

GRADE 9 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 five strands of health and fitness through one quarter of the ninth-grade year: keeping active, fluid balance, food energy, strength and the heart and lungs. Each lesson is built around a real study or moment: Hans Kraus's fitness tests that alarmed President Eisenhower, the Cooper Institute's FitnessGram, Ernest Verney's search for the body's water sensor, Korey Stringer's death from heat stroke in 2001 and the institute that now saves lives in his name, Antoine Lavoisier measuring the heat of breathing, Nicolas Appert's sealed bottles, the two 1954 papers that explained how muscle contracts, Thomas DeLorme's work with wounded soldiers, Adolf Fick's equation and Martti Karvonen's heart-rate study.

Every lesson follows the same path. First comes **the story**. Then **how they figured it out**: the question, the experiment and the measurement. Then **how your body works**, at a high-school level: energy systems, nephrons and antidiuretic hormone, actin and myosin, cardiac output and VO₂ max, with worked numbers. Last, **try it**: the student tests, logs, cooks, lifts or runs, records it in a fitness journal and tries to improve the second time.

God made the body good, and He gave it to us to steward. This course is about strength, endurance, wise habits and joy in movement, 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," describes training exactly: strength and fitness are built set by set and week by week. The quarter ends with a family fitness day that the student plans and leads.

Most videos come from trusted teaching and medical sources: TED-Ed, the Amoeba Sisters, Mayo Clinic, the Cooper Institute (which publishes FitnessGram), the Sports Institute at UW Medicine, KQED's Jacques Pépin series, and physiology teachers such as Armando Hasudungan and Mr Exham. A few come from smaller physical-

education and physiotherapy channels chosen because they teach the lesson's exact idea; the lesson notes say so. Every video was previewed for accuracy and modest dress. Some channels end with an invitation to subscribe or join a course; stop the video when the teaching ends.

Start with Lesson 1.1 →

WHO IT IS FOR

Written for students in grade 9 (about ages 14–15) who can work with formulas, percentages and unit conversions and can keep careful records. A parent or other knowledgeable adult supervises activities, is present for every session with free weights, and helps in the kitchen. Nothing needs to be bought: every activity works with household things such as a towel, a sturdy chair, a step, water jugs, a backpack with books, a broom handle, measuring cups and a timer. Light dumbbells 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. Session 2 is the activity (the test, the workout, the lab or the 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 the unit challenge. On the other days, aim for at least 60 minutes of activity in sport, chores, play and walking.
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 student who has a sports physical can use this course alongside team practice; do not double up on hard sessions.
3. **Story, then science, then doing.** The core ideas are written for the student to read. The paragraphs marked *The story* and *How they figured it out* tell what happened; *How your body works* explains the physiology; *Try it* explains the activity. Work every number in the core ideas with a pencil and calculator, and ask the student to explain each formula aloud in plain words.

4. **Picture study.** Each lesson has one public-domain painting or historic photograph chosen for what it shows about play, work, food, water or rest. Look at it quietly for two minutes, put it away and describe it from memory, then work through the “look for” items and questions.
5. **The fitness journal.** Use one notebook for the quarter. Every activity is done, recorded and done again: laps, reps, loads, seconds, cups and milliliters, heart rates and calculations. Date every page, show your working, 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. Calories appear only as a unit of food energy for growth and sport, never as something to restrict or count. Foods are “nutrient-dense foods” and “treat foods,” never good or bad, and feasts and treats are gifts in their place. No supplements, protein powders or energy drinks are used or needed. Grades come from effort, consistency and personal improvement.
7. **Strength training rules.** Strength work uses body weight, household loads and, if the family has them, light dumbbells. Free weights are used **only with a knowledgeable adult present**, with a spotter for any pressing lift. Technique comes first, with a broom handle or very light load. We never test a one-repetition maximum; strength is estimated from a set of 8–10 good reps instead.
8. **Optional books and gear.** Some units list a free government, university or children’s-hospital page, or simple gear such as a stopwatch or a light pair of dumbbells. 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 log and baseline report, a fluid log and heat-emergency plan, a home-cooked whole-food dinner, a strength program, 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. Use a clear space with a flat, non-slip floor and 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. Train outdoors with a buddy, away from traffic, and avoid the hottest part of the day. A parent supervises knives

and the stove and checks for food allergies. 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 warm-up, stations from every unit at each person's own pace, a water table, a whole-food snack the student prepares, and a family walk or run.

SCOPE AND SEQUENCE

UNIT 1 • WEEKS 1–2

Keeping Active

The Kraus–Weber tests, President Eisenhower's council and the 2018 *Physical Activity Guidelines*: the evidence behind 60 minutes a day and why the teen years build bone for life; and a FitnessGram-style baseline (PACER, push-ups, curl-ups, sit-and-reach) compared only with yourself.

1.1 Sixty Minutes and Strong Bones: The Physical Activity Guidelines

1.2 Your Fitness Baseline: FitnessGram and the PACER

UNIT 3 • WEEKS 5–6

Nutrition

Lavoisier's ice calorimeter, food energy, ATP and the energy systems, always as fuel for growth and sport; and Nicolas Appert, Clarence Birdseye, the processing spectrum and cooking a whole-food meal.

3.1 Energy and Metabolism: Lavoisier's Ice Calorimeter

3.2 Whole and Processed Foods: Appert's Bottles and a Home-Cooked Meal

UNIT 2 • WEEKS 3–4

Hydration

Fluid balance, the nephron and antidiuretic hormone, from Claude Bernard to Ernest Verney's osmoreceptors, with a fluid log and the danger of drinking far too much; and exertional heat illness, Korey Stringer and "cool first, transport second."

2.1 Fluid Balance: The Kidneys and the Body's Water Sensor

2.2 Exertional Heat Illness: Cool First, Transport Second

UNIT 4 • WEEKS 7–8

Strength

The 1954 sliding-filament papers of Huxley and Niedergerke and Huxley and Hanson, motor units and how strength grows; and Thomas DeLorme's progressive resistance exercise, sets, reps, rest and a four-week program with light loads.

4.1 How a Muscle Contracts: The Sliding-Filament Discovery of 1954

4.2 Program Design: DeLorme's Three Sets of Ten

UNIT 5 • WEEKS 9–10

Aerobic Training

Adolf Fick's equation, cardiac output and VO_2 max with the Cooper 12-minute run; and Martti Karvonen's 1957 study, heart-rate reserve and training zones, a four-week aerobic block and the family fitness day.

5.1 The Cardiorespiratory System: Fick's Equation and VO_2 Max

5.2 Heart-Rate Zones and the Karvonen Formula

WEEKLY PACING CALENDAR

WEEK	PLAN
1	• Session 1: Lesson 1.1 Sixty Minutes and Strong Bones: The Physical Activity Guidelines: 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>
2	• Session 1: Lesson 1.2 Your Fitness Baseline: FitnessGram and the PACER: 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 Fluid Balance: The Kidneys and the Body's Water Sensor: 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

WEEK	PLAN
4	• Session 1: Lesson 2.2 Exertional Heat Illness: Cool First, Transport Second: 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 Energy and Metabolism: Lavoisier's Ice Calorimeter: 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 Whole and Processed Foods: Appert's Bottles and a Home-Cooked Meal: 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 How a Muscle Contracts: The Sliding-Filament Discovery of 1954: 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 Program Design: DeLorme's Three Sets of Ten: 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
9	• Session 1: Lesson 5.1 The Cardiorespiratory System: Fick's Equation and VO_2 Max: 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 Heart-Rate Zones and the Karvonen Formula: 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

MATERIALS

Fitness journal (any notebook) and a calculator

One notebook for the quarter: logs, test scores, calculations, training tables and reflections.

A timer or stopwatch (a phone timer works)

For the PACER and push-up cadences, rest periods, pulse counts and the 12-minute run.

Good athletic shoes and comfortable, modest clothes for exercise

Every activity lesson.

A towel or mat, a sturdy chair or bench that will not slide, a wall, a step and a broom handle

For push-ups, curl-ups, step work, rows and technique practice.

Household loads: two water or milk jugs (a full gallon jug weighs about 8.3 pounds), a backpack with books

For the strength program in Unit 4. Light dumbbells may be used if the family has them.

A tape measure, sidewalk chalk or cones (cups or shoes work), and a ruler or yardstick

To mark a 20-meter PACER course, a measured running loop and the sit-and-reach.

A measuring cup, a reusable water bottle and a kitchen thermometer

For the fluid log and the cooling lab in Unit 2, and for cooking safely in Unit 3.

Whole-food ingredients for one family dinner, a cutting board and a sharp chef's knife

For the cooking lesson in Unit 3, with a parent supervising.

Graph paper and colored pencils

For graphs of fluid intake, heart rate, training load and test results.

GRADING

Grades come mostly from the activities and the fitness journal, because fitness is learned by doing, recording and doing again. A student who trains faithfully, keeps honest records, shows his or her working and improves on his or her own numbers earns full credit, whatever those numbers are.

PART	%
Activities (effort, participation, good form and safe practice)	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: repeat the activity or review with help.

- Fitness marks reward effort, consistency and improvement against the student's own earlier numbers. They never depend on body size, body measurements or comparison with other students. FitnessGram-style scores are used only as a personal baseline.
- A journal page earns full marks when it has a date, numbers with units, any calculation shown step by step, a sentence about how it felt and a sentence about what to change next time.
- Unit reviews may be done orally for a student who writes slowly; the parent writes down the answers. Calculations must show the working.
- 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 lesson, work the numbers with your student, and then be the timer, the spotter and the encourager. For every session with free weights, an adult who knows the movements must be in the room, and a spotter must stand ready for any pressing lift. If you are unsure of a movement, use the bodyweight or household-load version and the form videos until you are confident.

Keep the talk about bodies on what they can do and how to care for them. Ninth graders compare themselves with one another constantly; steer back to the journal: “Did you beat your own number from last month?” Praise good form, faithful training 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.

Two lessons mention deaths plainly, as the history requires: Korey Stringer, the professional football player who died of exertional heat stroke in 2001 (Lesson 2.2), and Antoine Lavoisier, executed during the Reign of Terror in France in 1794 (Lesson 3.1). Both are told briefly, with the focus on what was learned. Lesson 2.2 teaches how to recognize heat stroke and why rapid cooling saves lives; please read it together.

UNIT 1

KEEPING ACTIVE

How much activity does a growing person really need, and how do we know? In the early 1950s a doctor named Hans Kraus tested thousands of children in the United States and Europe and found the American children far weaker and stiffer. The results reached President Eisenhower, who founded the President's Council on Youth Fitness in 1956. Today the answer comes from decades of research gathered in the U.S. *Physical Activity Guidelines for Americans* (second edition, 2018): at least 60 minutes a day, with vigorous, muscle-strengthening and bone-strengthening activity on at least three days a week. You will learn why your teen years are the best years of your life for building bone, and audit your own week.

Then you will set your **fitness baseline** the way millions of American students do, with the FitnessGram tests developed by the Cooper Institute in 1982: the PACER shuttle run, the 90-degree push-up, the curl-up, the back-saver sit-and-reach and the trunk lift. Your scores are a starting point for you alone, compared with health standards and with your own retest later, never with anyone else.

PREREQUISITES

- Can work with percentages, averages and unit conversions (meters, kilometers, minutes and seconds)
- Can take a pulse at the wrist or neck and count for 15 seconds
- Has a doctor's go-ahead if any health condition applies, and a parent who knows about the course

MASTERY CHECKLIST

- ☐ I can state the 2018 activity guidelines for ages 6–17 and explain the difference between moderate and vigorous activity.
- ☐ I can explain why the teen years matter so much for bone, and name bone-strengthening activities.
- ☐ I can tell the story of the Kraus–Weber tests and the President's Council on Youth Fitness.
- ☐ I can run the FitnessGram-style tests with correct technique and cadence and record a personal baseline.
- ☐ I can explain the difference between a criterion standard and a comparison with other people, and set goals against my own numbers.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- ***Physical Activity Guidelines for Americans, 2nd edition* (U.S. Department of Health and Human Services)**: Free. The full guidelines and summaries; chapter 3 covers children and adolescents. Use with Lesson 1.1.
- **A tape measure and sidewalk chalk or cones**: To mark the 20-meter PACER course and the sit-and-reach in Lesson 1.2. Cups or shoes work as cones.

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 Sixty Minutes and Strong Bones: The Physical Activity Guidelines

3 sessions of 45–50 minutes

1.2 Your Fitness Baseline: FitnessGram and the PACER

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

State the 2018 *Physical Activity Guidelines* for ages 6–17, including the three kinds of activity that should happen on at least three days a week.

2. 10 pts

Describe the talk test. Classify each as light, moderate or vigorous: a slow stroll, brisk walking, a hard game of soccer, easy cycling on flat ground, running up a hill.

3. 10 pts

Calculation. A student logs these moderate-to-vigorous minutes for a week: 35, 80, 50, 60, 25, 90, 75. Find the total and the daily average (to the nearest minute). On how many days did the student meet the guideline? What should the student change?

4. 10 pts

Tell the story of the Kraus–Weber tests and what came of them.

5. 10 pts

Explain Wolff’s law and use it to explain why jumping rope builds bone better than swimming.

6. 10 pts

Why are the teen years called a once-in-a-lifetime window for bone? Give two facts and two things a teen can do.

7. 10 pts

What does “criterion-referenced” mean in FitnessGram, and how is it different from a percentile ranking?

