7 g), 6 oz Greek yogurt (16 g), 3 oz chicken (26 g), $\frac{1}{2}$ cup black beans (7 g). Find the total protein and the calories from protein.

5. **8 pts**

What happens to protein eaten beyond what the body needs? Why does this matter for athletes who think more is always better?

6. **8 pts**

How are dietary supplements regulated in the United States under the 1994 law (DSHEA)? What does the FDA not do?

7. **8 pts**

What did government chemists find in Clark Stanley's Snake Oil Liniment, and what lesson does the case teach?

8. **8 pts**

Explain the placebo effect and why a test of a product must be blinded and controlled.

9. **10 pts**

Calculation. In a blinded bracelet test, four people's best broad jumps were 72, 65, 80 and 59 inches with bracelet A and 71, 67, 79 and 60 inches with bracelet B. Find the average for each and the difference. Is there evidence that either bracelet works?

10. **20 pts**

Short written answer. A teammate shows you an online ad for a pre-workout powder that promises "massive energy and muscle gains, clinically proven." Write a paragraph using at least four claim-checking questions and what you know about supplement regulation to explain why you would not use it, and what you would do instead.

ANSWER KEY

1. Liebig claimed working muscles burn their own protein for energy. Fick and Wislicenus ate almost no protein (only starch, fat and sugar) before and during their climb of the Faulhorn, collected their urine to measure nitrogen (which shows how much protein was broken down), and calculated the work of lifting their bodies up the mountain. The protein broken down could supply only a fraction of the energy needed, so muscles must be fueled mainly by carbohydrate and fat; protein is mainly for building and repair.
2. Any four: building muscle fibers (actin and myosin), enzymes, hormones, antibodies, hemoglobin, skin and hair, tissue repair. Essential amino acids are the nine amino acids the body cannot make, so they must come from food.
3. $RDA = 0.85 \times 55 = 46.75 \approx 47$ g a day. Athletic range: $1.2 \times 55 = 66$ g to $2.0 \times 55 = 110$ g a day.
4. Total = $12 + 8 + 7 + 7 + 16 + 26 + 7 = 83$ g. Calories from protein = $83 \times 4 = 332$ calories (a unit of food energy).
5. The extra is not stored as muscle. Its nitrogen is removed as urea in the urine and the rest is used for energy. Eating far more protein than needed does not build more muscle; training, enough total food, carbohydrate, sleep and protein spread across meals matter more.
6. Supplements are regulated more like foods than drugs. The manufacturer is responsible for safety and truthful labeling. The FDA does not test or approve supplements before they are sold; it can act only after problems are found. Structure/function claims must carry a disclaimer that the FDA has not evaluated them.
7. Mostly mineral oil, about 1 percent fatty oil (probably beef fat), red pepper, turpentine and camphor, and no snake oil; Stanley was fined \$20 for misbranding. Lesson: test products instead of trusting advertising; big promises without evidence are a warning sign.
8. The placebo effect is a real improvement caused by expecting a treatment to work. Without a control (a look-alike fake or no treatment) and blinding (the subject not knowing which is real), you cannot tell whether a change came from the product or from expectations, practice or normal variation.
9. A: $(72 + 65 + 80 + 59) \div 4 = 276 \div 4 = 69.0$ in. B: $(71 + 67 + 79 + 60) \div 4 = 277 \div 4 = 69.25$ in. Difference = 0.25 in, far smaller than normal jump-to-jump variation (1–2 inches here). No evidence either bracelet works.

10. Answers vary. A full answer asks who profits, what the evidence is and whether a controlled, blinded study can be found, how many people were tested and whether it was repeated, and whether the promise is plausible; notes that “clinically proven” without a study is a red flag; explains that supplements are not FDA-approved before sale, that some have contained hidden drug ingredients, that pre-workouts often contain large doses of caffeine and other stimulants, and that the AAP advises teenagers against performance supplements; and names the real alternatives: sleep, food with protein and carbohydrate, water and steady training.

UNIT CHALLENGE: PLAN, SHOP AND COOK A TRAINING DAY

Plan a full day of meals and snacks for a hard training day, with protein at every meal (about 20–30 grams), carbohydrate for fuel, fruits and vegetables, and water. Make a shopping list with an estimated cost, help shop, and cook at least two of the meals with a parent supervising. Record the protein for each meal from labels, and write a short report comparing your plan with the RDA and the athletic range, and explaining why your plan needs no supplements.

LOOK FOR	WHAT IT MEANS
Balanced plan	Every meal has a protein food, carbohydrate and a fruit or vegetable; protein spread across the day; water included.
Accurate numbers	Protein per meal and per day totaled correctly from labels and compared with needs; shopping list with estimated cost.
Cooking	At least two meals cooked safely with good hygiene, with recipes written out.
Reflection	A clear report explaining the plan, what was learned and why real food is enough. Effort and care count most.

3.1 PROTEIN FOR GROWING ATHLETES: THE CLIMB OF THE FAULHORN

OBJECTIVES

- Tell how Fick and Wislicenus tested Liebig’s claim that muscles run on protein, and what they found.
- Explain the jobs of protein in the body, amino acids, essential amino acids and muscle repair after training.
- Calculate protein needs for a teenager and a teen athlete in grams per kilogram, and total protein from food labels.
- Plan, cook and record protein-rich meals from ordinary food, with protein spread across the day.

Warm-up. Mountain-climb warm-up (5 minutes): 1 minute of marching with high knees; 10 step-ups on each leg on the bottom stair; 20 slow mountain climbers (from a push-up position, drive knees toward the chest one at a time); 10 bodyweight squats; 10 arm circles each way. Think about it: when you climb a hill, what do you think your muscles are burning for fuel?

WATCH

Partners In KidsHealth: Young Athletes and Nutrition

Children's of Alabama • 6:29

<https://www.youtube.com/watch?v=ARvtppB7gFo>

WHEN TO WATCH

After “How your body works,” before planning meals. Watch for what a young athlete should eat before, during and after a game.

Note: A pediatrician at Children’s of Alabama answers questions about feeding young athletes with ordinary food and fluids.

KEY TERMS

protein

A large molecule built from chains of amino acids. Proteins form muscle, enzymes, hormones, antibodies and the hemoglobin that carries oxygen.

amino acid

One of 20 building blocks of proteins. Each contains nitrogen.

essential amino acid

One of 9 amino acids the body cannot make, so it must come from food.

complete protein

A food protein with all nine essential amino acids in good amounts, such as eggs, milk, meat, fish and soy; other plant proteins can be combined through the day.

muscle protein synthesis

The building of new muscle protein, which rises after strength training when amino acids from food are available.

nitrogen balance

The difference between the nitrogen taken in from protein and the nitrogen lost (mostly as urea in urine), a way to measure protein breakdown.

CORE IDEAS

The story. In 1842 the German chemist Justus von Liebig, the most respected food scientist of his day, argued that working muscles burn their own protein for energy. If he was right, laborers, soldiers and athletes needed enormous amounts of meat. Two professors in Zurich doubted it: Adolf Fick, a physiologist, and Johannes Wislicenus, a chemist. In 1865 they decided to test Liebig's idea on themselves by climbing the Faulhorn, a 2,681-metre (8,796-foot) peak in the Swiss Alps.

How they figured it out. Their method was clever. Every protein contains nitrogen, and when the body breaks protein down, the nitrogen leaves in urine. Starting before the climb and through the ascent, the two men ate only starch, fat and sugar, foods with almost no protein, and collected their urine to measure its nitrogen. From their body weight and the height they climbed, they calculated the mechanical work of lifting themselves up the mountain. Then they compared: the protein they broke down could supply only a fraction of the energy the climb required, even before counting the work of the heart and lungs. The English chemist Edward

Frankland soon measured the energy in protein by burning it, which made their case even stronger. Their conclusion: muscles are fueled mainly by carbohydrate and fat. Protein is chiefly for building and repairing the body.

How your body works. Your body is constantly breaking down and rebuilding proteins: muscle fibers (actin and myosin), enzymes, hormones, antibodies, hemoglobin, skin and hair. Food protein is digested into its 20 **amino acids**, which are rebuilt into whatever your body needs. Nine are **essential**; you must eat them. Strength training damages and challenges muscle fibers; in the hours afterward, **muscle protein synthesis** rises, and a meal with protein supplies the amino acids to rebuild them stronger. Protein the body does not need is not stored as extra muscle; its nitrogen is removed as urea and the rest is used for energy. Protein provides about 4 calories per gram, the same as carbohydrate, which remains the main fuel for hard training.

Think it through. The Recommended Dietary Allowance for teenagers aged 14–18 is about 0.85 grams of protein per kilogram of body weight per day. Sports-nutrition experts suggest about 1.2 to 2.0 g/kg for athletes in hard training, spread over three or four meals of roughly 20–30 grams each. For a 60-kilogram (132-pound) athlete: $RDA = 0.85 \times 60 = 51$ g; athletic range = $1.2 \times 60 = 72$ g to $2.0 \times 60 = 120$ g. Now total a simple day: breakfast of 2 eggs (12 g), a cup of milk (8 g) and a cup of cooked oatmeal (6 g) = 26 g; lunch of a sandwich with 3 oz of turkey (about 24 g) on whole-wheat bread (about 7 g) = 31 g; a snack of 6 oz of plain Greek yogurt (about 16 g); dinner of 3 oz of chicken (about 26 g), $\frac{1}{2}$ cup of black beans (about 7 g) and rice (about 4 g) = 37 g. Total ≈ 110 g, inside the athletic range, with no powders or shakes. Most American teenagers already eat enough protein; the most common gap is not eating enough food overall, or skipping breakfast.

Try it. This week you will total the protein in a real day of your own eating, then plan and cook protein-rich meals for training days. You do not need to weigh yourself for this lesson: use the RDA in grams (about 46 g a day for teenage girls and 52 g for teenage boys) as a floor, and aim for a protein food at every meal and after training.

PICTURE STUDY



An Old Woman Cooking Eggs, Diego Velázquez, 1618 · Oil on canvas · Scottish National Gallery, Edinburgh

Image: [Wikimedia Commons](#), public domain

Diego Velázquez painted this kitchen scene in Seville when he was only about eighteen or nineteen years old. An old woman is poaching eggs in oil in a clay dish over a small charcoal stove, and a boy has come to her with a flask and a melon. Velázquez painted every pot, egg and onion as carefully as other painters painted kings.

Look closely

- Find the eggs: the ones cooking in the dish and the one in her hand. How are they being cooked?
- List every food and drink you can find in the picture. Which are protein foods? Which give carbohydrate?
- Look at the kitchen tools: the mortar and pestle, the brass bowl, the jugs, the knife. What would each be used for?
- Look at the boy and the old woman. What do you think is about to happen? Who will eat this meal?

Talk about it

1. Eggs have been an everyday protein food for centuries. Why are they such a good food for a growing athlete? (Think about complete protein and cost.)

2. Add foods to this kitchen to make a balanced meal for someone who trained hard that afternoon.
3. Velázquez painted ordinary cooking as worth careful attention. Why might learning to cook simple meals be one of the most useful skills for an athlete?

Safety first. A parent supervises the stove, oven and knives. Wash hands before cooking and after touching raw eggs or meat, keep raw meat separate from ready-to-eat food, and cook eggs until the yolk is firm and chicken to 165°F (74°C). Check for food allergies (eggs, milk, nuts, soy, fish) before cooking for others.

ACTIVITY

A Day of Protein and a Training-Day Meal

You will measure the protein in a real day of your own eating, then plan and cook a protein-rich meal from ordinary food, and cook a second meal for your family after a workout.

You will need

- Food labels and measuring cups and spoons
- A kitchen with a stove, a skillet and a pot; a parent to supervise
- Ingredients for one of these meals (or your own plan): egg, bean and cheese breakfast burritos; chicken, black bean and rice bowls with vegetables; lentil soup with whole-wheat bread and a glass of milk; tuna or salmon and pasta with peas
- Fitness journal with a protein table: meal, food, amount, grams of protein

Steps

1. **Record a normal day (before Session 2).** Write down everything you eat and drink for one ordinary day, with amounts. Use labels or the USDA's FoodData Central website to find grams of protein. Total it and note how it was spread across meals.
2. **Compare.** Compare your total with the RDA (about 46 g for teenage girls, 52 g for teenage boys) and note whether every meal had a protein food. Circle any meal with less than about 15–20 grams.
3. **Plan (Session 2).** Plan one training day with three meals and one or two snacks, each with a protein food and carbohydrate for fuel, plus fruits or vegetables. Total the protein for each meal and the day.
4. **Cook meal 1.** With a parent supervising, cook one meal from your plan. Measure the protein foods so your numbers are real. Wash your hands, keep raw and cooked foods separate, and cook to safe temperatures.
5. **Train, then eat.** On a training day, eat your planned meal or snack with protein within about two hours after your workout. Record what you ate and how you felt at your next workout.

6. **Cook meal 2 (Session 3).** Cook a second, different meal for your family after a workout, aiming for 20–30 grams of protein per person from ordinary food. Write the recipe and the protein per serving.
7. **Reflect.** Write what you learned: Did your normal day already meet your needs? Was protein spread across meals? What simple change would help most?

Tips

- Cheap protein foods: eggs, milk, plain yogurt, canned beans, lentils, peanut butter, canned tuna, chicken thighs and cheese.
- Plant proteins can work together: beans with rice, peanut butter on whole-wheat bread, lentils with bread.
- Do not neglect carbohydrate. Rice, pasta, potatoes, bread and oats refuel the muscles; protein builds them.

Check your work

- ☐ I can tell the story of the Faulhorn climb and explain what it showed.
- ☐ I calculated protein needs and totaled a day of my own eating from labels.
- ☐ I cooked two protein-rich meals from ordinary food and recorded the protein per serving.

FITNESS JOURNAL

1. Copy your protein table for your normal day and your planned training day. Draw a bar graph of protein at each meal.
2. Write the recipes for your two meals with grams of protein per serving.
3. Draw a diagram: food protein → digestion → amino acids → new muscle protein, enzymes and hormones; extra → nitrogen removed as urea, the rest used for energy.
4. Write a paragraph explaining to a teammate why he or she does not need shakes or powders.

From history. Fick is also remembered for Fick's principle, a method of calculating how much blood the heart pumps from the oxygen the body uses, which is still taught in medical schools. Wislicenus became a leading organic chemist and later succeeded to a professorship at Leipzig.

COMMON MISTAKES

- Thinking more protein always means more muscle. Beyond what the body can use, extra protein is burned for energy, not built into muscle.
- Eating almost all your protein at dinner. Spreading it across meals supports repair better.
- Cutting carbohydrate to make room for protein. Carbohydrate is the main fuel for hard training, as the Faulhorn climb showed.
- Believing athletes need shakes or powders. Ordinary food easily meets the needs of almost every teen athlete.

Make it a game • Amino Acid Analysis. Make a list of nine essential amino acids as cards. Shuffle and draw: say what each does and name a complete protein source. Tell how Fick and Wislicenus tested Liebig's claim. Then design a training-day meal with protein spread across three meals. Your parent grades your muscle protein synthesis explanation.

3.2 FADS, MYTHS AND SUPPLEMENTS: THE SNAKE OIL TEST

OBJECTIVES

- Tell how government chemists tested Clark Stanley’s Snake Oil Liniment and what the case shows about health claims.
- Explain how dietary supplements are regulated in the United States and why the FDA does not approve them before sale.
- Explain why doctors advise teenagers not to use supplements, protein powders, pre-workouts or other performance products.
- Judge a health claim with clear questions and run a blinded test of a performance claim.

Warm-up. Balance-and-jump warm-up (5 minutes): 1 minute of jogging in place; 30 seconds standing on each foot with eyes open, then 15 seconds each with eyes closed (near a wall); 10 squats; 5 easy standing broad jumps with soft landings; 10 arm circles each way. Think about it: if someone sold you a bracelet that “improves balance,” how could you find out if it worked?

WATCH

What You Need to Know About Dietary Supplements (Module 3)

U.S. Food and Drug Administration • 10:18

<https://www.youtube.com/watch?v=JmDCil9HX7s>

WHEN TO WATCH

After “How your body works and the law.” Watch for what the FDA does and does not do before a supplement is sold.

Note: Made by the FDA with the American Medical Association for doctors and patients. It describes supplements in general; for teenagers, doctors advise against performance supplements.

BACKUP VIDEO

The power of the placebo effect - Emma Bryce

TED-Ed • 4:37

<https://www.youtube.com/watch?v=z03FQGlGgo0>

Before the blinded bracelet test, to understand why the test must be blinded.

KEY TERMS

dietary supplement

A product taken by mouth that contains a “dietary ingredient” such as vitamins, minerals, herbs, amino acids or extracts, sold as pills, powders, drinks or bars.

structure/function claim

A claim that a product affects the body’s structure or function (such as “supports muscle”), which supplements may make without FDA approval, followed by a disclaimer.

blinded test

A test in which the subject (and ideally the tester) does not know which treatment is real, so expectations cannot affect the result.

DSHEA

The Dietary Supplement Health and Education Act of 1994, the U.S. law under which supplements are regulated more like foods than drugs: makers are responsible for safety, and the FDA does not approve them before sale.

placebo effect

A real improvement in how a person feels or performs because he expects a treatment to work, even when it has no active effect.

control

A comparison condition (no treatment or a fake one) used to show whether the treatment itself made the difference.

CORE IDEAS

The story. In the late 1800s and early 1900s, travelling salesmen sold “patent medicines” that promised to cure almost everything. One of the most famous was Clark Stanley, who called himself “the Rattlesnake King” and sold Clark Stanley’s Snake Oil Liniment for rheumatism, sore muscles, sprains and much more. After Congress passed the Pure Food and Drug Act in 1906, government chemists at the Bureau of Chemistry, the forerunner of the FDA, analyzed his liniment. They found mostly mineral oil, about 1 percent fatty oil (probably beef fat), red pepper, turpentine and camphor, and no snake oil at all. A federal court in Rhode Island fined Stanley \$20 for misbranding. Ever since, “snake oil” has meant a product sold with big promises and no proof.

How they figured it out. The chemists did not argue with Stanley’s advertising; they tested the product. That is still the right way to judge a claim. Ask: **Who** is making

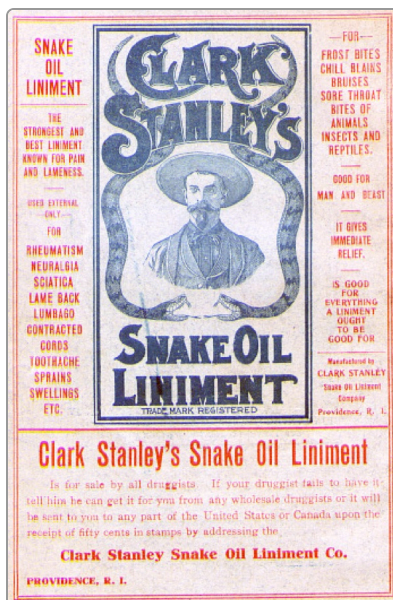
the claim, and do they profit from it? **What is the evidence:** personal stories and famous athletes, or controlled studies? Was there a **control** group, and were the people **blinded** so that a **placebo effect** could not explain the result? How many people were tested, and has anyone repeated it? Is the claim plausible given how the body works? Does it promise something quick, secret, “miracle” or “clinically proven” with no study you can find? A modern example: around 2010 a “hologram” wristband sold to athletes claimed to improve balance and strength; in Australia, government regulators made its maker admit there was no credible scientific evidence for its claims.

How your body works and the law. Under the **Dietary Supplement Health and Education Act of 1994**, supplements are regulated more like foods than medicines. The company, not the FDA, is responsible for making sure a product is safe and its label truthful. The FDA does not test or approve supplements before they are sold; it can act only after a problem is found. That is why supplement labels that claim to “support” the body must carry the line “This statement has not been evaluated by the Food and Drug Administration.” The FDA has warned about hundreds of products sold as supplements, many of them marketed for muscle building or energy, that contained hidden drug ingredients not listed on the label. For teenagers, the American Academy of Pediatrics advises against performance-enhancing supplements; protein powders, creatine, pre-workouts and similar products are unnecessary for a growing athlete who eats real food, and some carry real risks.

Think it through. Suppose a player tries a new drink before a game, scores 20 points instead of his usual 12, and tells everyone the drink works. One game proves nothing: his points vary from game to game, he may have felt confident because he expected the drink to help, and the other team may have been weaker. To test it fairly you would need many games, a control drink that looks and tastes the same, blinding, and a comparison of averages. If his average with the drink is 13.1 points and with the look-alike control drink 12.9 points over ten games each, the difference of 0.2 points is far smaller than the normal game-to-game variation of several points: no real effect.

Try it. This week you will investigate three real health or fitness claims and run your own blinded test of a “performance bracelet.” Proverbs says, “The simple believeth every word: but the prudent man looketh well to his going” (Proverbs 14:15). Testing claims is wisdom, not cynicism.

PICTURE STUDY



Clark Stanley's Snake Oil Liniment, Advertising pamphlet, Clark Stanley Snake Oil Liniment Company, About 1905 · Printed advertisement · Public domain image from the company's pamphlet

Image: [Wikimedia Commons](#), public domain

This advertisement comes from the years before the government tested Stanley's liniment. Look at it as a detective would: what does it promise, and what evidence does it offer?

Look closely

- Read the claims. How many different problems does it say the product will fix?
- Find the words chosen to persuade: “strongest and best,” “immediate relief,” “good for man and beast,” “good for everything a liniment ought to be good for.” Which promise the most?
- Look at the picture of the salesman. How is he trying to win your trust?
- Look for evidence: any test, any numbers, any comparison. What is missing?

Talk about it

1. Which of the claim-checking questions from the lesson does this advertisement fail?
2. Find a modern advertisement for a supplement or “energy” product. What does it have in common with this one?

3. Why do you think a product that claims to cure many unrelated problems is usually a warning sign?

Safety first. This lesson uses no supplements or drinks of any kind. For the jump test, warm up first, land softly on bent knees on a non-slip surface with clear space, and stop if anything hurts. Never try a supplement, pre-workout, caffeine product or powder because a friend, coach or video recommends it; talk to a parent and your doctor first.

ACTIVITY

The Claim Investigation and the Blinded Bracelet Test

First you will investigate three real claims with the questions from the lesson. Then you will run a blinded test of a “performance bracelet” on members of your family, to see the placebo effect for yourself and learn how fair tests are built.

You will need

- Three real health or fitness claims from ads, packages, websites or videos
- Two identical bracelets, ribbons or hair ties, labeled underneath only as A and B (both are ordinary)
- Masking tape and a tape measure for the standing broad jump; a timer for the balance test
- Fitness journal with a results table: person, trial order, bracelet, jump distance, balance time

Steps

1. **Investigate three claims (Session 2).** For each, write the claim exactly, who makes it, whether they profit, what evidence is offered, whether any controlled and blinded study is cited, and your verdict: supported, not supported, or unknown. One claim should be about a supplement or “energy” product.
2. **Set up the test.** Mark a starting line with tape. Choose two tests: the standing broad jump (feet together, swing arms, jump forward, land softly; measure to the back of the nearest heel) and the one-foot balance with eyes closed (time until the lifted foot touches down, maximum 60 seconds).
3. **Blind it.** Tell each volunteer honestly: “One of these bracelets may help balance and power; we are testing which.” You know both are ordinary; they do not know which is which, and you do not tell them during the test.
4. **Randomize the order.** Flip a coin to decide whether each person wears A or B first. Each person warms up, then does 2 jumps and 1 balance trial wearing the first bracelet, rests 2 minutes, then does the same wearing the second. Record the best jump and the balance time for each.

5. **Test at least three people**, including yourself if a parent runs your trials. Record everything.
6. **Repeat (Session 3)** with a third condition: no bracelet at all. Compare all three conditions.
7. **Analyze.** Find each person's difference between conditions and the group average. Were differences bigger than the normal difference between two jumps in the same condition? Did anyone feel the bracelet helped?
8. **Reveal and reflect.** Tell your volunteers that both bracelets were ordinary. Write what your results show about the placebo effect, variation and why companies' claims need controlled, blinded tests.

Tips

- Keep everything the same except the bracelet: same shoes, same surface, same warm-up, same rest.
- Always compare a change with the normal variation. If two jumps in a row differ by 3 inches, a 2-inch "improvement" means nothing.
- A good scientist is willing to find that something does work. Let the evidence decide.

Check your work

- ☐ I can explain how the FDA regulates supplements and why teenagers should not use them.
- ☐ I investigated three real claims with clear questions.
- ☐ I ran a blinded, randomized test and explained my results honestly.

FITNESS JOURNAL

1. Copy your claim-investigation table for all three claims with your verdicts.
2. Make a table and bar graph of the bracelet test: each person's jump and balance in each condition, and the averages.
3. Write a one-paragraph "lab report" conclusion: what you tested, what you found, and what would make the test stronger.
4. List five red-flag words or phrases you will watch for in health advertising.

From history. The Pure Food and Drug Act of 1906 was championed by Harvey Washington Wiley, the chief chemist of the Department of Agriculture, whose “Poison Squad” of young volunteers ate measured doses of common food preservatives to test their safety. The Bureau of Chemistry he led became the Food and Drug Administration.

COMMON MISTAKES

- Believing a product works because a famous athlete uses it or a friend felt better. Stories are not controlled tests.
- Assuming “natural” or “sold in a store” means safe and tested. Supplements are not approved by the FDA before sale.
- Reading one result as proof. Results vary; look at averages and repeated tests.
- Thinking a supplement can replace sleep, food, water and training. Nothing in a bottle does.

Make it a game • Snake Oil Investigation. Your parent invents a health claim, such as a bracelet that boosts focus. Play the government chemist: ask for evidence, a placebo, a blind test and a control. Explain the DSHEA and structure-function claims. Tell the Clark Stanley story. Score points for each good question. Switch roles and try to sell her a product.

Scripture. “The simple believeth every word: but the prudent man looketh well to his going.” (Proverbs 14:15, KJV)

Wisdom tests claims before trusting them. A prudent athlete looks for evidence before spending money or risking health on a promise.

NUTRITION

In the 1840s the most famous chemist in Europe, Justus von Liebig, taught that muscles burn their own protein for energy, so hard workers and athletes needed great quantities of meat. In 1865 two professors in Zurich, Adolf Fick and Johannes Wislicenus, tested the idea by climbing a mountain while eating almost no protein and measuring what their bodies broke down. Their answer still shapes sports nutrition: carbohydrate and fat are the main fuels, and protein is the building material. In this unit you will learn how much protein a growing athlete really needs, calculate it from ordinary food, and plan and cook protein-rich meals.

Then you will learn to judge the flood of claims about food, supplements and quick fixes. You will hear how government chemists tested Clark Stanley's Snake Oil Liniment and found no snake in it, learn why dietary supplements are not checked by the FDA before they are sold, and design a blinded test of a "performance" claim of your own.