8. **10 pts**

Calculation. PACER level 1 runs at 8.5 km/h. (a) Convert this speed to meters per second. (b) How long does one 20-meter lap take at this speed? (c) A student completes 42 laps. How many meters did he run?

9. **10 pts**

Name the five FitnessGram-style tests from this unit and the part of fitness each measures. Give one form rule for the push-up and one for the curl-up.

10. **10 pts**

Short written answer. In a paragraph, explain how 1 Timothy 4:8 shapes the way a Christian student should think about a fitness test score.

ANSWER KEY

1. Do 60 minutes or more of moderate-to-vigorous physical activity every day, mostly aerobic. As part of that 60 minutes, include vigorous-intensity activity on at least 3 days a week, muscle-strengthening activity on at least 3 days and bone-strengthening activity on at least 3 days.
2. In moderate activity you can talk but not sing; in vigorous activity you can say only a few words without pausing for breath; in light activity you can sing. Slow stroll: light. Brisk walking: moderate. Hard soccer: vigorous. Easy flat cycling: moderate. Running uphill: vigorous.
3. Total = $35 + 80 + 50 + 60 + 25 + 90 + 75 = 415$ minutes. Average = $415 \div 7 \approx 59$ minutes a day. The guideline (60 or more) was met on 4 days (80, 60, 90, 75). The student should raise the low days (35, 50, 25), for example with a brisk walk or a game, because the guideline is every day.
4. In the early 1950s Hans Kraus and Sonja Weber gave six simple strength and flexibility tests to thousands of children in the United States and in Austria, Italy and Switzerland. Published in 1953, the results showed more than half of the American children failed at least one test, compared with fewer than one in ten European children. Kraus blamed less walking and play in daily life. The results reached President Eisenhower, who founded the President's Council on Youth Fitness in 1956.
5. Wolff's law says bone adapts to the loads placed on it: when bone is strained, bone cells signal the body to add mineral there, making it stronger. Jumping rope creates repeated impact forces that strain the leg and hip bones; swimming is supported by water and puts little load on the bones, so it is good for the heart but builds little bone.
6. Up to 90 percent of peak bone mass is built by about age 18 in girls and 20 in boys, and roughly a quarter of adult bone mineral is laid down in about two years around the growth spurt. After the twenties, bone mass slowly declines. A teen can do bone-strengthening activity (running, jumping, hopping) at least 3 days a week and eat enough food with calcium, vitamin D and protein (milk, yogurt, cheese, leafy greens, fish, eggs).
7. A criterion-referenced standard links a score to good health: the student either reaches the Healthy Fitness Zone or has a goal to work toward. A percentile ranking compares the student with other students of the same age (for example, faster than 85 percent). FitnessGram uses health standards, not rankings; in this course we compare only with our own earlier scores.

8. (a) $8.5 \text{ km/h} = 8,500 \text{ m} \div 3,600 \text{ s} \approx 2.36 \text{ m/s}$. (b) $20 \text{ m} \div 2.36 \text{ m/s} \approx 8.5 \text{ seconds}$. (c) $42 \text{ laps} \times 20 \text{ m} = 840 \text{ meters}$.
9. PACER (or one-mile run): cardiorespiratory endurance. 90-degree push-up: upper-body muscular endurance. Curl-up: abdominal muscular endurance. Back-saver sit-and-reach: hamstring flexibility. Trunk lift: back-extensor strength and flexibility. Push-up: elbows bend to 90 degrees with the body straight, one every 3 seconds. Curl-up: fingertips slide across the 4½-inch strip and back until the head touches the mat, one every 3 seconds.
10. Answers will vary. A strong answer explains that exercise has real value (“profiteth little” means some profit), so the student should train faithfully and care for the body as God’s gift, but that godliness has far greater value, so a score is not a measure of worth. The student compares with his or her own baseline, works with diligence, and does not envy or look down on others.

UNIT CHALLENGE: TWO-WEEK ACTIVITY LOG AND PERSONAL BASELINE REPORT

Keep a daily activity log for fourteen days, recording moderate and vigorous minutes and ticking the vigorous, muscle-strengthening and bone-strengthening boxes each day. Graph your daily minutes with a line at 60, and calculate your average and the number of days you met each part of the guidelines. Write a one-page baseline report: your FitnessGram-style scores with units, what each measures, your goals for the Week 10 retest, and the two habits you changed in the second week to raise your lowest days.

LOOK FOR	WHAT IT MEANS
Complete log	Fourteen dated days with minutes and intensity recorded honestly and all four guideline boxes checked or left blank.
Graph and calculations	A clear graph with a 60-minute line, a correct average and correct counts of days meeting each guideline, with working shown.
Baseline report	All five test scores with units, what each measures, and specific, realistic goals for the retest.
Improvement and reflection	Two named habits changed in week two, with evidence from the log of whether they helped. Effort and honest records count, not the size of the numbers.

1.1 SIXTY MINUTES AND STRONG BONES: THE PHYSICAL ACTIVITY GUIDELINES

OBJECTIVES

- Tell the story of the Kraus–Weber tests and the founding of the President’s Council on Youth Fitness in 1956.
- State the 2018 *Physical Activity Guidelines* for ages 6–17 and classify activities as light, moderate or vigorous with the talk test.
- Explain how bone responds to load (Wolff’s law) and why the teen years are a once-in-a-lifetime window for building bone.
- Audit a full day of your own activity against the guidelines and complete a bone-building jump circuit.

Warm-up. Five-minute dynamic warm-up: 1 minute of brisk marching, 10 arm circles each way, 10 walking lunges, 10 leg swings each leg (hold a wall), 20 jumping jacks, then 30 seconds of easy skipping in place. Think about it: on a scale of light, moderate and vigorous, where was each part of this warm-up? Could you talk? Could you sing?

WATCH

Exercise and Bone Health in Children and Adolescents

Mayo Clinic • 2:40

https://www.youtube.com/watch?v=OKX27_IJR9g

WHEN TO WATCH

After the “How your body works” paragraph. Listen for when bone density peaks and which activities build bone best.

Note: A short talk by a pediatric rehabilitation physician at Mayo Clinic Children’s Center.

KEY TERMS

moderate-intensity activity

Activity that raises your breathing and heart rate so that you can talk but not sing, such as brisk walking or easy cycling.

bone-strengthening activity

Activity that puts impact or force on the bones, such as running, jumping rope, hopping and skipping, which signals bones to grow denser.

Wolff's law

The principle, described by the German surgeon Julius Wolff in 1892, that bone adapts to the loads placed on it, growing stronger where it is stressed.

vigorous-intensity activity

Activity hard enough that you can say only a few words without stopping for breath, such as running, fast swimming or a hard game of basketball.

peak bone mass

The greatest amount of bone a person ever has, reached in the late teens to twenties; most of it is built before about age 18–20.

CORE IDEAS

The story. In the late 1940s and early 1950s Dr. Hans Kraus, a New York physician who treated back pain, and his colleague Sonja Weber gave six simple tests of strength and flexibility to thousands of schoolchildren: lifting the trunk and legs, doing a sit-up with the knees straight and bent, and touching the floor with straight knees. They tested children in the United States and in Austria, Italy and Switzerland. When the results were published in 1953, more than half of the American children had failed at least one test, compared with fewer than one in ten of the European children. Kraus believed the difference was daily life: the European children walked, climbed and played for hours, while many American children rode in cars and buses. The findings reached President Dwight D. Eisenhower, a former army general who knew how much fitness mattered, and in July 1956 he founded the President's Council on Youth Fitness.

How they figured it out. Kraus's tests measured only a minimum of fitness. To learn how much activity truly protects health, scientists needed much larger studies: following thousands of people for years, comparing the active with the inactive, and testing exercise programs in schools. In 2008 the U.S. government gathered this research into the first *Physical Activity Guidelines for Americans*. A committee of scientists then spent two years reviewing the newer studies, and in November 2018 the second edition was published. For ages 6 through 17 it says: do **60 minutes or more** of moderate-to-vigorous activity every day, mostly aerobic, and as part of that 60 minutes include **vigorous** activity on at least 3 days a week, **muscle-strengthening** activity on at least 3 days and **bone-strengthening** activity on at least 3 days. The committee found strong evidence that active young people have better heart and lung fitness, stronger muscles and bones, and fewer symptoms of depression, and that activity helps children think and learn. Surveys by the Centers for Disease Control and Prevention have found that fewer than one in four American high-school students are active for 60 minutes on all seven days of the week.

How your body works. Bone is living tissue. Cells called **osteoblasts** lay down new bone, and **osteoclasts** remove old bone, all your life. When you land from a jump, the force bends your bones by a tiny amount; bone cells sense that strain and signal the body to add mineral where it is needed. This is **Wolff's law**: bone grows strong where it is loaded. Impact and quick, varied forces (running, jumping, hopping, skipping, basketball, volleyball, gymnastics) build bone far better than smooth activities such as swimming or cycling, which are excellent for the heart but put little load on the bones. Timing matters enormously. According to the National Institutes of Health, up to 90 percent of peak bone mass is built by about age 18 in girls and age 20 in boys. A Canadian study that followed children for years (the Saskatchewan bone study, led by Donald Bailey) found that roughly a quarter of adult bone mineral is laid down in about two years around the growth spurt. Bone you build now is like money in a savings account for the rest of your life; calcium, vitamin D, protein and enough food energy are the deposits that go with the jumping.

Think it through. Suppose your week looks like this: 45, 70, 30, 90, 60, 20 and 100 minutes of moderate-to-vigorous activity. The total is 415 minutes, an average of $415 \div 7 \approx 59$ minutes a day, but only three days reached 60. The guideline is *every* day, so the goal is to lift the low days (the 20 and the 30), not to pile more onto the high ones.

Exercise is good, and Scripture keeps it in its place: it “profiteth little” compared with godliness, but it does profit.

Try it. In Session 2 you will learn the talk test, run a bone-builder jump circuit and count every landing, and then log one whole day of your activity minute by minute. In Session 3 you will repeat the circuit with one more round and begin the week-long log for your unit challenge.

PICTURE STUDY



Children Jumping Rope on the White House Lawn during the Annual Easter Egg Roll, Frances Benjamin Johnston, 1890s (before 1902) · Gelatin silver print photograph · Library of Congress, Washington, D.C. (Frances Benjamin Johnston Collection)

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

Frances Benjamin Johnston was one of the first American women to work as a professional news photographer, and she photographed the White House for several presidents. Here she caught children jumping rope at the Easter Monday egg roll, a White House tradition since 1878. The glass greenhouses in the background were torn down in 1902, so the picture was taken before then.

Look closely

- Find the two jumpers. Are both feet off the ground? How are they landing?
- Look at the two rope turners. Which muscles are they using, and is this light, moderate or vigorous work for them?
- Look at the clothes and shoes. How would heavy coats and boots change the work of jumping?
- Find the children waiting their turn on the left. What will they be doing in a moment?

Talk about it

1. Jumping rope is one of the best bone-strengthening activities. From this lesson, explain why.

2. These children did not have phones, screens or cars. How might that have affected their daily minutes of activity, as Kraus suggested?
3. Which games or chores in your own week give your bones the kind of impact you see here?

Safety first. If you have asthma, a heart condition, diabetes, a recent injury or any health concern, check with your doctor before starting this course, and make sure a parent knows about every activity. Jump on a flat, non-slip surface (grass, a gym floor or a driveway) in supportive shoes, land softly on the balls of your feet with knees bent, and stop if you feel pain in your shins, knees or ankles. Stop and tell an adult right away at chest pain, dizziness, fainting or trouble breathing.

ACTIVITY

The 60-Minute Audit and the Bone-Builder Circuit

You will learn to judge intensity with the talk test, give your bones a measured dose of impact, and find out how close a real day of yours comes to the guidelines.

You will need

- A jump rope if you have one (or jump without a rope), a sturdy step or bottom stair, clear flat space
- A timer and a tally counter or pencil
- Fitness journal with two tables: a circuit table (station, landings, how it felt) and a day log (time block, activity, minutes, intensity: light, moderate or vigorous)

Steps

1. **Talk test (5 minutes).** Walk slowly for 1 minute, then walk briskly for 1 minute, then jog for 1 minute. At the end of each minute, try to say the Lord's Prayer aloud. Note where you could sing, where you could talk but not sing (moderate) and where you could say only a few words (vigorous). Take a 15-second pulse after each and multiply by 4.
2. **Warm up** with the lesson's 5-minute dynamic warm-up.
3. **Bone-builder circuit, round 1.** Do each station, resting 30 seconds between: (1) jump rope or rope-free skipping, 30 seconds, counting landings; (2) 10 squat jumps (squat to thighs about halfway down, jump, land softly and sink back into the squat); (3) 10 single-leg hops on each leg; (4) 10 lateral line jumps (side to side over a chalk line or rope); (5) 10 step-ups onto a sturdy step, each leg, followed by 5 gentle hop-downs if comfortable.
4. Rest 2 minutes and drink water. Do round 2. Add up your total landings for the session (most students reach about 100–150).
5. **Cool down:** walk 2 minutes, then hold calf, thigh and hip stretches for 20–30 seconds each.
6. **The day audit.** Choose one full day this week. From waking to bedtime, log every block of activity in 15-minute steps: walking to the car, chores,

practice, play, sitting at a desk. Mark each block light, moderate or vigorous. Add your moderate-plus-vigorous minutes and note whether the day included vigorous, muscle-strengthening and bone-strengthening activity.