PREREQUISITES

- Knows the food groups and what carbohydrate, protein and fat do (earlier grades)
- Can read a Nutrition Facts label, including serving size and grams of protein
- Knows that calories are a unit of food energy: about 4 per gram of carbohydrate or protein and 9 per gram of fat

MASTERY CHECKLIST

- ☐ I can tell how Fick and Wislicenus tested Liebig's idea on the Faulhorn and what they concluded.
- ☐ I can explain what protein does in the body, what amino acids are and why nine are essential.
- ☐ I can calculate protein needs in grams per kilogram and total the protein in a day of meals from labels.
- ☐ I can explain how dietary supplements are regulated and why teenagers should not use them.
- ☐ I can judge a health claim with clear questions and design a fair, blinded test.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **Dietary Guidelines for Americans (U.S. Departments of Agriculture and Health and Human Services)**: Free. The official guidelines, with food-group amounts and protein foods for teenagers, for planning the meals in Lesson 3.1.
- **Dietary Supplements (U.S. Food and Drug Administration)**: Free. The FDA's own explanation of how supplements are regulated and what it does not review before sale, for Lesson 3.2.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

3.1 Protein for Growing Athletes: The Climb of the Faulhorn

3 sessions of 45–50 minutes

3.2 Fads, Myths and Supplements: The Snake Oil Test

3 sessions of 45–50 minutes

UNIT 3 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **10 pts**

What did Liebig claim, and how did Fick and Wislicenus test it on the Faulhorn? What did they conclude?

2. **8 pts**

Name four jobs of protein in the body and explain what essential amino acids are.

3. **10 pts**

Calculation. For a 55-kg teenage athlete, find the RDA for protein (0.85 g/kg) and the athletic range (1.2–2.0 g/kg).

4. **10 pts**

Calculation. A day's meals: 2 eggs (6 g each), 1 cup of milk (8 g), a peanut butter sandwich (2 tbsp peanut butter, 7 g; 2 slices bread, 7 g), 6 oz Greek yogurt (16 g), 3 oz chicken (26 g), $\frac{1}{2}$ cup black beans (7 g). Find the total protein and the calories from protein.

5. **8 pts**

What happens to protein eaten beyond what the body needs? Why does this matter for athletes who think more is always better?

6. **8 pts**

How are dietary supplements regulated in the United States under the 1994 law (DSHEA)? What does the FDA not do?

7. **8 pts**

What did government chemists find in Clark Stanley's Snake Oil Liniment, and what lesson does the case teach?

8. **8 pts**

Explain the placebo effect and why a test of a product must be blinded and controlled.

9. **10 pts**

Calculation. In a blinded bracelet test, four people's best broad jumps were 72, 65, 80 and 59 inches with bracelet A and 71, 67, 79 and 60 inches with bracelet B. Find the average for each and the difference. Is there evidence that either bracelet works?

10. **20 pts**

Short written answer. A teammate shows you an online ad for a pre-workout powder that promises "massive energy and muscle gains, clinically proven." Write a paragraph using at least four claim-checking questions and what you know about supplement regulation to explain why you would not use it, and what you would do instead.

ANSWER KEY

1. Liebig claimed working muscles burn their own protein for energy. Fick and Wislicenus ate almost no protein (only starch, fat and sugar) before and during their climb of the Faulhorn, collected their urine to measure nitrogen (which shows how much protein was broken down), and calculated the work of lifting their bodies up the mountain. The protein broken down could supply only a fraction of the energy needed, so muscles must be fueled mainly by carbohydrate and fat; protein is mainly for building and repair.
2. Any four: building muscle fibers (actin and myosin), enzymes, hormones, antibodies, hemoglobin, skin and hair, tissue repair. Essential amino acids are the nine amino acids the body cannot make, so they must come from food.
3. $RDA = 0.85 \times 55 = 46.75 \approx 47$ g a day. Athletic range: $1.2 \times 55 = 66$ g to $2.0 \times 55 = 110$ g a day.
4. Total = $12 + 8 + 7 + 7 + 16 + 26 + 7 = 83$ g. Calories from protein = $83 \times 4 = 332$ calories (a unit of food energy).
5. The extra is not stored as muscle. Its nitrogen is removed as urea in the urine and the rest is used for energy. Eating far more protein than needed does not build more muscle; training, enough total food, carbohydrate, sleep and protein spread across meals matter more.
6. Supplements are regulated more like foods than drugs. The manufacturer is responsible for safety and truthful labeling. The FDA does not test or approve supplements before they are sold; it can act only after problems are found. Structure/function claims must carry a disclaimer that the FDA has not evaluated them.
7. Mostly mineral oil, about 1 percent fatty oil (probably beef fat), red pepper, turpentine and camphor, and no snake oil; Stanley was fined \$20 for misbranding. Lesson: test products instead of trusting advertising; big promises without evidence are a warning sign.
8. The placebo effect is a real improvement caused by expecting a treatment to work. Without a control (a look-alike fake or no treatment) and blinding (the subject not knowing which is real), you cannot tell whether a change came from the product or from expectations, practice or normal variation.
9. A: $(72 + 65 + 80 + 59) \div 4 = 276 \div 4 = 69.0$ in. B: $(71 + 67 + 79 + 60) \div 4 = 277 \div 4 = 69.25$ in. Difference = 0.25 in, far smaller than normal jump-to-jump variation (1–2 inches here). No evidence either bracelet works.

10. Answers vary. A full answer asks who profits, what the evidence is and whether a controlled, blinded study can be found, how many people were tested and whether it was repeated, and whether the promise is plausible; notes that “clinically proven” without a study is a red flag; explains that supplements are not FDA-approved before sale, that some have contained hidden drug ingredients, that pre-workouts often contain large doses of caffeine and other stimulants, and that the AAP advises teenagers against performance supplements; and names the real alternatives: sleep, food with protein and carbohydrate, water and steady training.

UNIT CHALLENGE: PLAN, SHOP AND COOK A TRAINING DAY

Plan a full day of meals and snacks for a hard training day, with protein at every meal (about 20–30 grams), carbohydrate for fuel, fruits and vegetables, and water. Make a shopping list with an estimated cost, help shop, and cook at least two of the meals with a parent supervising. Record the protein for each meal from labels, and write a short report comparing your plan with the RDA and the athletic range, and explaining why your plan needs no supplements.

LOOK FOR	WHAT IT MEANS
Balanced plan	Every meal has a protein food, carbohydrate and a fruit or vegetable; protein spread across the day; water included.
Accurate numbers	Protein per meal and per day totaled correctly from labels and compared with needs; shopping list with estimated cost.
Cooking	At least two meals cooked safely with good hygiene, with recipes written out.
Reflection	A clear report explaining the plan, what was learned and why real food is enough. Effort and care count most.

UNIT 4

STRENGTH

In 1879 a young doctor named Dudley Sargent took charge of Harvard's new Hemenway Gymnasium. Instead of drilling every student through the same routine, he examined each one and prescribed exercises on machines he designed himself, many of them pulley weights whose load could be set for each person. In this unit you will learn the five movement patterns that almost every strength exercise is built from (squat, hinge, push, pull and carry), practice them first with a broom handle, and then add light loads with a knowledgeable adult present.

Then you will learn how coaches plan training over weeks and months. The Soviet sport scientist Lev Matveyev studied the training records of Olympic athletes in the 1950s and early 1960s to learn why some reached their best form at the Games and others did not. His answer, periodization, organizes training into cycles of building, peaking and recovering. You will use it to design a six-week strength plan of your own.

PREREQUISITES

- Can perform bodyweight squats, push-ups, lunges and planks with good form (earlier grades)
- Knows progressive overload and the roles of rest, food and sleep in getting stronger
- Can calculate percentages and multiply sets $\times$ reps $\times$ load

MASTERY CHECKLIST

- ☐ I can name and show the five movement patterns and the main muscles each one uses.
- ☐ I can brace my core, keep a neutral spine and breathe correctly under a light load.
- ☐ I can explain and follow the high-school lifting safety rules: a knowledgeable adult present, a spotter for pressing lifts, technique first, and no one-repetition-maximum testing.
- ☐ I can explain periodization (macrocycle, mesocycle, microcycle, deload) and Selye's idea of adaptation to stress.
- ☐ I can design a six-week strength plan, calculate volume load and estimate strength safely from a set of 8–10 reps.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A light resistance band:** Optional, for band rows, pull-aparts and presses when dumbbells are not available.
- **A pair of light dumbbells (5–20 lb) or an adjustable kettlebell:** Optional. Gallon water jugs (about 8.3 lb each when full), a backpack with books and a sturdy bag with handles work just as well for this unit.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

4.1 The Five Movement Patterns: Dudley Sargent's Gymnasium

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. 8 pts

What did Dudley Sargent do differently at Harvard's Hemenway Gymnasium, and how do his machines relate to modern gyms?

2. 10 pts

Name the five movement patterns. For each, give one exercise and the main muscles used.

3. 8 pts

Explain the difference between a squat and a hinge, and give two form cues for the hinge.

4. 10 pts

State the four lifting safety rules for high-school students in this course and explain why maximal testing is not used.

5. 8 pts

Calculation. Find the volume load for 3 sets of 10 Romanian deadlifts with two 15-lb dumbbells. What would 3 sets of 11 be, and what is the percentage increase?

6. 10 pts

Calculation. Using the Epley formula ($\text{estimated max} \approx \text{load} \times (1 + \text{reps} \div 30)$), estimate the strength of a student who does 9 good goblet squats with 30 lb. Six weeks later he does 9 reps with 35 lb. Find the new estimate and the percentage gain.

7. (8 pts)

What question did Lev Matveyev ask, how did he try to answer it, and what did he find?

8. (8 pts)

Describe Hans Selye's three stages of the general adaptation syndrome and connect them to training and recovery.

9. (10 pts)

Define macrocycle, mesocycle, microcycle and deload, and give an example of each from a teenager's year.

10. (20 pts)

Short written answer. A friend plans to lift as heavy as possible every day to get strong for the season, and wants to test his maximum each week. Write a paragraph using the lessons of Sargent, Matveyev and Selye to explain a better approach and the safety rules he should follow.

ANSWER KEY

1. He examined each student and wrote an individual exercise prescription instead of drilling everyone the same way. He designed apparatus including pulley-weight machines with adjustable weight stacks, forerunners of today's cable machines.
2. Squat (goblet squat: quadriceps, glutes, adductors); hinge (Romanian deadlift: hamstrings, glutes, spinal erectors); push (push-up or floor press: chest, shoulders, triceps); pull (one-arm row: lats, upper back, biceps); carry (farmer's carry: grip, shoulders, trunk).
3. In a squat the knees and hips bend a lot and the torso stays fairly upright; in a hinge the hips move back and the torso tips forward with only a slight knee bend. Hinge cues (any two): soft knees, push hips back, neutral spine, broom touching head, upper back and tailbone, feel the hamstring stretch, stand by driving the hips forward.
4. A knowledgeable adult present for free weights; a spotter for any pressing lift; technique practiced first with a broom or body weight and loads you can lift 10–15 times with reps to spare; no one-repetition-maximum testing. Maximal lifts put the greatest strain on growing joints and on form, carry the most risk of injury, and are unnecessary, since strength can be estimated from a set of 8–10 reps.
5. Load = $2 \times 15 = 30$ lb. $3 \times 10 \times 30 = 900$ lb. $3 \times 11 \times 30 = 990$ lb. Increase = $90 \div 900 = 10$ percent.
6. First: $30 \times (1 + 9 \div 30) = 30 \times 1.3 = 39$ lb. Later: $35 \times 1.3 = 45.5$ lb. Gain = $6.5 \div 39 \approx 16.7$ percent. These are estimates only; no maximum is ever attempted.
7. Why some Soviet athletes peaked at the 1952 and 1956 Olympics while others did not. He studied the training records and results of many athletes in measurable sports over the year. Those who peaked followed a pattern: a preparatory period of high volume and moderate intensity, volume falling as intensity rose into the competition period, then a transition period of active rest. He called this periodization.
8. Alarm (the first response to a stress, when you are temporarily weaker), resistance (the body adapts and becomes stronger), exhaustion (if stress is too great for too long, the body breaks down). Training provides a planned stress; recovery (food, sleep, rest days, deloads) lets adaptation happen; too much training without recovery leads to exhaustion, overuse injury and burnout.

9. Macrocycle: a season or year (e.g., the school year of basketball training).
 Mesocycle: a block of 3–6 weeks with one goal (e.g., the six-week strength plan).
 Microcycle: a week or short series of sessions (e.g., Workout A Monday, Workout B Thursday). Deload: a planned easier week with less volume (e.g., Week 6 at lighter loads).
10. Answers vary. A full answer recommends an individual plan fitted to his starting point (Sargent); training in cycles with planned increases of about 5–10 percent a week, rest days and a deload (Matveyev); explains that adaptation happens during recovery and that constant maximal stress leads to exhaustion and injury (Selye); trains all five patterns with good technique; and lists the safety rules: a knowledgeable adult present, a spotter for pressing, technique before load, reps in reserve, and no maximal testing, using an estimate from 8–10 reps instead.

UNIT CHALLENGE: MY SIX-WEEK STRENGTH PLAN

Carry out your six-week strength plan from Lesson 4.2, two workouts a week, recording every set in your training log. At the end of Week 2 (inside this quarter) and again at Week 6, film one set of each movement pattern from the side and compare your form. Calculate weekly volume load, graph it, and write a report on your estimated strength at the start and end, how your form improved and what you learned about patient, planned training.

LOOK FOR	WHAT IT MEANS
Sound, safe plan	All five patterns, two workouts a week on non-consecutive days, gradual progression, a deload, and an adult's signature; no maximal testing.
Faithful training log	Every workout dated with loads, reps, reps in reserve and form notes.
Calculations and graph	Volume loads and strength estimates calculated correctly and graphed.
Form and reflection	Side-view video comparison with honest notes, and a thoughtful report. Effort, good form and improvement count, not the size of the loads.