7. **Session 3:** warm up and repeat the circuit with three rounds instead of two, keeping every landing soft. Record your landings and compare with Session 2. Then begin the seven-day activity log for the unit challenge.

Tips

- Quiet landings are good landings. If your feet slap the ground, bend your knees more and land on the balls of your feet.
- Bone needs short bursts of impact, not hours of pounding. A hundred good landings a few days a week is plenty.
- Count chores honestly: carrying groceries, raking, shoveling and stacking wood are real activity.

Check your work

- ☐ I can state the guidelines for my age and use the talk test to judge intensity.
- ☐ I completed the bone-builder circuit with soft landings and recorded my total.
- ☐ I audited a full day and know which part of the guidelines I most need to work on.

FITNESS JOURNAL

1. Copy the guidelines for ages 6–17 as a checklist you can tick each day of the week: 60 minutes, vigorous, muscle, bone.
2. Make a stacked bar chart of your day audit: light, moderate and vigorous minutes in different colors.
3. Record your talk-test pulses in a table and write the heart rate where you changed from moderate to vigorous.
4. Write two sentences: Which part of the guidelines is easiest for you? Which is hardest, and what will you change this week?

From history. The President's Council on Youth Fitness was renamed several times. In 1960, President-elect John F. Kennedy wrote an article called "The Soft American," and in 1966 the Presidential Physical Fitness Award began. In 2013 the old youth fitness test was replaced in many schools by the Presidential Youth Fitness Program, which used the FitnessGram tests you will meet in Lesson 1.2.

COMMON MISTAKES

- Counting the whole length of a practice as vigorous. Standing in line and listening to the coach are light activity; count only the moving minutes.
- Thinking swimming or cycling builds bone as well as running and jumping. They are excellent for the heart, but bones need impact or heavy load.
- Saving all the activity for the weekend. The guideline is every day; spread it out.
- Landing stiff-legged from jumps. Bend your knees and hips to absorb force through your muscles.

Make it a game • Sixty Minute Audit Duel. Audit yesterday minute by minute from memory and classify each block as light, moderate or vigorous using the talk test. Your parent does the same for her day. Compare totals against the 2018 guidelines for ages 6 to 17. Then explain Wolff's law and the Kraus-Weber story. Beat your best audit with a bone-builder circuit.

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)

Paul does not say exercise is useless; he says it has some value and godliness has more. We train our bodies faithfully, and we keep that training in its place.

1.2 YOUR FITNESS BASELINE: FITNESSGRAM AND THE PACER

OBJECTIVES

- Tell how the Cooper Institute created FitnessGram in 1982 and how Luc Léger's 20-meter shuttle run became the PACER.
- Explain the difference between criterion-referenced health standards and comparing yourself with other people.
- Perform the PACER (or one-mile run), 90-degree push-up, curl-up, back-saver sit-and-reach and trunk lift with correct technique and cadence.
- Record a personal baseline and set specific goals for a retest.

Warm-up. Five-minute warm-up for testing: 2 minutes of easy jogging back and forth across your 20-meter course, then 10 high-knee steps, 10 butt kicks, 10 walking lunges with a twist, 5 inchworms and 3 practice 20-meter jogs at an easy pace. Think about it: what makes a fitness test fair, so that next month's score can be compared with today's?

WATCH

PACER Test Protocol Video

The Kenneth H. Cooper Institute • 2:31

<https://www.youtube.com/watch?v=NuHkSCuap2A>

WHEN TO WATCH

Before Session 2. Watch how the runners reach the line before the beep, turn and wait, and when a runner's test ends.

Note: Made by the Cooper Institute, which publishes FitnessGram. It shows a school gym class running the PACER.

BACKUP VIDEO

FITNESSGRAM - How to Run the Pacer

Coach May's PE • 2:34

<https://www.youtube.com/watch?v=i2HmtmCzUrQ>

For pacing advice: why starting too fast makes you wait and tire early.

KEY TERMS

baseline

A first, carefully measured set of scores used as the starting point for judging your own improvement.

criterion-referenced standard

A score linked to good health (FitnessGram calls the range the Healthy Fitness Zone), rather than a ranking against other people.

PACER

Progressive Aerobic Cardiovascular Endurance Run: a 20-meter shuttle run that gets a little faster every minute, used to estimate aerobic fitness.

cadence

A set rhythm for a test, such as one push-up or curl-up every 3 seconds, so every rep is done the same way.

reliability

How well a test gives the same result when repeated under the same conditions.

CORE IDEAS

The story. Dr. Kenneth Cooper, an air force physician, had become famous for his 1968 book *Aerobics* and the 12-minute run. In 1970 he founded the Cooper Clinic and the Cooper Institute in Dallas, Texas, to study how fitness protects health. In 1982 the institute, led in this work by Charles Sterling, created **FitnessGram**, a set of school fitness tests with a report card that each student takes home. The same year, the Canadian exercise scientist Luc Léger and his colleague J. Lambert published a 20-meter shuttle run in which runners keep pace with recorded beeps that come a little faster each minute. FitnessGram adopted it as the **PACER**. Today FitnessGram is used in schools across the United States, and in many places it replaced the old Presidential fitness test.

How they figured it out. FitnessGram made one important change in thinking. Older tests ranked children against one another: a boy in the 85th percentile “beat” most boys his age. Cooper’s team asked a different question: *what level of fitness is linked with good health?* They studied the relationship between fitness and health in large groups and set **criterion-referenced standards**. A student either reaches the Healthy Fitness Zone for his or her age or has a goal to work toward; there is no prize for

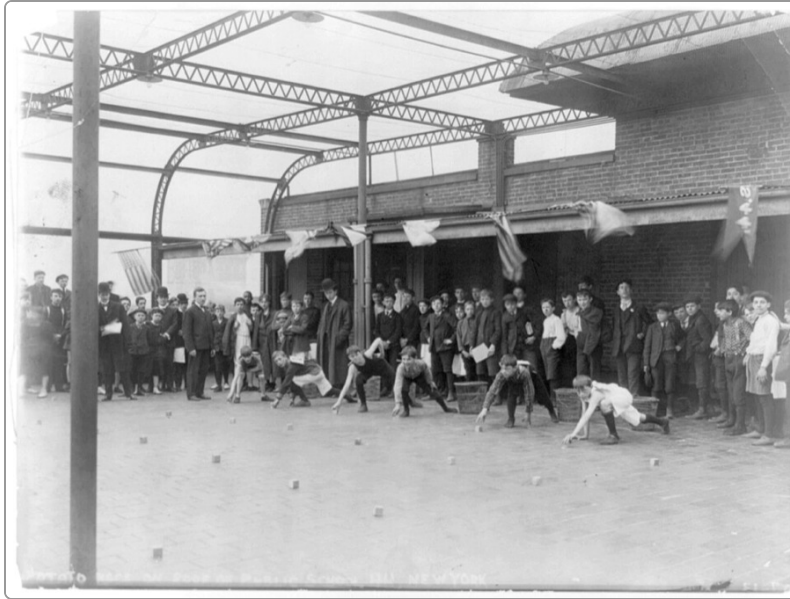
being the fastest in the class. In this course we go one step further: your scores are compared only with your own earlier scores.

How your body works. Each test measures a different part of health-related fitness. The **PACER** measures cardiorespiratory endurance: how well your heart, lungs and muscles deliver and use oxygen. Level 1 starts at 8.5 km/h and the speed rises by 0.5 km/h about every minute. At 8.5 km/h you run $8,500 \text{ m} \div 3,600 \text{ s} \approx 2.36 \text{ m/s}$, so each 20-meter lap takes $20 \div 2.36 \approx 8.5$ seconds. The test ends the second time you fail to reach the line before the beep. The **90-degree push-up**, done to a cadence of one every 3 seconds (20 per minute), measures upper-body muscular endurance; 30 push-ups therefore take 90 seconds. The **curl-up**, also one every 3 seconds up to 75, measures abdominal endurance with the lower back protected. The **back-saver sit-and-reach** measures hamstring flexibility one leg at a time, and the **trunk lift** measures back-extensor strength and flexibility, stopping at 12 inches to protect the spine.

Good form. Push-up: hands under the shoulders, body straight from head to heels, lower until the elbows bend to 90 degrees and the upper arms are parallel to the floor, push to straight arms; stop when you miss the cadence twice or your form breaks twice. **Curl-up:** lie on your back with knees bent about 140 degrees, feet flat, arms straight at your sides with fingertips at the near edge of a 4½-inch (11.4 cm) strip of cardboard (the strip FitnessGram uses for ages 10 and older); curl slowly until the fingertips reach the far edge, then back down until your head touches the mat. **Sit-and-reach:** one leg straight with the foot flat against a box, the other knee bent; reach forward slowly with both hands four times and hold the fourth reach for one second. Never bounce.

Try it. In Session 2 you will learn each test and practice the cadences in short trials. In Session 3, fully rested and warmed up, you will run the whole battery in a fixed order and record your baseline. You will retest during the family fitness day in Week 10 and again later in the year.

PICTURE STUDY



Potato Race on Roof of Public School 44, New York City, Bain News Service, Early 1900s · Photograph · Library of Congress, Washington, D.C. (George Grantham Bain Collection)

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

In crowded New York, some schools built playgrounds on their roofs. Here boys line up for a potato race, a favorite schoolyard event: each runner dashes out to pick up potatoes one at a time and carries each back to his basket. It is a shuttle run, the same idea as the PACER.

Look closely

- Count the potatoes in one runner's line. How many trips will he make, and how far will he run in all?
- Look at the starting positions. Which boy looks ready to push off fastest? Why?
- Find the men in hats and suits. Who might be the judges and timekeepers?
- Notice the floor and the roof above. Why would a rooftop be a good playground in a big city?

Talk about it

1. Like the PACER, the potato race makes runners stop, turn and accelerate again and again. Which muscles and skills does that use beyond plain endurance?

2. This race was a contest against other boys. How is the PACER, used as a personal baseline, different?
3. What would make a potato race a fair test if you ran it again next month?

Safety first. Get enough sleep and eat a normal meal 2–3 hours before testing, warm up fully and drink water. Run the PACER on a flat, non-slip surface with at least 2 meters of space past each line, turn with control, and stop at once if you feel chest pain, dizziness or unusual breathlessness. For the trunk lift, rise slowly and never above 12 inches; for the sit-and-reach, never bounce or force the stretch.

ACTIVITY

Your FitnessGram-Style Baseline

You will set up a fair testing station at home, learn each test, and then record a full baseline that you will retest in Week 10. Fair means the same course, the same order, the same rests and the same rules every time.

You will need

- A tape measure and chalk or cones to mark two lines 20 meters (about 65 feet 7 inches) apart; if you cannot find 20 meters, use the one-mile run instead
- A PACER audio recording if available (many physical-education departments post one), or a stopwatch and a measured 1-mile route (four laps of a 400-meter track, or a route measured by a car or map app)
- A mat or towel, a 4½-inch-wide strip of cardboard, a sturdy box about 12 inches high and a yardstick or ruler taped to the top, a ruler for the trunk lift
- A helper to count, watch form and keep time; fitness journal with a baseline table

Steps

1. **Set up (Session 2).** Measure and mark your 20-meter course. Tape the yardstick to the box so that the 9-inch mark is at the edge where your foot will rest. Cut the curl-up strip.
2. **Practice the cadences.** With the helper saying “up, down” every 1.5 seconds (one full rep every 3 seconds), do 5 practice push-ups and 5 practice curl-ups. Practice 3 PACER laps, arriving at the line just before the beep.
3. **Practice the flexibility tests.** Do two practice sit-and-reach trials on each leg and two slow trunk lifts. Write down any form cue you need to remember.
4. **Baseline day (Session 3), fixed order.** Warm up for 5 minutes. Test in this order, resting at least 5 minutes between tests: (1) back-saver sit-and-reach, right then left, recording the best of four reaches to the nearest half inch; (2) trunk lift, best of two, to the nearest inch, maximum 12; (3) curl-ups to

cadence; (4) 90-degree push-ups to cadence; (5) after a 10-minute rest, the PACER (count every completed lap) or the one-mile run (record the time).

5. **Record and convert.** Write each score with units. For the PACER, multiply laps by 20 to get meters. For the mile, convert your time to minutes per mile and to meters per second (1 mile $\approx$ 1,609 m).
6. **Cool down** with 3 minutes of walking and gentle stretches, then check your 1-minute recovery heart rate.
7. **Set goals.** For each test, write one realistic goal for the Week 10 retest (for example, +4 PACER laps, +3 push-ups) and one habit that will help you reach it.

Tips

- On the PACER, start slower than feels necessary. Early levels are easy; runners who sprint the first laps waste energy waiting at the line.
- On push-ups and curl-ups, the cadence is the boss. A rep done early or late does not count, so listen to the helper.
- Test at the same time of day and on the same surface for your retest, or the comparison is not fair.

Check your work

- ☐ I can explain what each test measures and why FitnessGram uses health standards instead of rankings.
- ☐ I performed each test with correct technique and cadence and recorded my scores with units.
- ☐ I set a specific goal for each test and a plan to reach it.