4.1 THE FIVE MOVEMENT PATTERNS: DUDLEY SARGENT'S GYMNASIUM

OBJECTIVES

- Tell how Dudley Sargent individualized exercise at Harvard's Hemenway Gymnasium with adjustable pulley weights.
- Name and show the squat, hinge, push, pull and carry, with the main muscles each uses and its key form cues.
- Brace the core, keep a neutral spine and breathe correctly, practicing with a broom handle before any load.
- Follow the lifting safety rules and complete a light-load movement-pattern circuit with a knowledgeable adult present.

Warm-up. Movement-prep warm-up (6 minutes): 1 minute of jogging or jumping jacks; 10 bodyweight squats; 10 hip hinges with hands on hips (push the hips back, chest proud); 10 incline push-ups on a counter; 10 band or towel pull-aparts; 30 seconds of walking with good posture; 5 inchworms. Think about it: which of these movements did you already use today carrying, lifting or reaching?

WATCH

FIX Your RDL Form! (Ultimate Romanian Deadlift Tutorial)

Squat University · 7:11

<https://www.youtube.com/watch?v=5bJEigM5iVg>

WHEN TO WATCH

In Session 2, after the broom-handle clinic and before you pick up any load.
Watch for how the hinge is taught step by step, from a dowel to a light weight.

Note: A physical therapist (Squat University) coaches an adult athlete through the Romanian deadlift. The athlete wears a sleeveless training shirt; the barbell loads shown are for an experienced adult. Teenagers in this course use light dumbbells, jugs or a backpack. The description links to the channel's books and sponsors; none are needed.

BACKUP VIDEO

How to Spot: Dumbbell Pressing Movements

OhioUCampusRec · 1:03

<https://www.youtube.com/watch?v=9Um3zljzrK8>

Before the floor press in Session 3, so your spotter knows where to stand and where to put his or her hands.

KEY TERMS

movement pattern

A basic way the body moves under load: squat, hinge, push, pull or carry. Most strength exercises are versions of these.

neutral spine

The back held in its natural, gently curved position, neither rounded nor over-arched.

hip hinge

Bending forward by pushing the hips back while the spine stays neutral and the knees bend only a little, as in picking up a box or a deadlift.

bracing

Tightening the muscles around the trunk after a breath in, like preparing to be bumped, to keep the spine stable under load.

spotter

A trained helper who stands ready to assist or take the load if a lifter cannot finish a rep, especially in pressing lifts.

reps in reserve (RIR)

How many more good reps you could have done at the end of a set. Beginners should finish most sets with 2–3 reps in reserve.

CORE IDEAS

The story. Dudley Allen Sargent grew up in Maine, performed as a gymnast as a young man, taught gymnastics at Bowdoin College and earned a medical degree at Yale. In 1879 he became director of Harvard’s brand-new Hemenway Gymnasium, a post he held for forty years. Most gymnasiums of the day put everyone through the same drills. Sargent did something different: he examined each student, noted his strengths and weak points, and wrote an individual exercise prescription. To carry it out, he designed his own apparatus, including pulley-weight machines with stacks of small iron weights that could be set for each person’s strength, a forerunner of the cable machines in gyms today.

How they figured it out. Sargent’s machines let a student pull down, pull across, push out and lift, each against a load he could handle with good form, and add a little as he grew stronger. Coaches since then have noticed that nearly every strength exercise falls into a few families of movement. Today they are usually called the five movement patterns: **squat** (sitting down and standing up), **hinge** (bending at the hips to lift from the floor), **push** (pressing away from the body, forward or overhead), **pull** (drawing toward the body, as in rowing or climbing) and **carry** (walking while holding a load). Train all five, and you train the whole body for sport and work.

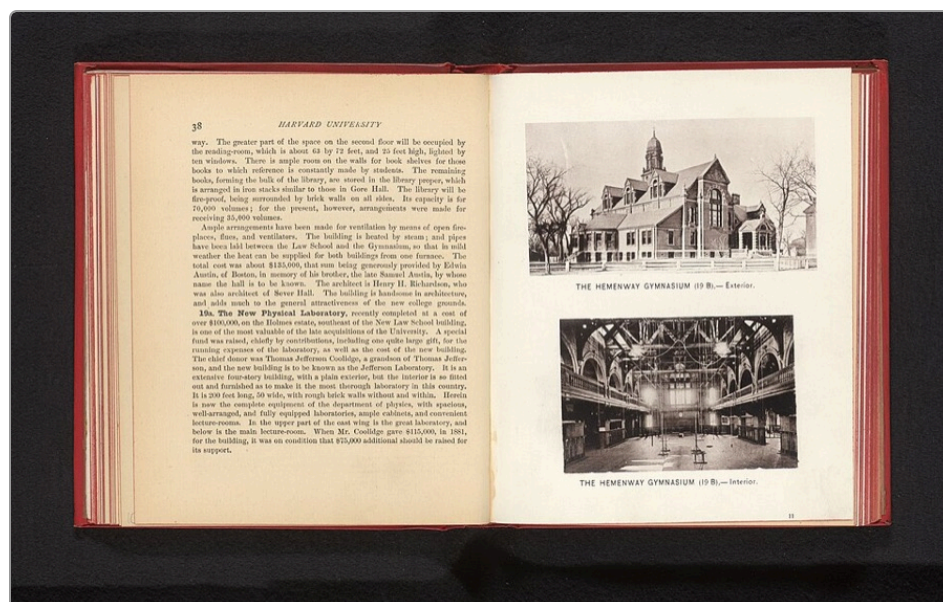
How your body works. The **squat** uses the quadriceps, glutes and adductors; cues: feet about shoulder-width, sit between your heels, knees track over toes, chest up. The **hinge** uses the hamstrings, glutes and the muscles along the spine; cues: soft knees, push the hips back, keep a neutral spine, feel a stretch in the hamstrings, stand by driving the hips forward. The **push** uses the chest, shoulders and triceps; cues: hands or weights over the shoulders, elbows about 45 degrees from the body, full control. The **pull** uses the lats, the upper back and the biceps; cues: squeeze the shoulder blades back and down, pull elbows toward the hips. The **carry** trains grip, shoulders and the whole trunk; cues: stand tall, shoulders back, short steady steps. In every pattern, take a breath, **brace** the trunk, move with control, and breathe out as you finish the hard part; do not hold your breath for long.

Good form and safety. The National Strength and Conditioning Association's position on youth training is clear: supervised strength training with good technique is safe and beneficial for teenagers, and most injuries come from lifting without supervision, with poor technique or with too much weight. In this course: free weights only with a **knowledgeable adult present**; a **spotter** for any pressing lift; technique practiced first with a broom handle or body weight; loads you can lift for 10–15 good reps with 2–3 reps in reserve; and **no one-repetition-maximum testing**, ever.

Think it through. A full gallon jug of water weighs about 8.3 lb; two jugs weigh about 16.7 lb. If you do a goblet squat holding a 15-lb load for 2 sets of 12 reps, your volume load is $2 \times 12 \times 15 = 360$ lb. If next week you keep the load and do 2 sets of 15, it rises to $2 \times 15 \times 15 = 450$ lb, an increase of $90 \div 360 = 25$ percent: too big a jump for one week. Adding reps or load in small steps (about 5–10 percent a week) is safer and works better.

Try it. In Session 2 you will hold a technique clinic with a broom handle, filming yourself from the side, and then do one light-load set of each pattern. In Session 3 you will complete a full movement-pattern circuit and record every set. Paul wrote that “bodily exercise profiteth little: but godliness is profitable unto all things” (1 Timothy 4:8): exercise has some value; godliness has more. We train the body as good stewards, and strength is for serving others.

PICTURE STUDY



The Hemenway Gymnasium, Harvard University: Exterior and Interior, Unknown photographer, from a Harvard University guidebook, About 1881–1886 · Photographs printed in a book · Rijksmuseum, Amsterdam

Image: [Wikimedia Commons](#), public domain

These photographs of the Hemenway Gymnasium appeared in a guidebook to Harvard printed in the 1880s, only a few years after Dudley Sargent took charge of it. In the interior view you can see the great hall where students trained under his individual prescriptions, with apparatus along the walls and ropes and rings hanging from the roof beams.

Look closely

- Look at the interior photograph. Find the ropes and rings hanging from the ceiling. Which movement pattern do they train?
- Find the gallery running around the upper level. What might it have been used for?
- Look along the walls for rows of apparatus. Sargent's pulley weights were mounted on walls like these. Which patterns could they train?
- Compare the outside of the building with a modern gym. What is the same? What is different?

Talk about it

1. Why was it new and important for Sargent to examine each student and write an individual plan instead of drilling everyone the same way?
2. Which of the five movement patterns could you train at home with no machines at all? With what?
3. Which pattern do you use most in daily work and chores, and which do you need most for your sport?

Safety first. Free weights only with a knowledgeable adult present; practice every pattern first with a broom handle or body weight. Use a spotter for any pressing lift, choose loads you can lift 10–15 times with good form and 2–3 reps to spare, and never test a one-repetition maximum. Clear the floor, wear shoes with grip, keep a neutral spine, breathe, and stop at sharp or joint pain, dizziness or chest pain.

ACTIVITY

Technique Clinic and the Five-Pattern Circuit

Like Sargent, you will start by checking each movement carefully and choosing the right load for you. Then you will train all five patterns in one session and record it, the foundation of the six-week plan you will design in Lesson 4.2.

You will need

- A broom handle or dowel, a phone to film from the side, and a knowledgeable adult
- Loads: two full gallon jugs, a backpack with books (10–20 lb), or light dumbbells; a sturdy bench, chair or low table for one-arm rows
- A towel or mat and a clear, non-slip floor
- Fitness journal with a training log: exercise, load, set 1, set 2, reps in reserve, form note

Steps

1. **Warm up** with the movement-prep warm-up above.
2. **Broom-handle clinic (Session 2).** Do 8 slow reps of each pattern holding the broom: (1) squat with the broom across the front of the shoulders; (2) hinge with the broom held along your back touching your head, upper back and tailbone (all three must stay in contact); (3) push: overhead press of the broom from the shoulders; (4) pull: bent-over row of the broom from a hinge position; (5) carry: walk 20 steps holding the broom overhead with straight arms. Film each from the side.
3. **Check the video** with your adult. For each pattern, write one thing done well and one thing to fix. Redo any pattern that needs it.
4. **Choose your loads.** For each exercise below, pick a load you think you can lift about 15 times with good form. Do one set of 10. If it felt like 5 or more reps were left, choose a heavier load; if form broke down, choose lighter.
5. **The circuit (Session 3).** Do 2 sets of each, resting 60–90 seconds: (a) goblet squat holding a jug, dumbbell or backpack at your chest, 10–12 reps; (b) Romanian deadlift (hinge) with two jugs, dumbbells or a backpack, 10–12 reps; (c) push-ups at your level, or a dumbbell floor press lying on your back

with a spotter kneeling beside you, 8–12 reps; (d) one-arm row with one hand and knee on a sturdy bench, 10–12 reps each arm; (e) farmer’s carry with a jug or bag in each hand, 2 trips of 20 yards (or 40 steps).

6. **Record** the load, reps and reps in reserve for every set, plus a form note.

7. **Cool down:** 2 minutes of walking, then the static stretches from Lesson 1.2 (hamstrings, hips, chest, calves), 30 seconds each.

8. **Plan the next step.** For each exercise, write whether you will add reps, add a little load, or stay the same next time, based on your reps in reserve and your form.

Tips

- The spotter for a floor press kneels at your head side and keeps hands near your wrists, ready to guide the dumbbells up or away. Agree on a word for “take it” before the set.
- If your back rounds in the hinge, shorten the range: lower only to just below the knees, and practice the broom drill more.
- Grip is often the limit in carries. That is fine: grip strength grows quickly and helps in every sport.

Check your work

- ☐ I can name and show the five movement patterns with key cues.
- ☐ I practiced with a broom handle, checked my form on video and chose safe loads.
- ☐ I completed and recorded the circuit with a knowledgeable adult present and a spotter for pressing.

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1. Make a chart of the five patterns: an exercise for each, the main muscles, and two form cues.
2. Copy your training log for the circuit with loads, reps and reps in reserve. Calculate the volume load for each exercise.
3. Write the form notes from your video: one strength and one fix for each pattern.
4. Write which pattern felt strongest and which weakest, and how you will balance them in your plan.

From history. Sargent also opened a school to train physical education teachers in Cambridge, Massachusetts, in 1881, and he designed a simple jump test (now called the Sargent jump or vertical jump test) still used to measure leg power. He taught that exercise should be fitted to the individual, an idea at the heart of every good training plan today.

COMMON MISTAKES

- Rounding the back in the hinge, or turning it into a squat by bending the knees too much.
- Letting the knees cave inward in the squat. Push them out over the toes.
- Holding the breath through a whole set. Brace, move, and breathe out through the hard part.
- Choosing a load to impress others. A weight you can lift with perfect form 12 times builds strength safely; ego loads cause injuries.

Make it a game • Pattern Technique Clinic. Perform the squat, hinge, push, pull and carry for your parent using bodyweight or a backpack, naming main muscles and two form cues for each. She grades with a checklist. Add reps in reserve for each set. Tell how Dudley Sargent individualized exercise. Retest next week for tidier form.

Scripture. “For bodily exercise profiteth little: but godliness is profitable unto all things, having promise of the life that now is, and of that which is to come.” (1 Timothy 4:8, KJV)

Exercise has real value for this life, and Paul does not dismiss it; but godliness is profitable for everything, now and forever. We train our bodies in the right place, under the greater work of loving God and others.