FITNESS JOURNAL

1. Make a baseline table: test, score, units, how it felt, form note, goal for the retest.
2. Show your PACER conversion: laps $\times$ 20 = meters. If you ran the mile, show the conversion to minutes per mile and meters per second.
3. Draw a simple diagram of each test position with two form cues beside it.
4. Write a paragraph: What is the difference between “I am the third fastest in my co-op” and “I am 6 laps better than last month”? Which helps you train faithfully?

From history. Kenneth Cooper's 1968 book *Aerobics* gave a new word to everyday English and helped start the American jogging boom of the 1970s. Luc Léger developed his shuttle run at the University of Montreal so that a whole class could be tested in a gymnasium at once, without a track.

COMMON MISTAKES

- Sprinting the early PACER levels. Arrive just before each beep; let the test get hard by itself.
- Going only partway down on push-ups. Elbows bend to 90 degrees every rep, or it does not count.
- Bouncing on the sit-and-reach or arching too high on the trunk lift. Both risk strain; slow and controlled is the rule.
- Comparing your scores with a sibling's or a friend's. Your baseline is yours; compare only with your own retest.

Make it a game • Shuttle Run Record. Mark twenty meters with tape and run PACER-style shuttles to a beat your parent claps or counts, getting faster each minute. Record your level, then explain why criterion-referenced standards beat comparing yourself with others. Tell how Luc Leger designed the test. Retest in two weeks and aim for one more shuttle than before.

UNIT 1

KEEPING ACTIVE

How much activity does a growing person really need, and how do we know? In the early 1950s a doctor named Hans Kraus tested thousands of children in the United States and Europe and found the American children far weaker and stiffer. The results reached President Eisenhower, who founded the President's Council on Youth Fitness in 1956. Today the answer comes from decades of research gathered in the U.S. *Physical Activity Guidelines for Americans* (second edition, 2018): at least 60 minutes a day, with vigorous, muscle-strengthening and bone-strengthening activity on at least three days a week. You will learn why your teen years are the best years of your life for building bone, and audit your own week.

Then you will set your **fitness baseline** the way millions of American students do, with the FitnessGram tests developed by the Cooper Institute in 1982: the PACER shuttle run, the 90-degree push-up, the curl-up, the back-saver sit-and-reach and the trunk lift. Your scores are a starting point for you alone, compared with health standards and with your own retest later, never with anyone else.

PREREQUISITES

- Can work with percentages, averages and unit conversions (meters, kilometers, minutes and seconds)
- Can take a pulse at the wrist or neck and count for 15 seconds
- Has a doctor's go-ahead if any health condition applies, and a parent who knows about the course

MASTERY CHECKLIST

- ☐ I can state the 2018 activity guidelines for ages 6–17 and explain the difference between moderate and vigorous activity.
- ☐ I can explain why the teen years matter so much for bone, and name bone-strengthening activities.
- ☐ I can tell the story of the Kraus–Weber tests and the President's Council on Youth Fitness.
- ☐ I can run the FitnessGram-style tests with correct technique and cadence and record a personal baseline.
- ☐ I can explain the difference between a criterion standard and a comparison with other people, and set goals against my own numbers.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- ***Physical Activity Guidelines for Americans, 2nd edition* (U.S. Department of Health and Human Services)**: Free. The full guidelines and summaries; chapter 3 covers children and adolescents. Use with Lesson 1.1.
- **A tape measure and sidewalk chalk or cones**: To mark the 20-meter PACER course and the sit-and-reach in Lesson 1.2. Cups or shoes work as cones.

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 Sixty Minutes and Strong Bones: The Physical Activity Guidelines

3 sessions of 45–50 minutes

1.2 Your Fitness Baseline: FitnessGram and the PACER

3 sessions of 45–50 minutes

UNIT 1 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

State the 2018 *Physical Activity Guidelines* for ages 6–17, including the three kinds of activity that should happen on at least three days a week.

2. 10 pts

Describe the talk test. Classify each as light, moderate or vigorous: a slow stroll, brisk walking, a hard game of soccer, easy cycling on flat ground, running up a hill.

3. 10 pts

Calculation. A student logs these moderate-to-vigorous minutes for a week: 35, 80, 50, 60, 25, 90, 75. Find the total and the daily average (to the nearest minute). On how many days did the student meet the guideline? What should the student change?

4. 10 pts

Tell the story of the Kraus–Weber tests and what came of them.

5. 10 pts

Explain Wolff’s law and use it to explain why jumping rope builds bone better than swimming.

6. 10 pts

Why are the teen years called a once-in-a-lifetime window for bone? Give two facts and two things a teen can do.

7. 10 pts

What does “criterion-referenced” mean in FitnessGram, and how is it different from a percentile ranking?

8. **10 pts**

Calculation. PACER level 1 runs at 8.5 km/h. (a) Convert this speed to meters per second. (b) How long does one 20-meter lap take at this speed? (c) A student completes 42 laps. How many meters did he run?

9. **10 pts**

Name the five FitnessGram-style tests from this unit and the part of fitness each measures. Give one form rule for the push-up and one for the curl-up.

10. **10 pts**

Short written answer. In a paragraph, explain how 1 Timothy 4:8 shapes the way a Christian student should think about a fitness test score.

ANSWER KEY

1. Do 60 minutes or more of moderate-to-vigorous physical activity every day, mostly aerobic. As part of that 60 minutes, include vigorous-intensity activity on at least 3 days a week, muscle-strengthening activity on at least 3 days and bone-strengthening activity on at least 3 days.
2. In moderate activity you can talk but not sing; in vigorous activity you can say only a few words without pausing for breath; in light activity you can sing. Slow stroll: light. Brisk walking: moderate. Hard soccer: vigorous. Easy flat cycling: moderate. Running uphill: vigorous.
3. Total = $35 + 80 + 50 + 60 + 25 + 90 + 75 = 415$ minutes. Average = $415 \div 7 \approx 59$ minutes a day. The guideline (60 or more) was met on 4 days (80, 60, 90, 75). The student should raise the low days (35, 50, 25), for example with a brisk walk or a game, because the guideline is every day.
4. In the early 1950s Hans Kraus and Sonja Weber gave six simple strength and flexibility tests to thousands of children in the United States and in Austria, Italy and Switzerland. Published in 1953, the results showed more than half of the American children failed at least one test, compared with fewer than one in ten European children. Kraus blamed less walking and play in daily life. The results reached President Eisenhower, who founded the President's Council on Youth Fitness in 1956.
5. Wolff's law says bone adapts to the loads placed on it: when bone is strained, bone cells signal the body to add mineral there, making it stronger. Jumping rope creates repeated impact forces that strain the leg and hip bones; swimming is supported by water and puts little load on the bones, so it is good for the heart but builds little bone.
6. Up to 90 percent of peak bone mass is built by about age 18 in girls and 20 in boys, and roughly a quarter of adult bone mineral is laid down in about two years around the growth spurt. After the twenties, bone mass slowly declines. A teen can do bone-strengthening activity (running, jumping, hopping) at least 3 days a week and eat enough food with calcium, vitamin D and protein (milk, yogurt, cheese, leafy greens, fish, eggs).
7. A criterion-referenced standard links a score to good health: the student either reaches the Healthy Fitness Zone or has a goal to work toward. A percentile ranking compares the student with other students of the same age (for example, faster than 85 percent). FitnessGram uses health standards, not rankings; in this course we compare only with our own earlier scores.

8. (a) $8.5 \text{ km/h} = 8,500 \text{ m} \div 3,600 \text{ s} \approx 2.36 \text{ m/s}$. (b) $20 \text{ m} \div 2.36 \text{ m/s} \approx 8.5 \text{ seconds}$. (c) $42 \text{ laps} \times 20 \text{ m} = 840 \text{ meters}$.
9. PACER (or one-mile run): cardiorespiratory endurance. 90-degree push-up: upper-body muscular endurance. Curl-up: abdominal muscular endurance. Back-saver sit-and-reach: hamstring flexibility. Trunk lift: back-extensor strength and flexibility. Push-up: elbows bend to 90 degrees with the body straight, one every 3 seconds. Curl-up: fingertips slide across the 4½-inch strip and back until the head touches the mat, one every 3 seconds.
10. Answers will vary. A strong answer explains that exercise has real value (“profiteth little” means some profit), so the student should train faithfully and care for the body as God’s gift, but that godliness has far greater value, so a score is not a measure of worth. The student compares with his or her own baseline, works with diligence, and does not envy or look down on others.

UNIT CHALLENGE: TWO-WEEK ACTIVITY LOG AND PERSONAL BASELINE REPORT

Keep a daily activity log for fourteen days, recording moderate and vigorous minutes and ticking the vigorous, muscle-strengthening and bone-strengthening boxes each day. Graph your daily minutes with a line at 60, and calculate your average and the number of days you met each part of the guidelines. Write a one-page baseline report: your FitnessGram-style scores with units, what each measures, your goals for the Week 10 retest, and the two habits you changed in the second week to raise your lowest days.

LOOK FOR	WHAT IT MEANS
Complete log	Fourteen dated days with minutes and intensity recorded honestly and all four guideline boxes checked or left blank.
Graph and calculations	A clear graph with a 60-minute line, a correct average and correct counts of days meeting each guideline, with working shown.
Baseline report	All five test scores with units, what each measures, and specific, realistic goals for the retest.
Improvement and reflection	Two named habits changed in week two, with evidence from the log of whether they helped. Effort and honest records count, not the size of the numbers.

UNIT 2

HYDRATION

Your body is more than half water, and it keeps the saltiness of that water within about one percent of its set point every hour of your life. In this unit you will follow the scientists who discovered how: Claude Bernard, who taught that living things keep a steady “internal environment”; Walter Cannon, who named the idea homeostasis; and Ernest Verney, whose experiments in 1947 located the brain’s water sensor. You will learn how a million nephrons in each kidney filter about 180 liters of fluid a day, how antidiuretic hormone fine-tunes what you keep, how much a teen needs to drink, and why drinking far too much can be as dangerous as drinking too little.

Then you will study the most serious heat danger for athletes: **exertional heat stroke**. You will hear the story of Korey Stringer, the Minnesota Vikings lineman who died after a hot practice in 2001, and of the Korey Stringer Institute that now teaches coaches and athletic trainers to save lives with one rule: **cool first, transport second**. You will test cooling methods with a thermometer and write a heat-emergency plan for your family or team.

PREREQUISITES

- Knows the activity guidelines and the talk test (Unit 1)
- Can convert between cups, fluid ounces, milliliters and liters (1 cup = 8 fl oz $\approx$ 240 mL; 1 L $\approx$ 4.2 cups)
- Can read a thermometer in °F and °C and calculate a rate of change

MASTERY CHECKLIST

- ☐ I can explain homeostasis and describe how the kidneys, antidiuretic hormone and thirst keep body water in balance.
- ☐ I can trace filtration and reabsorption through a nephron and calculate how much filtrate the kidneys make in a day.
- ☐ I can state about how much fluid a teen needs and explain the danger of drinking far more than the kidneys can remove (hyponatremia).
- ☐ I can recognize heat exhaustion and exertional heat stroke and explain “cool first, transport second.”
- ☐ I can explain heat acclimatization, the heat index and WBGT, and write a heat-emergency action plan.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Your Kidneys” (Nemours TeensHealth):** Free. A clear teen article on how the kidneys filter blood and balance fluids. Read it with Lesson 2.1.
- **Korey Stringer Institute, University of Connecticut:** Free. Research-based pages on heat stroke, cold-water immersion, heat acclimatization and state high-school safety policies. Use with Lesson 2.2.
- **A reusable water bottle with ounce or milliliter marks:** Handy for the fluid log. A measuring cup works just as well.

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 Fluid Balance: The Kidneys and the Body's Water Sensor

3 sessions of 45–50 minutes

2.2 Exertional Heat Illness: Cool First, Transport Second

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Define homeostasis and name the scientist who coined the word. What did Claude Bernard teach about the “internal environment”?

2. 10 pts

Describe Ernest Verney's 1947 experiment and his conclusion.

3. 10 pts

Calculation. The kidneys filter about 125 mL per minute. (a) How many liters is that per day? (b) If a student makes 1.8 L of urine in a day, what percentage of the filtrate was reabsorbed? (c) About how many times a day is a 5-liter blood volume filtered?

4. 10 pts

Explain step by step what happens to ADH, thirst and urine after a student sweats heavily at practice without drinking.

5. 10 pts

Calculation. During a 4-hour race a runner drinks 1.5 L of water per hour while sweating 0.5 L per hour. Because blood flow to the kidneys falls during hard exercise, her kidneys make only about 0.3 L of urine per hour. How much extra water does she gain each hour and by the end of the race? What danger does this create?

6. 10 pts

Name the four heat illnesses from Lesson 2.2 and give the key sign and first aid for each.

7. 10 pts

Calculation. In the cooling lab, a bottle in stirred ice water cooled from 106°F to 98°F in 10 minutes, and a bottle in still air cooled from 106°F to 104°F. Find each cooling rate. How long would each take to bring a body from 106°F to 102°F at those rates?

8. 10 pts

What does “cool first, transport second” mean, and why does it save lives?

9. 10 pts

Explain heat acclimatization, the heat index and WBGT, and give three ways a team can prevent heat illness.

10. 10 pts

Short written answer. Tell the story of Korey Stringer in a paragraph and explain what has changed in sports because of him.