4.2 PERIODIZATION: LEV MATVEYEV AND THE TRAINING YEAR

OBJECTIVES

- Tell how Lev Matveyev studied Olympic athletes' training to develop periodization, and how Hans Selye's idea of adaptation to stress underlies it.
- Explain macrocycles, mesocycles, microcycles, deloads, and the balance of training stress and recovery.
- Calculate volume load, plan safe weekly progression and estimate strength from a set of 8–10 reps without maximal testing.
- Design a six-week strength plan and complete its first week.

Warm-up. Repeat the movement-prep warm-up from Lesson 4.1 (6 minutes), then 5 slow broom-handle reps of each of the five patterns. Think about it: if you trained as hard as possible every single day, what would happen after a few weeks?

WATCH

Phases of Periodization | Long Term Planning of Athletic Training

Flow High Performance · 10:23

<https://www.youtube.com/watch?v=JBhYINsfZFI>

WHEN TO WATCH

After “How they figured it out.” Watch for how a training year is divided into phases before a competition.

Note: A strength coach's slide lecture for coaches; it uses adult sport examples and one brief clip of a weight room. The description links to the coach's paid services; they are not needed. Our plan uses the same ideas at a teenager's scale.

KEY TERMS

periodization

Planning training in cycles, changing volume and intensity over time so the athlete improves steadily and reaches best form when it matters.

macrocycle, mesocycle, microcycle

The training year or season (macrocycle), a block of several weeks with one main goal (mesocycle), and a single week or short series of workouts (microcycle).

volume and intensity

Volume is how much work is done (sets × reps, or volume load = sets × reps × load); intensity is how hard each rep is (the load, or the effort).

deload

A planned easier week with less volume, which lets the body recover and adapt before the next block.

general adaptation syndrome

Hans Selye's description (1936) of how the body responds to stress: alarm, then resistance (adaptation), then exhaustion if the stress is too great for too long.

estimated strength

A calculated estimate of a lifter's maximum from a lighter set of several reps. In this course it stays a number on paper and is never tested.

CORE IDEAS

The story. At the 1952 and 1956 Olympic Games, some Soviet athletes set personal records exactly when it mattered, while others had peaked weeks too early or arrived tired. Lev Matveyev, a young Soviet sport scientist, wanted to know why. He gathered the training diaries and competition results of a great many athletes in events that could be measured precisely (track and field, swimming and weightlifting) and studied how their training changed over the year. In the early 1960s he published his conclusions, and in the mid-1960s a book that made the idea famous across the world: **periodization**.

How they figured it out. Matveyev found that the athletes who peaked at the right time had followed a pattern. Their year began with a long **preparatory period** of high volume at moderate intensity, building a broad base; then volume gradually fell while intensity rose; then came the **competition period**, when they were sharpest; and last, a **transition period** of active rest before the cycle began again. Behind his work lay an older idea from the Canadian physiologist Hans Selye, who in 1936 described how the body answers stress: an **alarm** stage, a **resistance** stage when it adapts and grows stronger, and **exhaustion** if stress is too great for too long. Training is a planned stress; recovery is when adaptation happens; too much stress with too little rest leads to exhaustion and injury.

How your body works. A hard workout leaves you temporarily more tired and slightly weaker. With food, sleep and time, your muscles, tendons, nerves and energy systems rebuild a little beyond where they started, ready for a slightly

greater challenge. Plan that cycle in layers: the **microcycle** (a week of two or three strength sessions with rest days between), the **mesocycle** (three to six weeks with a goal, often ending in a **deload** week), and the **macrocycle** (a season or year). For teenagers, the American Academy of Pediatrics advises at least one or two days off from organized sport each week and time away from a single sport each year, to prevent overuse injuries and burnout. A plan also teaches patience: improvement comes from many faithful weeks, not one heroic workout.

Think it through. *Volume load.* Week 1: goblet squat $3 \times 10 \times 20 \text{ lb} = 600 \text{ lb}$. Week 2: $3 \times 12 \times 20 \text{ lb} = 720 \text{ lb}$ (+20%). Better: Week 2 at $3 \times 11 \times 20 = 660 \text{ lb}$ (+10%). *Tracking strength without a max test.* A common estimate (the Epley formula) is estimated max $\approx \text{load} \times (1 + \text{reps} \div 30)$. If you can do 10 good reps with 25 lb, your estimate is $25 \times (1 + 10 \div 30) = 25 \times 1.33 \approx 33 \text{ lb}$. That is only a number on paper to track progress; you never attempt it. If six weeks later you do 10 good reps with 30 lb, the estimate is $30 \times 1.33 = 40 \text{ lb}$, a gain of about $7 \div 33 \approx 21$ percent, measured safely.

Try it. This week you will design a six-week strength plan using the five patterns: two weeks of learning, two of building, one of harder work, and one deload week ending with a safe retest of 8–10-rep sets. In Sessions 2 and 3 you will complete its first two workouts.

PICTURE STUDY



The Pair-Oared Shell, Thomas Eakins, 1872 · Oil on canvas · Philadelphia Museum of Art

Image: [Wikimedia Commons](#), public domain

Thomas Eakins, himself an amateur rower, painted the brothers John and Barney Biglin, professional oarsmen, practicing on the Schuylkill River in Philadelphia. Eakins made careful perspective drawings before painting, working out the position of the boat, the oars and even the angle of the sunlight. Here the brothers are not racing; they are training.

Look closely

- Look at the two rowers. How can you tell they are moving in perfect time?
- Find the bridge pier and the shadows. What time of day might it be?
- Look at their posture: backs, arms and legs. Which movement patterns does rowing use?
- Look at the calm water. Why might rowers practice on quiet evenings, long before a race?

Talk about it

1. Rowers train for months before the racing season. How does that match Matveyev's preparatory and competition periods?
2. What would happen to the Biglins if they rowed all-out races every day all year?

3. Rowing is a pulling sport. What strength exercises from Lesson 4.1 would help a rower most?

Safety first. All lifting rules from Lesson 4.1 still apply: a knowledgeable adult present, a spotter for pressing lifts, technique first, and no one-repetition-maximum testing; estimate strength only from sets of 8–10 good reps. Increase volume or load by small steps (about 5–10 percent a week), keep at least one rest day between strength sessions for the same muscles, and take a deload week when planned or when you feel worn down.

ACTIVITY

Design a Six-Week Strength Plan

You will write your own mesocycle: two strength workouts a week for six weeks, built from the five movement patterns, with planned progression and a deload. Then you will complete the first week.

You will need

- Your training log from Lesson 4.1 with your starting loads
- Graph paper or a spreadsheet for a six-week plan table
- The same loads and equipment as Lesson 4.1, a knowledgeable adult and a spotter for pressing

Steps

1. **Set a goal.** Write one goal for the six weeks (for example, “do 10 good-form goblet squats with 25 lb” or “carry two full jugs for 60 yards with good posture”).
2. **Choose two workouts.** Workout A: goblet squat, push-up or floor press, one-arm row, farmer’s carry. Workout B: Romanian deadlift, split squat (lunge), band or towel row, plank, suitcase carry (one load in one hand). Do A and B on non-consecutive days (for example, Monday and Thursday).
3. **Plan the progression.** Weeks 1–2 (learn): 2 sets of 12, light, 3+ reps in reserve. Weeks 3–4 (build): 3 sets of 10, adding reps or a little load when all sets feel easy. Week 5 (harder): 3 sets of 8 with a slightly heavier load, still 2 reps in reserve. Week 6 (deload and retest): 2 sets of 8 at Week 3 loads, then one set of 8–10 reps at your best load to estimate strength.
4. **Calculate** the volume load for each exercise in Weeks 1, 3, 5 and 6, and check that no week rises more than about 10 percent over the one before (except where you add a set at Week 3).
5. **Estimate your starting strength** for the goblet squat and Romanian deadlift from your Lesson 4.1 sets using the Epley formula. Write it down; do not test it.
6. **Workout A (Session 2).** Warm up, do Week 1 Workout A, and record every set with load, reps, reps in reserve and a form note.

7. **Workout B (Session 3).** Warm up, do Week 1 Workout B, and record it. Adjust any loads that were too light or too heavy.
8. **Have your plan checked.** Ask your knowledgeable adult to read your plan and sign it. Continue it as your unit challenge.

Tips

- Write the plan in pencil. A good plan bends a little for sickness, sports games and life.
- If you play a sport in season, keep strength work to two short sessions a week and do not schedule a hard workout the day before a game.
- Track sleep and how you feel. Feeling worn out several days in a row is a signal to deload early.

Check your work

- ☐ I can explain periodization and the stages of Selye's general adaptation syndrome.
- ☐ I wrote a six-week plan with progression, a deload and volume-load calculations.
- ☐ I completed Week 1 and estimated my strength safely, without a maximal test.

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1. Copy your six-week plan as a table: week, phase, sets × reps, planned loads, volume load.
2. Draw a line graph of planned volume load across the six weeks for one exercise. Mark the deload.
3. Draw Selye's three stages as a simple graph of "resistance to stress" over time, and label where training and recovery fit.
4. Write a short paragraph: How will you know if you are doing too much? What will you change?

From history. Matveyev's model was soon adapted by coaches everywhere, and later scientists proposed other ways of organizing training, such as "block" periodization and undulating plans that vary the load within each week. All of them share his central idea: plan the stress, plan the recovery and aim for the right moment.

COMMON MISTAKES

- Making every workout as hard as possible. Progress comes from planned, gradual increases and recovery.
- Skipping the deload week because you feel good. It is part of the plan that lets the gains settle in.
- Testing a one-repetition maximum to see progress. Use an estimate from a set of 8–10 reps instead.
- Changing the whole plan every week. Keep the same exercises long enough to measure improvement.

Make it a game • Periodization Design Duel. Each of you draws a six-week plan with micro- and mesocycles and a deload week. Compare volume and intensity lines. Defend each phase with Selye's adaptation idea. Your parent plays Matveyev and picks one flaw to challenge. A parent supervises any loaded work. Best defense wins; revise your plan afterward.

UNIT 4

STRENGTH

In 1879 a young doctor named Dudley Sargent took charge of Harvard's new Hemenway Gymnasium. Instead of drilling every student through the same routine, he examined each one and prescribed exercises on machines he designed himself, many of them pulley weights whose load could be set for each person. In this unit you will learn the five movement patterns that almost every strength exercise is built from (squat, hinge, push, pull and carry), practice them first with a broom handle, and then add light loads with a knowledgeable adult present.

Then you will learn how coaches plan training over weeks and months. The Soviet sport scientist Lev Matveyev studied the training records of Olympic athletes in the 1950s and early 1960s to learn why some reached their best form at the Games and others did not. His answer, periodization, organizes training into cycles of building, peaking and recovering. You will use it to design a six-week strength plan of your own.

PREREQUISITES

- Can perform bodyweight squats, push-ups, lunges and planks with good form (earlier grades)
- Knows progressive overload and the roles of rest, food and sleep in getting stronger
- Can calculate percentages and multiply sets $\times$ reps $\times$ load

MASTERY CHECKLIST

- ☐ I can name and show the five movement patterns and the main muscles each one uses.
- ☐ I can brace my core, keep a neutral spine and breathe correctly under a light load.
- ☐ I can explain and follow the high-school lifting safety rules: a knowledgeable adult present, a spotter for pressing lifts, technique first, and no one-repetition-maximum testing.
- ☐ I can explain periodization (macrocycle, mesocycle, microcycle, deload) and Selye's idea of adaptation to stress.
- ☐ I can design a six-week strength plan, calculate volume load and estimate strength safely from a set of 8–10 reps.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A light resistance band:** Optional, for band rows, pull-aparts and presses when dumbbells are not available.
- **A pair of light dumbbells (5–20 lb) or an adjustable kettlebell:** Optional. Gallon water jugs (about 8.3 lb each when full), a backpack with books and a sturdy bag with handles work just as well for this unit.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

4.1 The Five Movement Patterns: Dudley Sargent's Gymnasium

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. 8 pts

What did Dudley Sargent do differently at Harvard's Hemenway Gymnasium, and how do his machines relate to modern gyms?

2. 10 pts

Name the five movement patterns. For each, give one exercise and the main muscles used.

3. 8 pts

Explain the difference between a squat and a hinge, and give two form cues for the hinge.

4. 10 pts

State the four lifting safety rules for high-school students in this course and explain why maximal testing is not used.

5. 8 pts

Calculation. Find the volume load for 3 sets of 10 Romanian deadlifts with two 15-lb dumbbells. What would 3 sets of 11 be, and what is the percentage increase?

6. 10 pts

Calculation. Using the Epley formula ($\text{estimated max} \approx \text{load} \times (1 + \text{reps} \div 30)$), estimate the strength of a student who does 9 good goblet squats with 30 lb. Six weeks later he does 9 reps with 35 lb. Find the new estimate and the percentage gain.

7. **8 pts**

What question did Lev Matveyev ask, how did he try to answer it, and what did he find?

8. **8 pts**

Describe Hans Selye's three stages of the general adaptation syndrome and connect them to training and recovery.

9. **10 pts**

Define macrocycle, mesocycle, microcycle and deload, and give an example of each from a teenager's year.

10. **20 pts**

Short written answer. A friend plans to lift as heavy as possible every day to get strong for the season, and wants to test his maximum each week. Write a paragraph using the lessons of Sargent, Matveyev and Selye to explain a better approach and the safety rules he should follow.