ANSWER KEY

1. Homeostasis is the body's work of keeping internal conditions such as water, salt, temperature and sugar steady within narrow limits. Walter Cannon coined the word in 1926. Claude Bernard taught that the fluid inside the body, the blood and the fluid bathing the cells, must stay nearly constant even when the outside world changes, and that this makes a free, active life possible.
2. Verney gave water-loaded, trained dogs a small infusion of concentrated salt solution into the artery leading to the brain. Urine flow dropped sharply within minutes, while infusing water had the opposite effect. He concluded that osmoreceptors near the base of the brain sense when the blood is too concentrated and trigger the release of antidiuretic hormone from the pituitary, which makes the kidneys save water.
3. (a) $125 \text{ mL} \times 1,440 \text{ min} = 180,000 \text{ mL} = 180 \text{ L}$ per day. (b) $(180 - 1.8) \div 180 = 178.2 \div 180 = 0.99$, so 99 percent was reabsorbed. (c) $180 \div 5 = 36$ times a day. (Strictly, the kidneys filter plasma, about 3 L, so the plasma is filtered about 60 times a day; either reasoning with the working shown earns credit.)
4. Sweat removes water, so the blood becomes slightly more concentrated (higher osmolality). Osmoreceptors in the hypothalamus sense this and make the student thirsty, and the pituitary releases more ADH. ADH opens aquaporin water channels in the collecting ducts, so more water returns to the blood. The student makes a smaller amount of darker urine until he drinks and balance is restored.
5. Gain each hour = intake – sweat – urine = $1.5 - 0.5 - 0.3 = 0.7 \text{ L}$. Over 4 hours: $0.7 \times 4 = 2.8 \text{ L}$ of extra water. The extra water dilutes the sodium in her blood, risking exercise-associated hyponatremia: headache, nausea, confusion and swelling, and in severe cases seizures or death. She should drink to thirst instead of forcing fluids.
6. Heat cramps: painful muscle spasms; stop, stretch, massage, drink fluids with some salt. Heat syncope: fainting or light-headedness; lie down in shade with legs raised. Heat exhaustion: weakness, heavy sweating, headache, nausea with clear thinking; stop, move to shade, remove equipment, cool with wet towels and fans, sip fluids, seek care if not better. Exertional heat stroke: core temperature above about 104°F with confusion or collapse; call 911 and cool immediately, ideally in an ice-water tub, until about 102°F , then transport.
7. Ice water: $(106 - 98) \div 10 = 0.8^{\circ}\text{F}$ per minute; $4^{\circ}\text{F} \div 0.8 = 5$ minutes. Still air: $(106 - 104) \div 10 = 0.2^{\circ}\text{F}$ per minute; $4^{\circ}\text{F} \div 0.2 = 20$ minutes. Ice water cools four times

faster. (A real body is much larger than a bottle and cools more slowly, but the comparison holds.)

8. When trained medical staff are present, an athlete with exertional heat stroke is cooled on the spot, ideally by cold-water immersion, until the core temperature falls to about 102°F, and only then taken to the hospital (911 is called at once). Damage depends on how hot the body gets and how long it stays hot; nearly all athletes cooled below about 104°F within 30 minutes of collapse survive, while delay during transport allows organ damage.
9. Heat acclimatization is the body's adjustment over about 10–14 days of gradually increasing exercise in the heat: earlier and more sweating, lower heart rate, cooler core. The heat index combines temperature and humidity into how hot it feels; WBGT also includes sun and wind and is used by many schools to set practice rules. Prevention (any three): a gradual 14-day acclimatization period; practicing in cooler hours; regular water and shade breaks; checking WBGT or heat index and changing or canceling practice; lighter clothing and equipment; not practicing while sick; an emergency plan with a cooling tub.
10. Answers will vary. A strong answer states that Korey Stringer, a Minnesota Vikings Pro Bowl tackle, collapsed after a hot practice at training camp in Mankato on July 31, 2001, with a body temperature near 108.8°F, and died the next morning; that his widow helped found the Korey Stringer Institute at the University of Connecticut in 2010 with Douglas Casa; and that because of this work many schools and states now require heat acclimatization, WBGT-based practice rules, emergency action plans and cold-water immersion tubs.

UNIT CHALLENGE: FIVE-DAY FLUID LOG AND HEAT-EMERGENCY ACTION PLAN

Keep a fluid log for five days, including at least two training days, recording every drink in cups and milliliters, morning urine color and thirst. Total each day in liters, graph intake beside urine color, and compare with the adequate intake for your age. Then write and post a one-page heat-emergency action plan for your family, team or co-op: the signs of heat exhaustion and heat stroke, who calls 911 and what address to give, where cooling supplies are kept, how cooling is done, and who meets the ambulance. Walk your family through it.

LOOK FOR	WHAT IT MEANS
Accurate log	Five dated days with every drink measured and recorded in two units, urine color and thirst noted honestly.
Analysis	Correct daily totals in liters, a clear graph, and a sensible comparison with the adequate intake, with working shown.
Action plan	Clear, correct steps for recognizing and treating heat illness, with names, address and cooling supplies, practiced with the family.
Reflection	A paragraph on what the student changed in his or her drinking and training habits, and why. Effort and honest records count, not the size of the numbers.

2.1 FLUID BALANCE: THE KIDNEYS AND THE BODY'S WATER SENSOR

OBJECTIVES

- Explain homeostasis and tell how Bernard, Cannon and Verney discovered how the body controls its water.
- Trace filtration, reabsorption and the action of antidiuretic hormone (ADH) in the nephron, with numbers.
- Estimate a teen's daily fluid needs and keep a three-day fluid log with urine-color checks.
- Explain exercise-associated hyponatremia and why athletes should drink to thirst rather than force large amounts.

Warm-up. Five-minute warm-up: 1 minute of jogging in place, 10 squats, 10 push-ups (knees or full), 20 jumping jacks, 10 alternating reverse lunges and 30 seconds of fast feet. Then sip some water and think about it: where does the water you just drank go, and how does your body decide how much to keep?

WATCH

How do your kidneys work? - Emma Bryce

TED-Ed · 3:54

<https://www.youtube.com/watch?v=FN3MFhYPWWo>

WHEN TO WATCH

After the “How your body works” paragraph. Watch for the glomerulus, the tubule and how much blood the kidneys filter in a day.

BACKUP VIDEO

Excretion - ADH and Homeostasis - GCSE Biology (9-1)

Mr Exham Biology · 2:59

https://www.youtube.com/watch?v=yXWISve_7Uw

For a closer look at how the hypothalamus, pituitary gland and ADH control the water in your blood.

KEY TERMS

homeostasis

The body's work of keeping its internal conditions (temperature, water, salt, sugar, pH) steady within narrow limits; the word was coined by Walter Cannon in 1926.

glomerular filtration

The pressing of water, salts, sugar and wastes out of the blood in the glomerulus into the tubule, about 125 mL every minute (180 L a day).

osmolality

A measure of how concentrated the body's fluids are with dissolved particles, mostly sodium; the brain senses it and adjusts thirst and ADH.

nephron

One of about a million tiny filtering units in each kidney, made of a glomerulus and a long tubule.

antidiuretic hormone (ADH)

A hormone made in the hypothalamus and released by the pituitary gland that tells the kidneys' collecting ducts to put water back into the blood; also called vasopressin.

hyponatremia

A dangerously low level of sodium in the blood (below 135 millimoles per liter), which can happen when someone drinks far more water than the body loses.

CORE IDEAS

The story. In the mid-1800s the French physiologist Claude Bernard taught that animals live in two environments: the world outside, which may be hot or cold, and the fluid inside, the blood and the liquid bathing every cell, which must stay nearly the same. A free and active life, he wrote, depends on keeping that inner environment steady. In 1926 the Harvard physiologist Walter Cannon gave this steadiness a name, **homeostasis**, and in 1932 he described it in a book called *The Wisdom of the Body*. But how does the body know when its water is too low? In 1947 the Cambridge physiologist Ernest Verney answered with a set of careful experiments.

How they figured it out. Verney worked with trained dogs who had drunk plenty of water and were making large amounts of dilute urine. He infused a small amount of concentrated salt solution into the artery leading to the brain. Within minutes the flow of urine dropped sharply, as if the body had suddenly decided to save water,

even though the blood elsewhere had barely changed. Infusing water had the opposite effect. Verney concluded that cells near the base of the brain act as **osmoreceptors**: when the blood becomes slightly too concentrated, they trigger the release of an antidiuretic hormone from the pituitary gland, and the kidneys hold on to water. Later scientists found the same sensors drive **thirst**. In 2003 Peter Agre shared a Nobel Prize for discovering **aquaporins**, the protein water channels that ADH inserts into kidney cells.

How your body works. About 50–60 percent of the body is water. Each kidney has about a million **nephrons**. In each nephron's **glomerulus**, a knot of capillaries, blood pressure pushes water, sodium, potassium, glucose, urea and other small molecules into the tubule, while blood cells and large proteins stay in the blood. Together the kidneys filter about 125 mL a minute: $125 \text{ mL} \times 1,440 \text{ minutes} \approx 180,000 \text{ mL}$, or **180 liters a day**. Yet you make only about 1–2 liters of urine. If you make 1.5 L, the kidneys have put back $(180 - 1.5) \div 180 \approx 99.2$ percent of the filtered fluid. Most is reabsorbed in the first part of the tubule; the last adjustment happens in the **collecting ducts**, where ADH opens aquaporin channels. When you sweat and do not drink, your blood becomes slightly more concentrated; within a change of only about 1–2 percent, the brain releases ADH and makes you thirsty, and your urine becomes darker and smaller in amount. When you drink plenty, ADH falls and you make more, paler urine.

Think it through. The National Academies set adequate intakes of total water (from drinks and food) for ages 14–18 at about 3.3 liters a day for boys and 2.3 liters for girls, of which roughly 2.6 L (about 11 cups) for boys and 1.8 L (about 8 cups) for girls comes from drinks; athletes training in heat need more. But the kidneys can remove at most about 0.8–1.0 liter of water an hour. A runner who forces down 2 liters an hour while sweating 1 liter gains about 1 liter of extra water every hour, which dilutes the blood's sodium. When doctors tested 488 runners at the end of the 2002 Boston Marathon, about 13 percent had **hyponatremia**, and the main risk was drinking more than they sweated; a few were critically ill. Symptoms (headache, nausea, confusion, swelling of the hands) can look like dehydration, which is why forcing more water is the wrong answer. The safe rule: drink regularly, drink to thirst, aim for pale-yellow urine, and never force huge amounts.

Try it. In Session 2 you will build a model glomerulus and calculate filtration rates, then begin a three-day fluid log with urine-color checks. In Session 3 you will repeat

a workout with a planned drinking schedule and compare how you felt.

PICTURE STUDY



Young Woman with a Water Pitcher, Johannes Vermeer, About 1662 · Oil on canvas · The Metropolitan Museum of Art, New York

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

Johannes Vermeer painted quiet rooms in the Dutch city of Delft, filled with soft light from a window. Here a young woman pauses with one hand on the window and the other on a polished pitcher of water standing in its basin. In Vermeer's day, clean water had to be fetched, carried and stored; every pitcherful was work.

Look closely

- Find the pitcher and the basin. How much water might the pitcher hold? Estimate it in cups and in liters.
- Look at how the light from the window falls on the water vessels. What does Vermeer make you notice first?
- Look at her clothing: linen head covering, collar, long sleeves. How would these protect her indoors and outdoors?
- Find the map on the wall. Why might a household keep a map, and what does it say about the wider world beyond this room?

Talk about it

1. In 1660s Delft, clean water was carried and stored by hand. How might that have changed how much people drank?

2. Your kidneys handle about 180 liters of filtered fluid a day. How many pitchers like this one would that fill?
3. This painting is calm and steady, like homeostasis. What steady habits of drinking and resting help your body stay in balance?

Safety first. Drink regularly, but never force down large amounts of water; drink to thirst and stop if you feel full or bloated. During the model lab, do not taste any of the mixtures, and wipe up spills so the floor is not slippery. Warm up before the workout and stop at once if you feel dizzy, confused or develop a headache.

ACTIVITY

Model Glomerulus and the Three-Day Fluid Log

You will see filtration with your own eyes, run the numbers on your kidneys, and then measure how much you actually drink and how your body responds.

You will need

- Two clear cups or jars, a coffee filter or paper towel, a funnel or strainer, salt, a few drops of food coloring, a spoonful of sand or coffee grounds, a handful of dried beans or beads, a measuring cup
- A urine-color chart (draw one: eight shades from very pale yellow to dark amber, numbered 1–8)
- Fitness journal with a fluid-log table: time, drink, amount in cups and mL, thirst (yes or no), urine color number

Steps

1. **Model blood.** Mix 1 cup (240 mL) of water with $\frac{1}{2}$ teaspoon of salt, 3 drops of food coloring, a spoonful of sand and a handful of beans. The water, salt and dye stand for plasma, salts and small molecules; the sand and beans stand for blood cells and proteins.
2. **Filter.** Line the funnel with the coffee filter and pour the mixture through into a clean cup. Record what passed through (the filtrate) and what stayed behind. Measure the volume of filtrate in mL. Which parts of real blood stay behind in the glomerulus?
3. **Run the numbers.** In your journal, calculate: (a) daily filtrate at 125 mL per minute; (b) the percentage reabsorbed if you make 1.6 L of urine a day; (c) how many times your total blood volume (about 5 L) is filtered each day.
4. **Start the fluid log (three days).** Measure and record every drink in cups and mL, including milk, soup and juice. Each time you use the bathroom in the morning, compare urine color with your chart and record the number (1–3 is well hydrated; 6–8 means drink more). Mark whether you felt thirsty.
5. **Workout (Session 2):** warm up, then do 3 rounds of 40 seconds of work and 20 seconds of rest: squats, push-ups, mountain climbers, lunges, plank.

Before you begin, drink about 1–2 cups; afterward, drink to thirst and record the amounts.

6. **Session 3:** repeat the same workout with a planned drinking schedule: about 2 cups 1–2 hours before, a few sips between rounds, and drink to thirst afterward. Record your reps, how you felt and your urine color two hours later. Compare with Session 2.
7. **Analyze.** At the end of three days, total each day's drinks in liters, compare with the adequate intake for your age, and graph daily intake beside your average urine color.

Tips

- Some foods are mostly water: fruit, vegetables, soup and yogurt all count toward your total, which is why drinks are only part of the adequate intake.
- Many vitamins (especially the B vitamin riboflavin) make urine bright yellow for a few hours; note it in your log.
- Carry a bottle and refill it at set times (breakfast, lunch, practice, dinner) rather than trying to catch up with a huge amount at once.

Check your work

- ☐ I can explain filtration and reabsorption and calculate daily filtrate and percent reabsorbed.
- ☐ I kept a three-day fluid log with urine-color checks and compared it with the adequate intake for my age.
- ☐ I can explain why forcing large amounts of water during long exercise is dangerous.

FITNESS JOURNAL

1. Draw and label a nephron: glomerulus, Bowman's capsule, tubule, collecting duct. Show with arrows where filtration happens and where ADH acts.
2. Copy your three-day fluid log totals in liters and cups. Graph them as bars, with your average urine color as a line.
3. Draw the feedback loop: sweat and no drink → blood more concentrated → osmoreceptors → ADH and thirst → kidneys save water and you drink → balance restored.

4. Write a short paragraph explaining to a younger runner why “more water is always better” is false.

From history. Claude Bernard’s best-known book, *An Introduction to the Study of Experimental Medicine* (1865), taught generations of doctors to test ideas with careful experiments rather than to rely on authority. Walter Cannon also coined the phrase “fight or flight” for the body’s response to danger.

COMMON MISTAKES

- Thinking clear urine all day is the goal. Pale yellow is ideal; completely clear all day can mean you are drinking more than you need.
- Forcing large amounts of water during long events. The kidneys can remove only about a liter an hour; drink to thirst.
- Ignoring thirst during practice. Thirst is a real signal from your osmoreceptors; drink regularly when you can.
- Counting only water. Milk, soup, fruit and other foods and drinks all supply water too.

Make it a game • Nephron Walkthrough. Model the nephron on the kitchen table with cups: filtration, reabsorption and ADH. Pour water through a strainer for filtration and pour most back to show reabsorption, giving the numbers. Explain homeostasis and Verney's discovery. Your parent plays an examiner and asks what happens if osmolality rises. Fastest correct explanation wins.

Scripture. “For thou hast possessed my reins” (Psalm 139:13, KJV)

In the King James Bible “reins” means the kidneys, a picture of the hidden, inmost parts of a person. The quiet, careful work of the kidneys every minute is part of how we are fearfully and wonderfully made.

2.2 EXERTIONAL HEAT ILLNESS: COOL FIRST, TRANSPORT SECOND

OBJECTIVES

- Tell the story of Korey Stringer and the founding of the Korey Stringer Institute.
- Distinguish heat cramps, heat syncope, heat exhaustion and exertional heat stroke by their signs, and give the first aid for each.
- Explain why cold-water immersion is the best treatment for heat stroke and compare cooling rates in a lab.
- Use the heat index and WBGT, explain heat acclimatization, and write a heat-emergency action plan.

Warm-up. Five-minute warm-up in the shade or indoors: 1 minute of brisk walking, 10 arm circles each way, 10 walking knee hugs, 10 lateral shuffles each way, 10 squats and 30 seconds of easy jogging. Think about it: how does your body get rid of the heat your muscles are making right now?

WATCH

What happens when you get heat stroke? - Douglas J. Casa

TED-Ed • 3:54

<https://www.youtube.com/watch?v=PpHM4DfPZQU>

WHEN TO WATCH

After “The story.” Listen for the difference between compensable and uncompensable heat stress and the action plan at the end.

Note: The lesson is by Douglas Casa, who directs the Korey Stringer Institute. It opens with his own collapse during a race as a young runner.

BACKUP VIDEO

Exertional heat stroke: Cooling people quickly

The Sports Institute at UW Medicine • 1:55

<https://www.youtube.com/watch?v=ClybGMbA9N8>

After the “Good form” paragraph on first aid.

KEY TERMS

heat exhaustion

Inability to keep exercising in the heat, with heavy sweating, weakness, headache, nausea or dizziness; body temperature is raised but the person thinks clearly.

cold-water immersion

Placing a person with heat stroke in a tub of ice water up to the neck, stirring the water, until the core temperature falls to about 102°F (39°C); the fastest cooling method known.

WBGT (wet-bulb globe temperature)

A measure of heat stress that combines air temperature, humidity, sunshine and wind; many schools use it to decide whether and how practice may be held.

exertional heat stroke

A medical emergency in which hard exercise drives the core temperature above about 104°F (40°C) and the brain is affected: confusion, odd behavior, collapse or seizure.

heat acclimatization

The body's adjustment to heat over about 10–14 days of gradually increasing exercise in the heat: earlier and more sweating, a lower heart rate and a cooler core.

CORE IDEAS

The story. Korey Stringer was a 27-year-old Pro Bowl offensive tackle for the Minnesota Vikings, a big, strong, well-liked man who was married and had a young son. On July 31, 2001, at the team's training camp in Mankato, Minnesota, he practiced in full pads on a day when the heat index was above 100°F. He had been unwell the day before. After practice he became confused and collapsed. By the time he reached the hospital his body temperature was about 108.8°F, and he died early the next morning, August 1. His death shocked the nation. In 2010 his widow, Kelci Stringer, worked with the University of Connecticut and the exercise physiologist Douglas Casa to found the **Korey Stringer Institute**, which studies and prevents sudden death in sport. Casa himself had collapsed with heat stroke during a 10,000-meter race in 1985 and was saved by quick cooling.

How they figured it out. Military doctors and sports scientists had noticed for decades that heat stroke victims who were cooled quickly almost always survived,

while those who were cooled slowly often died or were left with damage to the brain, kidneys or liver. The damage depends on how hot the body gets and *how long* it stays hot. Researchers compared cooling methods by measuring core temperature minute by minute. Ice-water immersion cooled people several times faster than ice packs, fans or air-conditioned rooms. The lesson for coaches was clear: if trained staff can measure the athlete's temperature and cool him on the spot, do it there, before the ambulance ride: **cool first, transport second**. When an athlete with heat stroke is cooled below about 104°F within 30 minutes of collapse, nearly all survive.

How your body works. Working muscles turn only about a quarter of their fuel energy into motion; the rest becomes heat. At rest you make about 100 watts of heat; in hard exercise, a teen can make 800–1,000 watts. The body sheds heat by sending blood to the skin and by **sweating**: each liter of sweat that evaporates carries away about 580 kilocalories of heat. In humid air, sweat drips off instead of evaporating; in hot sun, the skin gains heat. When the heat you make and gain is more than you can shed (**uncompensable heat stress**), core temperature climbs. **Heat cramps** are painful muscle spasms; **heat syncope** is fainting as blood pools in the legs; **heat exhaustion** is weakness, nausea and headache with clear thinking; **exertional heat stroke** is a core temperature above about 104°F (40°C) with brain dysfunction. The key warning sign is change in the brain: confusion, stumbling, irritability, saying odd things.

Good form. Heat cramps: stop, stretch and massage, drink fluids with some salt. Heat syncope: lie down in the shade with legs raised. Heat exhaustion: stop, move to shade or air conditioning, remove extra clothing and equipment, cool with cold wet towels and fans, sip fluids; seek medical care if not improving in about 30 minutes. **Suspected heat stroke: call 911**, remove equipment, and cool aggressively at once: an ice-water tub up to the neck if available, otherwise a tarp of ice water, or cold wet towels rotated over the whole body with ice. Medical staff cool until the core temperature falls to about 102°F (39°C), then transport. **Prevention:** acclimatize over about 14 days (many state high-school associations require it, starting with shorter practices and helmets only), check the heat index or WBGT (at 90°F and 60 percent humidity the heat index is about 100°F; some state rules stop outdoor practice when WBGT is above about 92°F), schedule hard work for cooler hours, rest in shade, drink regularly, and never practice while sick.

Try it. In Session 2 you will compare three cooling methods on bottles of warm water with a thermometer and calculate cooling rates. In Session 3 you will plan and carry out a heat-smart training session and write a heat-emergency action plan for your family or team.

PICTURE STUDY



Dorando Pietri Helped across the Finish Line, Olympic Marathon, London, Unknown photographer, July 24, 1908 · Photograph · Public domain photograph (Olympic Games, White City Stadium, London)

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

The Italian runner Dorando Pietri entered the stadium first at the end of the 1908 Olympic marathon, run on a warm afternoon. He was so exhausted that he turned the wrong way, fell several times and was helped across the line by officials. Because he had been helped, he was disqualified, and the gold medal went to the American Johnny Hayes. Queen Alexandra gave Dorando a gilded silver cup for his courage.

Look closely

- Look at Dorando's face and legs. What signs of exhaustion can you see?
- Find the officials holding him up. What would you have done in their place?
- Look at what he wears on his head and body. How might clothing help or hurt in a long race on a warm day?
- Look at the crowd behind. How might excitement push a runner to keep going when he should stop?

Talk about it

1. From this photograph alone, we cannot tell whether Dorando had heat exhaustion, heat stroke or simple exhaustion. What one sign would tell a medical team that it was heat stroke?

2. Today, what would medical staff at the finish line do for a collapsed runner with confusion?
3. Dorando was praised for courage. When is it brave to keep going, and when is it wise to stop?

Safety first. Use only hot tap water for the cooling lab (never boiling water), and have an adult handle it. Do the training session in the cooler part of the day, in shade if possible, with water available and a buddy; stop and move to shade at the first sign of dizziness, nausea, headache, chills or confusion. If anyone becomes confused or collapses during exercise in the heat, call 911 at once and begin cooling.

ACTIVITY

The Cooling Lab and a Heat-Smart Session

Why is ice water the gold standard for heat stroke? You will find out by measuring how fast three methods cool a “body” of warm water. Then you will put prevention into practice with a training session planned around the heat.

You will need

- Three identical plastic bottles (16–20 oz), hot tap water, a kitchen thermometer (an instant-read probe is best)
- A bucket or large bowl of ice water, a towel soaked in cold water, an electric fan
- A timer; graph paper; fitness journal with a cooling table (minute, bottle A ice water, bottle B wet towel and fan, bottle C still air)
- A weather app or local forecast showing temperature and relative humidity

Steps

1. **Set up.** An adult fills three bottles with hot tap water and adjusts each to about 106°F (41°C), a heat-stroke temperature. Measure and record each starting temperature.
2. **Start the clock.** At the same moment, place bottle A in the ice water up to its neck and stir the water gently; wrap bottle B in the cold wet towel in front of the fan; leave bottle C standing in still air.
3. **Measure.** Every minute for 10 minutes, quickly measure the temperature inside each bottle (the same depth each time). Record every reading.
4. **Calculate.** For each method, find the cooling rate: (starting temperature – final temperature) ÷ 10 minutes, in °F per minute. How many minutes would each method take to bring a body from 106°F to 102°F at that rate?
5. **Graph** all three lines on one set of axes and write a conclusion: which method would you want for a teammate with heat stroke, and why? (Water carries heat away about 25 times faster than air.)

6. **Session 3: the heat-smart session.** Check the temperature and humidity and use a heat-index chart to find the heat index. Choose the coolest time of day. Plan a 30-minute session (warm-up, 15 minutes of brisk running, skipping or a game, cool-down), with a water break every 10–15 minutes in shade. Before, during and after, a buddy asks you three questions (name, date, where you are) and you rate how you feel from 1 to 10.
7. **Write your heat-emergency action plan:** who calls 911, the address to give, where the cooling supplies are (tub or tarp, ice, towels), how to recognize heat stroke, and who meets the ambulance.

Tips

- Stirring the ice water matters: still water warms up next to the bottle and slows cooling.
- Acclimatize gradually when the weather turns hot or before a season begins: shorter, easier sessions the first several days.
- Light-colored, loose, breathable clothing helps sweat evaporate; dark, heavy layers trap heat.

Check your work

- ☐ I can name the signs of heat exhaustion and exertional heat stroke and the key difference between them.
- ☐ I measured and graphed three cooling methods and calculated cooling rates.
- ☐ I wrote a heat-emergency action plan and can explain “cool first, transport second.”

FITNESS JOURNAL

1. Make a table of the four heat illnesses: signs, body temperature, first aid, when to call 911.
2. Copy your cooling data and graph. Show the cooling-rate calculation for each method.
3. Record the heat index for three times of day (morning, midafternoon, evening) and circle the safest time to train.
4. Write a paragraph about Korey Stringer and what changed because of him.

From history. After Korey Stringer's death, many states adopted heat-acclimatization rules for high-school sports, and the Korey Stringer Institute now ranks states on their athlete-safety policies. Dorando Pietri's 1908 marathon was the first to be run at the distance of 26 miles 385 yards, which later became the standard marathon distance.