ANSWER KEY

1. He examined each student and wrote an individual exercise prescription instead of drilling everyone the same way. He designed apparatus including pulley-weight machines with adjustable weight stacks, forerunners of today's cable machines.
2. Squat (goblet squat: quadriceps, glutes, adductors); hinge (Romanian deadlift: hamstrings, glutes, spinal erectors); push (push-up or floor press: chest, shoulders, triceps); pull (one-arm row: lats, upper back, biceps); carry (farmer's carry: grip, shoulders, trunk).
3. In a squat the knees and hips bend a lot and the torso stays fairly upright; in a hinge the hips move back and the torso tips forward with only a slight knee bend. Hinge cues (any two): soft knees, push hips back, neutral spine, broom touching head, upper back and tailbone, feel the hamstring stretch, stand by driving the hips forward.
4. A knowledgeable adult present for free weights; a spotter for any pressing lift; technique practiced first with a broom or body weight and loads you can lift 10–15 times with reps to spare; no one-repetition-maximum testing. Maximal lifts put the greatest strain on growing joints and on form, carry the most risk of injury, and are unnecessary, since strength can be estimated from a set of 8–10 reps.
5. Load = $2 \times 15 = 30$ lb. $3 \times 10 \times 30 = 900$ lb. $3 \times 11 \times 30 = 990$ lb. Increase = $90 \div 900 = 10$ percent.
6. First: $30 \times (1 + 9 \div 30) = 30 \times 1.3 = 39$ lb. Later: $35 \times 1.3 = 45.5$ lb. Gain = $6.5 \div 39 \approx 16.7$ percent. These are estimates only; no maximum is ever attempted.
7. Why some Soviet athletes peaked at the 1952 and 1956 Olympics while others did not. He studied the training records and results of many athletes in measurable sports over the year. Those who peaked followed a pattern: a preparatory period of high volume and moderate intensity, volume falling as intensity rose into the competition period, then a transition period of active rest. He called this periodization.
8. Alarm (the first response to a stress, when you are temporarily weaker), resistance (the body adapts and becomes stronger), exhaustion (if stress is too great for too long, the body breaks down). Training provides a planned stress; recovery (food, sleep, rest days, deloads) lets adaptation happen; too much training without recovery leads to exhaustion, overuse injury and burnout.

9. **Macrocycle:** a season or year (e.g., the school year of basketball training).
Mesocycle: a block of 3–6 weeks with one goal (e.g., the six-week strength plan).
Microcycle: a week or short series of sessions (e.g., Workout A Monday, Workout B Thursday). **Deload:** a planned easier week with less volume (e.g., Week 6 at lighter loads).
10. Answers vary. A full answer recommends an individual plan fitted to his starting point (Sargent); training in cycles with planned increases of about 5–10 percent a week, rest days and a deload (Matveyev); explains that adaptation happens during recovery and that constant maximal stress leads to exhaustion and injury (Selye); trains all five patterns with good technique; and lists the safety rules: a knowledgeable adult present, a spotter for pressing, technique before load, reps in reserve, and no maximal testing, using an estimate from 8–10 reps instead.

UNIT CHALLENGE: MY SIX-WEEK STRENGTH PLAN

Carry out your six-week strength plan from Lesson 4.2, two workouts a week, recording every set in your training log. At the end of Week 2 (inside this quarter) and again at Week 6, film one set of each movement pattern from the side and compare your form. Calculate weekly volume load, graph it, and write a report on your estimated strength at the start and end, how your form improved and what you learned about patient, planned training.

LOOK FOR	WHAT IT MEANS
Sound, safe plan	All five patterns, two workouts a week on non-consecutive days, gradual progression, a deload, and an adult's signature; no maximal testing.
Faithful training log	Every workout dated with loads, reps, reps in reserve and form notes.
Calculations and graph	Volume loads and strength estimates calculated correctly and graphed.
Form and reflection	Side-view video comparison with honest notes, and a thoughtful report. Effort, good form and improvement count, not the size of the loads.

AEROBIC TRAINING

In the 1950s an Auckland milk-round worker named Arthur Lydiard began coaching a handful of young men from his neighborhood. He had them run about 100 miles (160 kilometres) a week at a steady, conversational pace, including a long Sunday run over the hills of the Waitākere Ranges. On one afternoon at the 1960 Rome Olympics, two of them, Peter Snell and Murray Halberg, won gold medals about an hour apart. In this unit you will learn why that patient aerobic base works: what happens to the heart, blood, muscles and mitochondria with steady training, and how to set an easy-training zone with the Karvonen formula.

Then you will study the opposite tool: short, very hard intervals. In 1996 Izumi Tabata and his colleagues in Japan published a study of a speed-skating workout of 20 seconds of all-out cycling and 10 seconds of rest, repeated about eight times, and compared it with an hour of moderate cycling. You will learn what each kind of training does, run a safe interval session, measure your heart-rate recovery, and finish the quarter with a family fitness day.

PREREQUISITES

- Can find a pulse and calculate beats per minute (earlier grades)
- Knows the heart and lungs deliver oxygen to working muscles, and the difference between aerobic and anaerobic energy
- Has done the conductor's workout (Lesson 1.1) and knows the talk test

MASTERY CHECKLIST

- ☐ I can tell how Arthur Lydiard built his runners' aerobic base and what they achieved.
- ☐ I can explain the main aerobic adaptations: stroke volume, plasma volume, capillaries, mitochondria and resting heart rate.
- ☐ I can calculate an easy-training heart-rate zone with the Karvonen formula and run in it.
- ☐ I can describe the 1996 Tabata study accurately and explain what high-intensity intervals improve.
- ☐ I can complete a safe interval session, measure heart-rate recovery, and plan a balanced four-week aerobic block.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A jump rope:** Optional, for warm-ups and an interval station on the family fitness day.
- **A heart-rate monitor or sports watch:** Optional. A 15-second pulse count at the wrist or neck works for every activity in this unit.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

5.1 Arthur Lydiard and the Aerobic Base

3 sessions of 45–50 minutes

5.2 High-Intensity Intervals: The Tabata Study and the Family Fitness Day

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **8 pts**

Describe Arthur Lydiard's training approach and what his athletes achieved at the 1960 and 1964 Olympics.

2. **10 pts**

Name four changes in the body caused by months of aerobic base training and explain why resting heart rate falls.

3. **12 pts**

Calculation. A 16-year-old has a resting heart rate of 58 bpm. Using $HR_{max} = 208 - 0.7 \times \text{age}$, find HR_{max} , heart-rate reserve, and the easy zone at 60–70 percent with the Karvonen formula.

4. (8 pts)

Calculation. A runner's weekly running is 90 minutes. Using the 10 percent guideline, what is the most for each of the next two weeks? What would a recovery week at 20 percent less than week 3 be?

5. (10 pts)

Describe the 1996 Tabata study: the two training programs and the results for VO₂ max and anaerobic capacity.

6. (8 pts)

Explain where the energy comes from in a 20-second all-out effort, and why repeated short bouts also train the aerobic system.

7. (8 pts)

Calculation. Find the total hard-work time in one 8-round 20-and-10 set, and compare the weekly time of the moderate group ($60 \text{ min} \times 5 \text{ days}$) with roughly $2.7 \text{ minutes of hard work} \times 5 \text{ days}$.

8. (8 pts)

Calculation. After an interval set your heart rate is 184 bpm; one minute later it is 146 bpm. Three weeks later the numbers are 182 and 138. Find both recoveries and the change.

9. (8 pts)

Give three safety rules for high-intensity interval training for teenagers.

10. (20 pts)

Short written answer. A friend says, "Tabata proved that four minutes of intervals is all the exercise anyone needs." Write a paragraph correcting this claim using what the study actually tested, Lydiard's approach, and the physical activity guidelines.

ANSWER KEY

1. Months of steady aerobic running, about 100 miles (160 km) a week including a long hilly weekend run, followed by hill training, faster track work and sharpening. In 1960 Peter Snell won the 800 m and Murray Halberg the 5,000 m about an hour apart, and Barry Magee won marathon bronze; in 1964 Snell won the 800 m and 1,500 m.
2. Any four: larger left ventricle and higher stroke volume; increased plasma volume; more capillaries around muscle fibers; more mitochondria and aerobic enzymes; better use of fat for fuel; stronger tendons and bones. Because each beat pumps more blood, the heart needs fewer beats per minute at rest to deliver the same blood, so resting heart rate falls.
3. $\text{HR}_{\text{max}} = 208 - 0.7 \times 16 = 208 - 11.2 = 196.8 \approx 197$ bpm. $\text{HRR} = 197 - 58 = 139$ bpm.
60%: $139 \times 0.60 + 58 = 83.4 + 58 \approx 141$ bpm. 70%: $139 \times 0.70 + 58 = 97.3 + 58 \approx 155$ bpm. Easy zone ≈ 141 –155 bpm.
4. Week 2: $90 \times 1.10 = 99$ minutes. Week 3: $99 \times 1.10 = 108.9 \approx 109$ minutes. Recovery week: $109 \times 0.80 \approx 87$ minutes.
5. Over six weeks, a moderate group cycled 60 minutes at 70% of VO_2 max five days a week; an interval group did 7–8 bouts of 20 seconds at about 170% of VO_2 max power with 10 seconds of rest, four days a week, plus one day of 30 minutes moderate riding and four bouts. Moderate group: VO_2 max up about 5 mL/kg/min, anaerobic capacity unchanged. Interval group: VO_2 max up about 7 mL/kg/min and anaerobic capacity up 28%.
6. Energy comes first from the phosphagen system (a small store of high-energy phosphate in the muscle), then from anaerobic glycolysis, which breaks down glucose quickly and produces lactate and hydrogen ions. Repeating the bouts with very short rests drives heart rate and oxygen uptake close to maximum, so the aerobic system is also pushed hard.
7. $8 \times 20 \text{ s} = 160 \text{ s} = 2 \text{ min } 40 \text{ s}$. Moderate group: 300 minutes a week. Interval group hard work: about $2.7 \times 5 \approx 13.5$ minutes a week (plus warm-ups and one 30-minute ride).
8. First: $184 - 146 = 38$ bpm. Later: $182 - 138 = 44$ bpm. Improvement = 6 bpm, a sign of improving fitness.
9. Any three: build an aerobic base for several weeks first; get a doctor's clearance; warm up fully; limit hard intervals to once or twice a week; work hard but controlled rather than all-out; use safe surfaces; cool down by walking; stop at chest pain, dizziness, faintness or unusual breathlessness.

10. Answers vary. A full answer explains that the study tested young, trained men on a lab bike at about 170% of VO₂ max power, five days a week for six weeks, including a weekly moderate ride; that the intervals were exhausting and far harder than most “Tabata” workouts; that the interval group improved VO₂ max and anaerobic capacity, but intervals are a tool used sparingly on top of an aerobic base, as Lydiard showed with his champions; and that teenagers still need at least 60 minutes of activity daily with strength and bone-strengthening work, so four minutes is not enough.

UNIT CHALLENGE: MY FOUR-WEEK AEROBIC TRAINING BLOCK

Carry out a four-week aerobic block: three or four sessions a week, mostly easy runs in your Karvonen zone, one longer easy run each week, and one interval or hill session in Weeks 2 and 3, with a lighter Week 4 and your Unit 4 strength workouts on other days. Record every session, measure your resting heart rate weekly and repeat the same easy route at the same heart rate in Week 1 and Week 4. Graph your weekly minutes, resting heart rate and the route time, and write a report that ends with how the family fitness day went.

LOOK FOR	WHAT IT MEANS
Balanced, safe plan	Mostly easy training, no more than about 10 percent increase a week, a recovery week, intervals limited to once a week, rest days.
Complete records	Every session dated with time, distance or route, heart rates and RPE; weekly resting heart rate.
Calculations and graphs	Karvonen zone, weekly totals and percentage changes, and heart-rate recovery calculated correctly and graphed.
Leadership and reflection	A family fitness day planned and led, and a thoughtful report. Faithful effort and improvement count, not speed.

5.1 ARTHUR LYDIARD AND THE AEROBIC BASE

OBJECTIVES

- Tell how Arthur Lydiard developed base training in New Zealand and what his athletes achieved in 1960 and 1964.
- Explain how steady aerobic training changes the heart, blood and muscles, including stroke volume, capillaries and mitochondria.
- Calculate an easy-training heart-rate zone with the Karvonen formula and check it with the talk test.
- Complete two easy zone runs and plan a four-week base block that increases gradually.

Warm-up. Easy-start warm-up (6 minutes): 2 minutes of brisk walking; 10 leg swings each way on each leg; 10 walking lunges; 10 skips (A-skips, knee up, opposite arm); 2 minutes of very easy jogging. Think about it: could you talk in full sentences during that jog? That is what most of today's run should feel like.

WATCH

The Karvonen Formula for Target Heart Rate Calculation

[Physiotutors](#) • 3:43

https://www.youtube.com/watch?v=UzRZDDMoD_M

WHEN TO WATCH

After “Think it through,” before you calculate your own zone. Check his steps against the worked example in the lesson.

Note: A physiotherapy teaching channel. It uses $220 - \text{age}$ for maximum heart rate; the lesson also shows the $208 - 0.7 \times \text{age}$ formula. The description advertises the channel's course and app; they are not needed.

KEY TERMS

aerobic base

A foundation of endurance built by many weeks of steady, easy-to-moderate training, on which faster training can later be built.

stroke volume

The amount of blood the heart pumps with each beat. Endurance training increases it.

mitochondria

Structures inside cells where oxygen is used to release energy from fuel. Aerobic training increases their number in muscle.

capillaries

The tiniest blood vessels, where oxygen passes from the blood into the muscle. Endurance training adds more of them around each muscle fiber.

heart-rate reserve

Maximum heart rate minus resting heart rate: the range available for exercise.

Karvonen formula

Target heart rate = (maximum HR – resting HR) × percentage + resting HR. Published by the Finnish physician Martti Karvonen and colleagues in 1957.