COMMON MISTAKES

- Waiting for the ambulance before cooling someone with suspected heat stroke. Call 911 and start cooling at once; minutes matter.
- Thinking an athlete who is still sweating cannot have heat stroke. Many athletes with exertional heat stroke are still sweating.
- Judging heat by temperature alone. Humidity and sun matter; use the heat index or WBGT.
- Training hard in the heat on the first hot days of the season. Acclimatize over about two weeks.

Make it a game • Heat Illness Triage. Your parent reads signs from a practice field and you triage: heat cramps, heat syncope, heat exhaustion or exertional heat stroke. State the first aid and why cool first, transport second. Score a point per correct call within fifteen seconds. Then tell Korey Stringer's story. Set a goal of eight in a row.

UNIT 2

HYDRATION

Your body is more than half water, and it keeps the saltiness of that water within about one percent of its set point every hour of your life. In this unit you will follow the scientists who discovered how: Claude Bernard, who taught that living things keep a steady “internal environment”; Walter Cannon, who named the idea homeostasis; and Ernest Verney, whose experiments in 1947 located the brain’s water sensor. You will learn how a million nephrons in each kidney filter about 180 liters of fluid a day, how antidiuretic hormone fine-tunes what you keep, how much a teen needs to drink, and why drinking far too much can be as dangerous as drinking too little.

Then you will study the most serious heat danger for athletes: **exertional heat stroke**. You will hear the story of Korey Stringer, the Minnesota Vikings lineman who died after a hot practice in 2001, and of the Korey Stringer Institute that now teaches coaches and athletic trainers to save lives with one rule: **cool first, transport second**. You will test cooling methods with a thermometer and write a heat-emergency plan for your family or team.

PREREQUISITES

- Knows the activity guidelines and the talk test (Unit 1)
- Can convert between cups, fluid ounces, milliliters and liters (1 cup = 8 fl oz $\approx$ 240 mL; 1 L $\approx$ 4.2 cups)
- Can read a thermometer in °F and °C and calculate a rate of change

MASTERY CHECKLIST

- ☐ I can explain homeostasis and describe how the kidneys, antidiuretic hormone and thirst keep body water in balance.
- ☐ I can trace filtration and reabsorption through a nephron and calculate how much filtrate the kidneys make in a day.
- ☐ I can state about how much fluid a teen needs and explain the danger of drinking far more than the kidneys can remove (hyponatremia).
- ☐ I can recognize heat exhaustion and exertional heat stroke and explain “cool first, transport second.”
- ☐ I can explain heat acclimatization, the heat index and WBGT, and write a heat-emergency action plan.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Your Kidneys” (Nemours TeensHealth):** Free. A clear teen article on how the kidneys filter blood and balance fluids. Read it with Lesson 2.1.
- **Korey Stringer Institute, University of Connecticut:** Free. Research-based pages on heat stroke, cold-water immersion, heat acclimatization and state high-school safety policies. Use with Lesson 2.2.
- **A reusable water bottle with ounce or milliliter marks:** Handy for the fluid log. A measuring cup works just as well.

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 Fluid Balance: The Kidneys and the Body's Water Sensor

3 sessions of 45–50 minutes

2.2 Exertional Heat Illness: Cool First, Transport Second

3 sessions of 45–50 minutes

UNIT 2 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Define homeostasis and name the scientist who coined the word. What did Claude Bernard teach about the “internal environment”?

2. 10 pts

Describe Ernest Verney's 1947 experiment and his conclusion.

3. 10 pts

Calculation. The kidneys filter about 125 mL per minute. (a) How many liters is that per day? (b) If a student makes 1.8 L of urine in a day, what percentage of the filtrate was reabsorbed? (c) About how many times a day is a 5-liter blood volume filtered?

4. 10 pts

Explain step by step what happens to ADH, thirst and urine after a student sweats heavily at practice without drinking.

5. 10 pts

Calculation. During a 4-hour race a runner drinks 1.5 L of water per hour while sweating 0.5 L per hour. Because blood flow to the kidneys falls during hard exercise, her kidneys make only about 0.3 L of urine per hour. How much extra water does she gain each hour and by the end of the race? What danger does this create?

6. **10 pts**

Name the four heat illnesses from Lesson 2.2 and give the key sign and first aid for each.

7. **10 pts**

Calculation. In the cooling lab, a bottle in stirred ice water cooled from 106°F to 98°F in 10 minutes, and a bottle in still air cooled from 106°F to 104°F. Find each cooling rate. How long would each take to bring a body from 106°F to 102°F at those rates?

8. **10 pts**

What does “cool first, transport second” mean, and why does it save lives?

9. **10 pts**

Explain heat acclimatization, the heat index and WBGT, and give three ways a team can prevent heat illness.

10. **10 pts**

Short written answer. Tell the story of Korey Stringer in a paragraph and explain what has changed in sports because of him.

ANSWER KEY

1. Homeostasis is the body's work of keeping internal conditions such as water, salt, temperature and sugar steady within narrow limits. Walter Cannon coined the word in 1926. Claude Bernard taught that the fluid inside the body, the blood and the fluid bathing the cells, must stay nearly constant even when the outside world changes, and that this makes a free, active life possible.
2. Verney gave water-loaded, trained dogs a small infusion of concentrated salt solution into the artery leading to the brain. Urine flow dropped sharply within minutes, while infusing water had the opposite effect. He concluded that osmoreceptors near the base of the brain sense when the blood is too concentrated and trigger the release of antidiuretic hormone from the pituitary, which makes the kidneys save water.
3. (a) $125 \text{ mL} \times 1,440 \text{ min} = 180,000 \text{ mL} = 180 \text{ L}$ per day. (b) $(180 - 1.8) \div 180 = 178.2 \div 180 = 0.99$, so 99 percent was reabsorbed. (c) $180 \div 5 = 36$ times a day. (Strictly, the kidneys filter plasma, about 3 L, so the plasma is filtered about 60 times a day; either reasoning with the working shown earns credit.)
4. Sweat removes water, so the blood becomes slightly more concentrated (higher osmolality). Osmoreceptors in the hypothalamus sense this and make the student thirsty, and the pituitary releases more ADH. ADH opens aquaporin water channels in the collecting ducts, so more water returns to the blood. The student makes a smaller amount of darker urine until he drinks and balance is restored.
5. Gain each hour = intake – sweat – urine = $1.5 - 0.5 - 0.3 = 0.7 \text{ L}$. Over 4 hours: $0.7 \times 4 = 2.8 \text{ L}$ of extra water. The extra water dilutes the sodium in her blood, risking exercise-associated hyponatremia: headache, nausea, confusion and swelling, and in severe cases seizures or death. She should drink to thirst instead of forcing fluids.
6. Heat cramps: painful muscle spasms; stop, stretch, massage, drink fluids with some salt. Heat syncope: fainting or light-headedness; lie down in shade with legs raised. Heat exhaustion: weakness, heavy sweating, headache, nausea with clear thinking; stop, move to shade, remove equipment, cool with wet towels and fans, sip fluids, seek care if not better. Exertional heat stroke: core temperature above about 104°F with confusion or collapse; call 911 and cool immediately, ideally in an ice-water tub, until about 102°F , then transport.
7. Ice water: $(106 - 98) \div 10 = 0.8^{\circ}\text{F}$ per minute; $4^{\circ}\text{F} \div 0.8 = 5$ minutes. Still air: $(106 - 104) \div 10 = 0.2^{\circ}\text{F}$ per minute; $4^{\circ}\text{F} \div 0.2 = 20$ minutes. Ice water cools four times

faster. (A real body is much larger than a bottle and cools more slowly, but the comparison holds.)

8. When trained medical staff are present, an athlete with exertional heat stroke is cooled on the spot, ideally by cold-water immersion, until the core temperature falls to about 102°F, and only then taken to the hospital (911 is called at once). Damage depends on how hot the body gets and how long it stays hot; nearly all athletes cooled below about 104°F within 30 minutes of collapse survive, while delay during transport allows organ damage.
9. Heat acclimatization is the body's adjustment over about 10–14 days of gradually increasing exercise in the heat: earlier and more sweating, lower heart rate, cooler core. The heat index combines temperature and humidity into how hot it feels; WBGT also includes sun and wind and is used by many schools to set practice rules. Prevention (any three): a gradual 14-day acclimatization period; practicing in cooler hours; regular water and shade breaks; checking WBGT or heat index and changing or canceling practice; lighter clothing and equipment; not practicing while sick; an emergency plan with a cooling tub.
10. Answers will vary. A strong answer states that Korey Stringer, a Minnesota Vikings Pro Bowl tackle, collapsed after a hot practice at training camp in Mankato on July 31, 2001, with a body temperature near 108.8°F, and died the next morning; that his widow helped found the Korey Stringer Institute at the University of Connecticut in 2010 with Douglas Casa; and that because of this work many schools and states now require heat acclimatization, WBGT-based practice rules, emergency action plans and cold-water immersion tubs.

UNIT CHALLENGE: FIVE-DAY FLUID LOG AND HEAT-EMERGENCY ACTION PLAN

Keep a fluid log for five days, including at least two training days, recording every drink in cups and milliliters, morning urine color and thirst. Total each day in liters, graph intake beside urine color, and compare with the adequate intake for your age. Then write and post a one-page heat-emergency action plan for your family, team or co-op: the signs of heat exhaustion and heat stroke, who calls 911 and what address to give, where cooling supplies are kept, how cooling is done, and who meets the ambulance. Walk your family through it.

LOOK FOR	WHAT IT MEANS
Accurate log	Five dated days with every drink measured and recorded in two units, urine color and thirst noted honestly.
Analysis	Correct daily totals in liters, a clear graph, and a sensible comparison with the adequate intake, with working shown.
Action plan	Clear, correct steps for recognizing and treating heat illness, with names, address and cooling supplies, practiced with the family.
Reflection	A paragraph on what the student changed in his or her drinking and training habits, and why. Effort and honest records count, not the size of the numbers.

UNIT 3

NUTRITION

Food is a gift and fuel. In this unit you will see how scientists discovered what “fuel” means. In 1782–83 Antoine Lavoisier and Pierre-Simon Laplace put a guinea pig inside a jacket of ice and measured how much ice its body heat melted, and they concluded that breathing is a slow, gentle kind of burning. You will follow the energy from a plate of food into ATP, the molecule every muscle cell spends, and learn the three energy systems that power a sprint, a 400-meter race and a long hike. Calories appear here only as a unit for measuring food energy; your growing body needs plenty of it, and under-fueling harms bones and growth.

Then you will look at what happens to food before it reaches the plate. Nicolas Appert won a French government prize in 1810 for preserving food in sealed, boiled bottles, and Clarence Birdseye learned to flash-freeze fish from the Inuit of Labrador. Processing can keep food safe and nutritious, or it can turn whole foods into products loaded with added sugar, refined starch and salt. You will learn to tell the difference on a label, and you will plan, shop for and cook a whole-food dinner for your family.

PREREQUISITES

- Knows that carbohydrate, protein and fat are the macronutrients and can read a Nutrition Facts label (earlier grades)
- Can multiply grams by 4 or 9 and find a percentage
- Has a parent available to supervise knives and the stove, and has checked for food allergies in the family

MASTERY CHECKLIST

- ☐ I can describe Lavoisier's ice calorimeter and his work with Seguin, and explain what they showed about breathing and work.
- ☐ I can explain how food energy becomes ATP and describe the phosphagen, glycolytic and aerobic energy systems.
- ☐ I can calculate the energy in a food from grams of carbohydrate, protein and fat, treating calories as units, not limits.
- ☐ I can explain the processing spectrum, using Appert and Birdseye as examples, and read an ingredient list and added-sugar line wisely.
- ☐ I can plan, prepare and safely cook a whole-food meal with good knife skills and food safety.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **"How to Understand and Use the Nutrition Facts Label" (U.S. Food and Drug Administration)**: Free. The FDA's guide to serving size, percent Daily Value, added sugars, sodium and fiber. Use with Lessons 3.1 and 3.2.
- **An instant-read kitchen thermometer**: For checking that meat, poultry and eggs are cooked to a safe temperature in Lesson 3.2. Many kitchens already have one.

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 Energy and Metabolism: Lavoisier's Ice Calorimeter

3 sessions of 45–50 minutes

3.2 Whole and Processed Foods: Appert's Bottles and a Home-Cooked Meal

UNIT 3 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Describe Lavoisier and Laplace's ice calorimeter experiment and their conclusion.

2. 10 pts

What did Lavoisier and Seguin measure in 1789–90, and what did they find?

3. 10 pts

Calculation. The latent heat of melting ice is about 80 calories per gram (0.08 kilocalories per gram). If an animal melted 330 grams of ice in 10 hours, how much heat did it produce in kilocalories, and how much per hour?

4. 10 pts

Compare the three energy systems: how fast each remakes ATP, about how long it can lead, and an example of each.

5. 10 pts

Calculation. A lunch has 85 g of carbohydrate, 35 g of protein and 22 g of fat. Calculate its energy in kilocalories and the percentage that comes from carbohydrate.

6. 10 pts

Why should growing athletes never try to under-eat for their training? Give two effects of low energy and two practical habits.

7. 10 pts

Tell how Nicolas Appert and Clarence Birdseye changed food preservation, and explain the science behind each method.