CORE IDEAS

The story. Arthur Lydiard was born in Auckland, New Zealand, in 1917. In his late twenties, out of shape after a short run with a friend, he began running himself and experimenting with how to train. He tried enormous distances on himself and settled on a plan: months of steady running, about 100 miles (160 km) a week, including a long weekend run on a hilly course of about 35 km through the Waitākere Ranges near his home. He supported himself with a milk round and coached a group of local young men for free. At the 1960 Rome Olympics, which New Zealand's officials had not even sent him to (local supporters raised the money), Peter Snell won the 800 metres and Murray Halberg, whose left arm had been badly damaged in a rugby injury as a teenager, won the 5,000 metres, about an hour apart. Barry Magee took bronze in the marathon a few days later. In Tokyo in 1964, Snell won both the 800 and the 1,500 metres.

How they figured it out. Lydiard's system had phases: first a long **conditioning** period of steady aerobic running; then hill training for strength; then shorter, faster track work; then sharpening and rest before races. His great insight was that the speed work works best on top of a deep aerobic base, and that most of an endurance athlete's training should be easy. Modern studies of top endurance athletes find the same thing: roughly 80 percent of their training is done at low intensity. When the American coach Bill Bowerman visited New Zealand in 1962 and joined Lydiard's easy group runs for ordinary men and women, he brought the idea home and helped start the American jogging movement.

How your body works. Months of steady aerobic training change the body in ways that intervals alone cannot. The heart's left ventricle grows larger and fills more fully, so **stroke volume** rises; blood **plasma volume** increases; more **capillaries** grow around each muscle fiber; the muscles build more **mitochondria** and aerobic enzymes and become better at using fat as well as carbohydrate for fuel. Because each beat pumps more blood, the heart needs fewer beats at rest and at any given pace, so **resting heart rate falls**. Easy training also strengthens tendons and bones gradually and leaves energy for harder sessions. Hebrews 12:1 speaks of running “with patience the race that is set before us”; base training is patience made into a plan.

Think it through. To set an easy zone, first estimate maximum heart rate. A common formula is $220 - \text{age}$; a more accurate one for many people is $208 - 0.7 \times \text{age}$. For a 15-year-old: $208 - 0.7 \times 15 = 208 - 10.5 = 197.5 \approx 198$ bpm. Suppose the student's resting heart rate (averaged over three mornings) is 62 bpm. Heart-rate reserve = $198 - 62 = 136$ bpm. Easy aerobic zone at 60–70 percent: low end = $136 \times 0.60 + 62 = 81.6 + 62 \approx 144$ bpm; high end = $136 \times 0.70 + 62 = 95.2 + 62 \approx 157$ bpm. So the easy zone is about 144–157 bpm, and at that pace the student should still pass the talk test. Formulas are estimates; if the talk test and the heart rate disagree, slow down.

Try it. This week you will measure your resting heart rate, calculate your zone, and run (or run-walk) two easy sessions in it, checking your pulse and the talk test. Then you will plan a four-week base block that adds no more than about 10 percent a week.

PICTURE STUDY



Clarence DeMar in the Olympic Marathon at Pierrelaye, Agence Rol (French press agency), July 13, 1924 ·

Photograph · Bibliothèque nationale de France (Gallica)

Image: [Wikimedia Commons](#), public domain

Clarence DeMar of Massachusetts won the Boston Marathon seven times between 1911 and 1930, more than anyone else in its history, and took the bronze medal in the marathon at the 1924 Paris Olympics. A French press agency photographed him passing the refreshment station in the village of Pierrelaye during that race. A marathon is about 26.2 miles (42.2 km); like Lydiard's runners decades later, DeMar built his endurance through years of steady miles.

Look closely

- Look at the runner's posture: head, shoulders, arms and stride. Does he look relaxed or strained?
- Find the table by the road. This was a refreshment station. What might runners have been handed there, and why (think of Unit 2)?
- Find the soldiers, officials and townspeople. How can you tell this was an important event?
- Look at the road and at his clothing and shoes. How has running changed since 1924?

Talk about it

1. A marathoner must run for more than two hours. Which energy system supplies almost all of that energy?
2. Why would a marathon runner do most of his training at an easy, conversational pace?
3. What could you learn from a runner who kept competing at the highest level for nearly twenty years?

Safety first. Run on a safe route away from traffic with a buddy or a parent's knowledge, in daylight or with reflective clothing, and carry water on warm days. Increase total weekly running time by no more than about 10 percent a week, and run on softer surfaces when you can. Stop and tell an adult at chest pain, dizziness, unusual shortness of breath or sharp pain; shin, foot or knee pain that lasts after rest is a reason to rest and get it checked.

ACTIVITY

Find Your Zone: Two Easy Runs and a Base Block

You will find your easy aerobic zone with real numbers, run in it twice, and plan four weeks of base training, the same foundation Lydiard gave his champions, at the scale of a tenth grader.

You will need

- A timer and your pulse (or an optional heart-rate monitor)
- A safe route or loop of known length (a track, a measured loop around the block, a park path)
- Water, good running shoes, and a buddy or adult
- Fitness journal with a run log: date, route, time, distance, heart rate at 10, 20 and 30 minutes, talk test, how it felt

Steps

1. **Resting heart rate.** On three mornings this week, before getting out of bed, count your pulse for 60 seconds. Average the three.
2. **Calculate your zone** with the Karvonen formula at 60 and 70 percent, using $208 - 0.7 \times \text{age}$ for maximum heart rate. Write the calculation in your journal.
3. **Easy run 1 (Session 2).** Warm up, then run or run-walk for 25 minutes at a pace where you can talk in full sentences. Every 10 minutes, stop briefly and count your pulse for 15 seconds ($\times 4$). If you are above your zone, slow down or walk until you are back in it.
4. **Record** distance (laps or route length), time, heart rates, talk test and how it felt. Cool down with 5 minutes of walking and the static stretches from Lesson 1.2.
5. **Easy run 2 (Session 3).** Repeat the same route for 30 minutes, staying in the zone. Compare: at the same heart rate, did you cover the same distance, or a little more?
6. **Plan a four-week base block.** Three or four easy sessions a week. Week 1: total minutes equal to your current week. Weeks 2 and 3: add no more than about 10 percent each. Week 4: drop back about 20 percent to recover. Keep

one session a little longer than the others, as Lydiard's runners did on Sundays, and schedule rest days.

7. Add strength. Fit your two strength workouts from Unit 4 on non-running days or after easy runs, never before a hard session.

Tips

- Easy should feel easy. Many beginners run their easy days too fast and their hard days too slow.
- If running continuously is too hard, run 4 minutes and walk 1 minute; aerobic fitness builds either way.
- Over weeks, watch your resting heart rate and your heart rate on the same route. Falling numbers mean your aerobic base is growing.

Check your work

- ☐ I can tell Lydiard's story and explain why a base of easy running works.
- ☐ I calculated my easy zone with the Karvonen formula and ran twice in it.
- ☐ I planned a four-week base block that increases gradually and includes recovery.

FITNESS JOURNAL

1. Show your resting heart rate average and your full Karvonen calculation.
2. Copy your run log for both runs. Graph heart rate at 10, 20 and 30 minutes for each run.
3. Draw a muscle fiber before and after months of base training, showing more capillaries and mitochondria. Label stroke volume and resting heart rate changes in a note.
4. Write out your four-week base block as a table of days and minutes, with the weekly totals and percentage changes.

From history. Lydiard later coached national teams in Mexico, Denmark and Finland, where his methods helped Lasse Virén win the 5,000 and 10,000 metres at both the 1972 and 1976 Olympics. His book *Run to the Top*, written with the journalist Garth Gilmour, first appeared in 1962.

COMMON MISTAKES

- Running every run hard. Most endurance training should be easy; save hard efforts for planned sessions.

- Increasing weekly distance too fast, which leads to shin splints and other overuse injuries.
- Trusting a formula over your body. Use the talk test along with heart rate.
- Skipping the long, easy run. It builds the base more than any single hard workout.

Make it a game • Base Building Challenge. Compute your heart-rate reserve with the Karvonen formula and set your easy zone. Run or walk twenty minutes keeping your pulse within it, checking every five minutes. Your parent records the checks. Tell Arthur Lydiard's story. Then name three adaptations from aerobic training. Match your pace with less effort next week.

Scripture. “let us run with patience the race that is set before us” (Hebrews 12:1, KJV)

An aerobic base is built by patient, faithful miles, not by one great effort. The Christian life is described the same way: a long race run with endurance.

5.2 HIGH-INTENSITY INTERVALS: THE TABATA STUDY AND THE FAMILY FITNESS DAY

OBJECTIVES

- Describe the 1996 Tabata study accurately: who was tested, the two training programs, and the results.
- Explain how very short, very hard intervals stress both the anaerobic and aerobic energy systems, and why they must be used sparingly.
- Complete a safe interval session at a controlled effort and calculate one-minute heart-rate recovery.
- Plan and lead a family fitness day that brings together all five units.

Warm-up. Interval warm-up (8 minutes): 3 minutes of easy jogging; 10 leg swings each way per leg; 10 walking lunges; 10 A-skips; 3 strides of about 15 seconds at a smooth, fast pace with full walking recovery. Think about it: how is your breathing different during a 15-second stride than during an easy jog?

WATCH

TABATA Training Message from Professor Izumi Tabata

Ritsumeikan Channel • 1:54

<https://www.youtube.com/watch?v=R6diyOp1TAo>

WHEN TO WATCH

After the story, to hear Professor Tabata himself describe his training and see students do a bodyweight version.

Note: A short university video in which Izumi Tabata explains his protocol; students show a bodyweight version.

BACKUP VIDEO

The Benefits of High Intensity Training

ABC Science • 7:24

<https://www.youtube.com/watch?v=Dfk4sZjgSw0>

Optional, after “How they figured it out,” to see how scientists measure oxygen use in a sports lab.

KEY TERMS

high-intensity interval training (HIIT)

Training that alternates short periods of very hard effort with periods of rest or easy movement.

anaerobic capacity

The total energy the body can produce without enough oxygen in a short, all-out effort; Tabata measured it as the maximal accumulated oxygen deficit.

heart-rate recovery

How much the heart rate falls in the first minute after hard exercise stops. It tends to improve as fitness improves.

VO₂ max

The maximum rate at which the body can take in and use oxygen, measured in milliliters of oxygen per kilogram of body weight per minute (mL/kg/min).

rating of perceived exertion (RPE)

A 1–10 scale of how hard an effort feels: 1 is resting, 10 is all-out.

CORE IDEAS

The story. Koichi Irisawa, head coach of Japan's national speed-skating team, used a brutal workout with his skaters: about eight rounds of 20 seconds of all-out effort on an exercise bike with 10 seconds of rest between. A young scientist at Japan's National Institute of Fitness and Sports, Izumi Tabata, set out to measure what it actually did. In 1996 he and his colleagues published the results in the journal *Medicine & Science in Sports & Exercise*.

How they figured it out. The study compared two groups of young, active men over six weeks. One group cycled for 60 minutes at a moderate intensity (70 percent of VO₂ max), five days a week. The other group, on four days a week, did seven or eight 20-second bouts at about 170 percent of the power that matched their VO₂ max, with 10 seconds of rest, until they could not keep the pace; on the fifth day they rode 30 minutes moderately and then did four bouts. The scientists measured each man's VO₂ max and his anaerobic capacity before and after. Results: the moderate group's VO₂ max rose by about 5 mL/kg/min, but their anaerobic capacity did not change. The interval group's VO₂ max rose by about 7 mL/kg/min, and their anaerobic capacity rose by 28 percent, all from about four minutes of hard work per session.

How your body works. In a 20-second all-out effort, the muscles need energy faster than oxygen can arrive. They draw first on the phosphagen system, a small store of high-energy phosphate in the muscle, and then on anaerobic glycolysis, which breaks down glucose quickly and produces lactate and hydrogen ions that make muscles burn and slow down. Repeating those efforts with tiny rests drives the heart and oxygen uptake close to their maximum, so both the anaerobic and the aerobic systems are trained. But such work is extremely stressful. The original protocol was so hard that trained subjects were exhausted after seven or eight bouts. Many workouts sold as “Tabata” today are far easier than the real thing. Intervals are a powerful tool, used once or twice a week at most, on top of an aerobic base, never every day.

Think it through. *Work time.* Eight bouts $\times$ 20 seconds = 160 seconds = 2 minutes 40 seconds of hard work in a 4-minute set. Compare weekly training time: the moderate group rode $60 \times 5 = 300$ minutes a week; the interval group’s hard work was roughly $2.5 \text{ minutes} \times 5 \text{ days} \approx 13 \text{ minutes}$, plus warm-ups and one 30-minute ride. Short intervals are time-efficient, but they are not easy and they do not replace the base. *Heart-rate recovery.* If your heart rate is 186 bpm at the end of an interval set and 152 bpm one minute later, your recovery is $186 - 152 = 34 \text{ bpm}$. Track it over weeks; a larger drop usually means improving fitness.

Try it. In Session 2 you will do a controlled interval session based on the 20-and-10 pattern, at a hard but not all-out effort, and measure your heart-rate recovery. In Session 3 you will run hill or shuttle repeats. Then you will plan and lead the family fitness day.

PICTURE STUDY



The Hunters in the Snow, Pieter Bruegel the Elder, 1565 · Oil on wood panel · Kunsthistorisches Museum, Vienna

Image: [Wikimedia Commons](#), public domain

Pieter Bruegel painted this winter scene as one of a series of pictures of the seasons. Tired hunters return through the snow with very little to show for their day, while down below the whole village has turned the frozen ponds into a playground. It is one of the most famous pictures of winter ever painted, and it shows skating, the sport in which the Tabata workout began.

Look closely

- Find the hunters and their dogs. How do their bodies show that they have walked a long way through deep snow?
- Look down at the frozen ponds. Count the skaters. Find someone who has fallen, someone pulling a sled, and a game being played with sticks.
- Find the fire outside the inn on the left. What are the people there doing?
- Look for the birds, the mill wheel frozen in the stream and the far mountains. What is the weather like?

Talk about it

1. The hunters' long, slow walk and a skater's short, fast sprint use different energy systems. Which is mostly aerobic, and which is anaerobic?

2. Why might skaters, who race in short, intense bursts, need both a deep aerobic base and hard intervals?
3. This village found ways to play together even in the hardest season. How could your family keep moving together in winter?

Safety first. Do intervals only after a full warm-up, only if you have been training aerobically for several weeks, and no more than once or twice a week; a doctor's clearance matters especially here. Work hard but controlled (about 8 out of 10), not all-out, on a flat non-slip surface or a gentle grassy hill, and walk to cool down afterward rather than stopping suddenly. Stop at once and tell an adult at chest pain, dizziness, faintness, unusual breathlessness or nausea that does not pass quickly.

ACTIVITY

A Safe Interval Session, Hill Repeats and the Family Fitness Day

You will feel what interval training does, at a safe effort, and measure your heart-rate recovery. Then you will plan and lead a family fitness day that brings together everything from the quarter.

You will need

- A timer that can count 20 and 10 seconds (many free interval-timer apps work), and your pulse or a heart-rate monitor
- A flat, non-slip surface, a gentle grassy hill or a flat area for 30-yard shuttles
- Water, and for the family day: stations, a water table, a protein-rich meal you cook, and a route for a walk-run
- Fitness journal with an interval log: date, workout, effort (RPE) each round, heart rate at end, heart rate 1 minute later, recovery

Steps

1. **Warm up** fully with the interval warm-up (8 minutes).
2. **The 20-and-10 set (Session 2).** Eight rounds of 20 seconds of work and 10 seconds of rest, rotating four moves: (1) high-knee running in place, (2) bodyweight squats, (3) fast step-ups on a low, sturdy step, (4) mountain climbers. Aim for a hard but controlled effort of about 8 out of 10 with good form; you should be able to finish all eight rounds.
3. **Measure recovery.** The moment the set ends, count your pulse for 15 seconds ($\times 4$). Walk slowly, and at exactly one minute count again. Recovery = end HR – 1-minute HR. Record both and your RPE.
4. Walk easily for 4 minutes. If you feel well, do a second set, then measure recovery again. Cool down with 5 minutes of walking and stretching.
5. **Hill or shuttle repeats (Session 3).** After the warm-up, do 6 repeats of 30 seconds of strong running up a gentle grassy hill (or 30-yard shuttles), walking back down (or walking 90 seconds) between. Effort about 8 out of 10. Record each repeat's effort and your heart-rate recovery after the last one. Compare with Session 2.

6. **Plan the family fitness day.** Choose a date in the last week and plan 60–90 minutes: (1) you lead a dynamic warm-up (Lesson 1.2); (2) five stations, one from each unit: a mobility test, a water-and-sweat display, a protein-snack table, a movement-pattern station with body weight or light jugs, and a jump-rope or step interval station; (3) a family walk-run or relay where everyone goes at his or her own pace; (4) a cool-down; (5) a meal you cook.
7. **Lead it.** Explain each station in one or two sentences, keep everyone safe (water, shade, good shoes, no one pushed past what is comfortable), and record who did what and how it went.
8. **Reflect.** Write what you learned about leading others, and present your fitness journal from the quarter to your family.

Tips

- On the 20-and-10 set, it is better to start a little easier and finish strong than to sprint the first round and fade.
- Real all-out Tabata intervals are done on a stationary bike in a lab with trained adults. Your version keeps the pattern and the benefits at a safe effort.
- On the family day, praise effort, not speed. Make sure the youngest and oldest have something they can enjoy.

Check your work

- ☐ I can describe the Tabata study accurately and explain what intervals improve.
- ☐ I completed a controlled interval session and hill repeats and calculated my heart-rate recovery.
- ☐ I planned and led a family fitness day that included all five units.

FITNESS JOURNAL

1. Copy your interval log for both sessions, with RPE for each round and your heart-rate recovery calculations.
2. Draw a bar chart comparing the two groups in the Tabata study: change in VO_2 max and change in anaerobic capacity.
3. Draw a timeline of a 20-and-10 set and label which energy systems are working hardest early and late in the set.

4. Write your family fitness day plan and, afterward, a paragraph about how it went and what you would change.

From history. Tabata later became a professor at Ritsumeikan University in Japan.

The protocol became world-famous in the 2000s, often in much easier forms than the original. His study is a reminder to read what a study actually tested before believing what is said about it.

COMMON MISTAKES

- Doing hard intervals every day. They require recovery and work best once or twice a week on top of a base.
- Calling any 4-minute workout “Tabata.” The original protocol was all-out cycling at about 170 percent of the VO₂ max power.
- Skipping the warm-up before hard efforts, which raises the risk of strains.
- Stopping suddenly after a hard set. Walk to let the heart rate come down gradually.

Make it a game · Tabata Truth Check. Your parent reads claims about HIIT from a hypothetical article; you check them against the 1996 Tabata study: who was tested, what the programs were, what changed. Then do a safe short interval session of four rounds with generous rest. Rate perceived exertion each round. Win by finding exaggeration.

AEROBIC TRAINING

In the 1950s an Auckland milk-round worker named Arthur Lydiard began coaching a handful of young men from his neighborhood. He had them run about 100 miles (160 kilometres) a week at a steady, conversational pace, including a long Sunday run over the hills of the Waitākere Ranges. On one afternoon at the 1960 Rome Olympics, two of them, Peter Snell and Murray Halberg, won gold medals about an hour apart. In this unit you will learn why that patient aerobic base works: what happens to the heart, blood, muscles and mitochondria with steady training, and how to set an easy-training zone with the Karvonen formula.

Then you will study the opposite tool: short, very hard intervals. In 1996 Izumi Tabata and his colleagues in Japan published a study of a speed-skating workout of 20 seconds of all-out cycling and 10 seconds of rest, repeated about eight times, and compared it with an hour of moderate cycling. You will learn what each kind of training does, run a safe interval session, measure your heart-rate recovery, and finish the quarter with a family fitness day.

PREREQUISITES

- Can find a pulse and calculate beats per minute (earlier grades)
- Knows the heart and lungs deliver oxygen to working muscles, and the difference between aerobic and anaerobic energy
- Has done the conductor's workout (Lesson 1.1) and knows the talk test

MASTERY CHECKLIST

- ☐ I can tell how Arthur Lydiard built his runners' aerobic base and what they achieved.
- ☐ I can explain the main aerobic adaptations: stroke volume, plasma volume, capillaries, mitochondria and resting heart rate.
- ☐ I can calculate an easy-training heart-rate zone with the Karvonen formula and run in it.
- ☐ I can describe the 1996 Tabata study accurately and explain what high-intensity intervals improve.
- ☐ I can complete a safe interval session, measure heart-rate recovery, and plan a balanced four-week aerobic block.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A jump rope:** Optional, for warm-ups and an interval station on the family fitness day.
- **A heart-rate monitor or sports watch:** Optional. A 15-second pulse count at the wrist or neck works for every activity in this unit.

Not required. Every activity in this unit works without them. School Launch has no ties to these authors, publishers or companies.

LESSONS IN THIS UNIT

5.1 Arthur Lydiard and the Aerobic Base

3 sessions of 45–50 minutes

5.2 High-Intensity Intervals: The Tabata Study and the Family Fitness Day

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question in complete sentences, and show every step of each calculation with units. The review is worth 100 points.

1. **8 pts**

Describe Arthur Lydiard's training approach and what his athletes achieved at the 1960 and 1964 Olympics.

2. **10 pts**

Name four changes in the body caused by months of aerobic base training and explain why resting heart rate falls.

3. **12 pts**

Calculation. A 16-year-old has a resting heart rate of 58 bpm. Using $HR_{max} = 208 - 0.7 \times \text{age}$, find HR_{max} , heart-rate reserve, and the easy zone at 60–70 percent with the Karvonen formula.

4. (8 pts)

Calculation. A runner's weekly running is 90 minutes. Using the 10 percent guideline, what is the most for each of the next two weeks? What would a recovery week at 20 percent less than week 3 be?

5. (10 pts)

Describe the 1996 Tabata study: the two training programs and the results for VO₂ max and anaerobic capacity.

6. (8 pts)

Explain where the energy comes from in a 20-second all-out effort, and why repeated short bouts also train the aerobic system.

7. (8 pts)

Calculation. Find the total hard-work time in one 8-round 20-and-10 set, and compare the weekly time of the moderate group ($60 \text{ min} \times 5 \text{ days}$) with roughly $2.7 \text{ minutes of hard work} \times 5 \text{ days}$.

8. (8 pts)

Calculation. After an interval set your heart rate is 184 bpm; one minute later it is 146 bpm. Three weeks later the numbers are 182 and 138. Find both recoveries and the change.

9. (8 pts)

Give three safety rules for high-intensity interval training for teenagers.

10. (20 pts)

Short written answer. A friend says, "Tabata proved that four minutes of intervals is all the exercise anyone needs." Write a paragraph correcting this claim using what the study actually tested, Lydiard's approach, and the physical activity guidelines.

ANSWER KEY

1. Months of steady aerobic running, about 100 miles (160 km) a week including a long hilly weekend run, followed by hill training, faster track work and sharpening. In 1960 Peter Snell won the 800 m and Murray Halberg the 5,000 m about an hour apart, and Barry Magee won marathon bronze; in 1964 Snell won the 800 m and 1,500 m.
2. Any four: larger left ventricle and higher stroke volume; increased plasma volume; more capillaries around muscle fibers; more mitochondria and aerobic enzymes; better use of fat for fuel; stronger tendons and bones. Because each beat pumps more blood, the heart needs fewer beats per minute at rest to deliver the same blood, so resting heart rate falls.
3. $\text{HR}_{\text{max}} = 208 - 0.7 \times 16 = 208 - 11.2 = 196.8 \approx 197 \text{ bpm}$. $\text{HRR} = 197 - 58 = 139 \text{ bpm}$.
60%: $139 \times 0.60 + 58 = 83.4 + 58 \approx 141 \text{ bpm}$. 70%: $139 \times 0.70 + 58 = 97.3 + 58 \approx 155 \text{ bpm}$. Easy zone $\approx 141\text{--}155 \text{ bpm}$.
4. Week 2: $90 \times 1.10 = 99$ minutes. Week 3: $99 \times 1.10 = 108.9 \approx 109$ minutes. Recovery week: $109 \times 0.80 \approx 87$ minutes.
5. Over six weeks, a moderate group cycled 60 minutes at 70% of VO_2 max five days a week; an interval group did 7–8 bouts of 20 seconds at about 170% of VO_2 max power with 10 seconds of rest, four days a week, plus one day of 30 minutes moderate riding and four bouts. Moderate group: VO_2 max up about 5 mL/kg/min, anaerobic capacity unchanged. Interval group: VO_2 max up about 7 mL/kg/min and anaerobic capacity up 28%.
6. Energy comes first from the phosphagen system (a small store of high-energy phosphate in the muscle), then from anaerobic glycolysis, which breaks down glucose quickly and produces lactate and hydrogen ions. Repeating the bouts with very short rests drives heart rate and oxygen uptake close to maximum, so the aerobic system is also pushed hard.
7. $8 \times 20 \text{ s} = 160 \text{ s} = 2 \text{ min } 40 \text{ s}$. Moderate group: 300 minutes a week. Interval group hard work: about $2.7 \times 5 \approx 13.5$ minutes a week (plus warm-ups and one 30-minute ride).
8. First: $184 - 146 = 38 \text{ bpm}$. Later: $182 - 138 = 44 \text{ bpm}$. Improvement = 6 bpm, a sign of improving fitness.
9. Any three: build an aerobic base for several weeks first; get a doctor's clearance; warm up fully; limit hard intervals to once or twice a week; work hard but controlled rather than all-out; use safe surfaces; cool down by walking; stop at chest pain, dizziness, faintness or unusual breathlessness.

10. Answers vary. A full answer explains that the study tested young, trained men on a lab bike at about 170% of VO₂ max power, five days a week for six weeks, including a weekly moderate ride; that the intervals were exhausting and far harder than most “Tabata” workouts; that the interval group improved VO₂ max and anaerobic capacity, but intervals are a tool used sparingly on top of an aerobic base, as Lydiard showed with his champions; and that teenagers still need at least 60 minutes of activity daily with strength and bone-strengthening work, so four minutes is not enough.

UNIT CHALLENGE: MY FOUR-WEEK AEROBIC TRAINING BLOCK

Carry out a four-week aerobic block: three or four sessions a week, mostly easy runs in your Karvonen zone, one longer easy run each week, and one interval or hill session in Weeks 2 and 3, with a lighter Week 4 and your Unit 4 strength workouts on other days. Record every session, measure your resting heart rate weekly and repeat the same easy route at the same heart rate in Week 1 and Week 4. Graph your weekly minutes, resting heart rate and the route time, and write a report that ends with how the family fitness day went.

LOOK FOR	WHAT IT MEANS
Balanced, safe plan	Mostly easy training, no more than about 10 percent increase a week, a recovery week, intervals limited to once a week, rest days.
Complete records	Every session dated with time, distance or route, heart rates and RPE; weekly resting heart rate.
Calculations and graphs	Karvonen zone, weekly totals and percentage changes, and heart-rate recovery calculated correctly and graphed.
Leadership and reflection	A family fitness day planned and led, and a thoughtful report. Faithful effort and improvement count, not speed.