8. **10 pts**

Sort these foods into whole or minimally processed, processed, and ultra-processed: frozen peas, a sports candy bar, canned black beans, plain oats, cheese, a cola, fresh-baked bread from a bakery, an apple.

9. **10 pts**

Calculation. A teen needs about 2,400 kilocalories a day. (a) What is the added-sugar limit in grams under the 10 percent guideline? (b) A breakfast of flavored yogurt (15 g added sugar) and a frosted cereal (12 g added sugar) uses what percentage of that limit?

10. **10 pts**

Short written answer. Describe the whole-food meal you cooked: what you made, one food-safety rule and one knife-safety rule you followed, and what you would change next time.

ANSWER KEY

1. In 1782–83 they placed a guinea pig in a chamber surrounded by packed ice (with an outer ice jacket to block room heat) and measured how much ice its body heat melted in about ten hours. They compared this with the heat from burning charcoal that produced the same amount of carbon dioxide. The amounts were close, so they concluded that respiration is a slow combustion: the animal combines food with oxygen and releases heat.
2. They measured the oxygen Seguin used while resting before eating, after a meal, in the cold, and while lifting a weight repeatedly with his foot. Oxygen use rose with digestion and cold, and work raised it to roughly two to four times the resting amount, showing that the body uses more fuel and oxygen for work.
3. $330 \text{ g} \times 0.08 \text{ kcal/g} = 26.4$ kilocalories in 10 hours, or $26.4 \div 10 = 2.64$ kilocalories per hour.
4. Phosphagen system: fastest, leads for about the first 10 seconds; example, a 40-meter sprint or a heavy set of 3. Anaerobic glycolysis: fast, 2 ATP per glucose, leads from about 10 seconds to 2 minutes; example, a 400-meter race. Aerobic system: slower but huge capacity, about 30–32 ATP per glucose, uses glucose and fat with oxygen; leads beyond about 2 minutes; example, a soccer game, a long run or a hike. All three work at once.
5. Carbohydrate $85 \times 4 = 340$; protein $35 \times 4 = 140$; fat $22 \times 9 = 198$. Total = $340 + 140 + 198 = 678$ kilocalories. Carbohydrate share = $340 \div 678 \approx 0.50$, about 50 percent.
6. The body needs energy for growth, repair and training; too little energy harms performance and health. Effects (any two): weaker bones and more stress fractures, poorer growth, more injuries, slower recovery, tiredness, poorer concentration. Habits (any two): eat regular meals and snacks, eat a carbohydrate-rich snack 1–3 hours before training, eat carbohydrate and protein after training, include fruits and vegetables, drink water.
7. Appert, a Paris cook, sealed food in glass bottles and heated them in boiling water; he won a 12,000-franc government prize in 1810 and published his method. Heat destroys the germs that spoil food (explained later by Pasteur), and the seal keeps new ones out. Birdseye learned in Labrador that fish frozen very quickly stayed fresh; fast freezing forms tiny ice crystals that do not burst cells, and in the 1920s he built quick-freezing machines; Birds Eye frozen foods went on sale in 1930.
8. Whole or minimally processed: frozen peas, plain oats, an apple. Processed: canned black beans, cheese, fresh-baked bakery bread. Ultra-processed: the

candy bar and the cola. (Canned beans may be called minimally processed; either answer with a reason earns credit.)

9. (a) 10% of 2,400 = 240 kilocalories; $240 \div 4 = 60$ grams of added sugar. (b) $15 + 12 = 27$ g; $27 \div 60 = 0.45$, or 45 percent of the daily limit at breakfast.

10. Answers will vary. A strong answer names the dishes and their food groups, states a correct food-safety rule (hand washing for 20 seconds, separate boards, chicken to 165°F , refrigerate leftovers within 2 hours) and a correct knife rule (damp towel under the board, claw grip, cut away from the body, never catch a falling knife), and gives a specific improvement.

UNIT CHALLENGE: A FAMILY DINNER FROM WHOLE FOODS

Plan, shop for, cook and serve a complete dinner for your family made from whole and simply processed foods: a protein, a whole grain or potato, at least two vegetables and fruit. Prepare a planning sheet with the menu, shopping list and time plan; calculate the approximate energy and the carbohydrate, protein and fat of one serving from labels or a food database, treating calories as fuel units; and photograph or draw the plate. After the meal, write a reflection with your family's ratings, what went well, what you would change, and a short prayer or note of thanks for the meal.

LOOK FOR	WHAT IT MEANS
Planning	A complete menu, shopping list and realistic time plan, with whole-food choices and allergies checked.
Safe, skilled cooking	A parent confirms good knife skills, hand washing, separate boards and safe cooking temperatures.
Nutrition analysis	Correct energy and macronutrient calculations for one serving, with working shown and a sentence about what the meal supplies.
Reflection	Family ratings, honest notes on what went well and what to change, and thanks for the meal. Effort and growth count, not perfection.

3.1 ENERGY AND METABOLISM: LAVOISIER’S ICE CALORIMETER

OBJECTIVES

- Describe Lavoisier and Laplace’s ice calorimeter and the Lavoisier–Seguin experiments, and explain what they showed.
- Explain how food energy becomes ATP through cellular respiration, and compare the three energy systems.
- Calculate food energy from grams of macronutrients, and explain why growing athletes need ample energy.
- Measure how breathing and heart rate rise with work, as Seguin’s oxygen use did, and plan a pre-training snack.

Warm-up. Five-minute warm-up: 1 minute of marching, 1 minute of step-ups on the bottom stair, 10 squats, 10 push-ups, 10 glute bridges and 30 seconds of jumping jacks. Put a hand in front of your mouth and feel your breath. Think about it: your breath is warm and damp. Where did that heat and water come from?

WATCH

Cellular Respiration (UPDATED)

Amoeba Sisters • 8:47

<https://www.youtube.com/watch?v=eJ9Zjc-jdys>

WHEN TO WATCH

After the “How your body works” paragraph. Watch for the equation, where glycolysis and the Krebs cycle happen, and how much ATP comes from one glucose.

Note: A cartoon biology lesson for high-school students. It compares respiration with photosynthesis in plants before focusing on the cell’s energy pathways.

KEY TERMS

metabolism

All the chemical reactions in the body, including breaking down food for energy and building new tissue.

ATP (adenosine triphosphate)

The molecule cells use as ready energy; splitting off one phosphate releases energy for muscle contraction and other work.

energy systems

The three ways muscles remake ATP: the phosphagen system (about the first 10 seconds), anaerobic glycolysis (about 10 seconds to 2 minutes) and the aerobic system (longer efforts).

calorie (kilocalorie)

A unit of energy: the heat needed to raise 1 kilogram of water by 1°C (4.184 kilojoules). The “Calories” on food labels are kilocalories.

cellular respiration

The process in which cells use oxygen to break down glucose and fats into carbon dioxide and water, making ATP:
$$\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} + \text{energy.}$$

resting metabolic rate

The energy the body uses at rest to keep the heart beating, the brain working, the body warm and tissues growing and repairing.

CORE IDEAS

The story. Antoine Lavoisier was the great chemist of eighteenth-century France. He showed that air contains a gas he named oxygen and that burning is the combination of a substance with oxygen. He wondered whether the warmth of a living animal came from the same kind of process. In the winter of 1782–83 he and the mathematician Pierre-Simon Laplace built an **ice calorimeter**: an inner chamber surrounded by a jacket of packed ice, with an outer jacket of more ice to keep out the heat of the room. They placed a guinea pig in the inner chamber for about ten hours and collected the water from the melted ice. Then they compared the heat with the heat from burning charcoal that produced the same amount of carbon dioxide (“fixed air”).

How they figured it out. The two amounts of heat were close. Lavoisier and Laplace concluded that **respiration is a slow combustion**: the animal combines food with oxygen and releases heat, just as burning charcoal does, only gently and steadily. In

1789–90 Lavoisier and his young assistant Armand Seguin went further. Seguin breathed through a mask while they measured the oxygen he used: resting before breakfast, resting after a meal, sitting in a cold room, and lifting a weight again and again with his foot. Work raised his oxygen use to roughly two to four times the resting amount. They had discovered that the body uses more fuel and oxygen for warmth, for digestion and above all for work. Lavoisier's work was cut short: he was executed in 1794 during the Reign of Terror in France. Later scientists, such as Wilbur Atwater in America, built large calorimeters and measured the energy in thousands of foods.

How your body works. Food energy cannot be used directly; it must first be transferred into **ATP**. Your muscles store only a few seconds' worth of ATP, so they must remake it constantly. The **phosphagen system** (high-energy phosphate stored in the muscle) remakes ATP almost instantly and powers about the first 10 seconds of an all-out sprint or a heavy set. **Anaerobic glycolysis** splits glucose without oxygen, makes ATP fast but only 2 molecules per glucose, and powers hard efforts lasting about 10 seconds to 2 minutes, such as a 400-meter race. The **aerobic system** in the mitochondria uses oxygen to break down glucose and fat completely, yielding about 30–32 ATP per glucose; it powers everything longer, from a soccer game to a long hike, and does most of the work of recovery. All three run at once; the blend shifts with intensity and time.

Think it through. Carbohydrate and protein each supply about 4 kilocalories per gram and fat about 9. A breakfast of two eggs, two slices of whole-wheat toast, a banana and a cup of milk has roughly 64 g of carbohydrate, 30 g of protein and 20 g of fat: $64 \times 4 + 30 \times 4 + 20 \times 9 = 256 + 120 + 180 = 556$ kilocalories of fuel. The Dietary Guidelines estimate that active 14- and 15-year-olds need about 2,400 kilocalories a day for girls and about 2,800–3,000 for boys, more in hard training; this is not a number to count but a picture of how much fuel growth and sport require. Athletes who regularly eat too little for their training can lose bone strength, stop growing well and get injured more often. Eat regular meals, with carbohydrate for fuel, protein for repair and plenty of fruits and vegetables, and give thanks: whether you eat or drink, do it all to the glory of God.

Try it. In Session 2 you will repeat Lavoisier and Seguin's question at home: how much harder do your lungs and heart work as you go from rest to heavy work? In

Session 3 you will repeat the test with a planned snack beforehand and compare how you felt and performed.

PICTURE STUDY



The Potato Eaters, Vincent van Gogh, 1885 · Oil on canvas · Van Gogh Museum, Amsterdam

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

Before he became famous, Vincent van Gogh lived among farm families in the Dutch village of Nuenen. He wanted to show that these people had earned their meal with their own hands, “dug the earth,” he wrote, and he painted their rough hands in the lamplight. Their supper is a platter of potatoes they grew themselves.

Look closely

- Count the people. What food is on the table, and how do they divide it among themselves?
- Look closely at their hands. What kind of work do you think those hands did all day?
- Find the lamp. How much light is there? What time of day is it?
- Look at the wall above the left side. What small picture hangs there?

Talk about it

1. Potatoes are mostly carbohydrate with some protein, vitamin C and potassium. Why would a meal of potatoes suit people who did hard physical work all day?
2. Lavoisier showed that work raises the body's need for fuel. How does this painting show that idea?

3. This family eats together after work. What does eating together give besides food energy?

Safety first. Warm up first and use a sturdy bottom stair or step with a rail or wall nearby; stop if you feel dizzy or have chest pain. Do not skip meals before training; eat a normal meal or snack 1–3 hours beforehand. If you have diabetes or any medical eating plan, follow your doctor’s plan for food around exercise.

ACTIVITY

Seguin's Experiment at Home and a Fueling Plan

You cannot measure oxygen at home, but you can measure two things that rise with it: breathing rate and heart rate. You will repeat Lavoisier and Seguin's question with your own body and then plan how to fuel a training session.

You will need

- A sturdy bottom stair or step about 7–8 inches high, a backpack with a few books, a timer
- A helper to count your breaths
- A few food labels (bread, cereal, milk, yogurt) and a calculator
- Fitness journal with a table: condition, breaths per minute, heart rate (beats per minute), how it felt (1–10)

Steps

1. **Rest.** Sit quietly for 5 minutes (at least an hour after eating). Your helper counts your breaths for 1 minute while you breathe normally; take your pulse for 15 seconds and multiply by 4. Record both.
2. **Light work.** Walk slowly around the room for 3 minutes. In the last 30 seconds, count breaths for 30 seconds and double; take your pulse right after. Record.
3. **Moderate work.** Step up and down the stair at a steady rhythm (up-up-down-down) for 3 minutes, about 20 steps a minute. Measure again.
4. **Heavy work (Seguin's weight).** Put on the backpack and step at about 30 steps a minute for 3 minutes. Measure again.
5. **Recovery.** Sit down and measure breaths and pulse at 1, 2 and 3 minutes. Graph breathing rate and heart rate against work level. How many times higher than resting did each go?
6. **Label energy.** Choose your usual breakfast. From the labels, find grams of carbohydrate, protein and fat, and calculate its energy in kilocalories. Which macronutrient supplies most of the fuel?

7. Session 3: the fueling plan. One to two hours before the session, eat a carbohydrate-rich snack with a little protein (a banana and peanut-butter toast, yogurt and fruit, a bowl of oatmeal) and drink water. Repeat all the measurements. Record how you felt and whether your heart rate at the heavy stage or your recovery changed. Within an hour after, eat a meal or snack with carbohydrate and protein.

Tips

- Count breaths without telling yourself; once you think about breathing, it changes. Let your helper count by watching your shoulders.
- One session's snack will not change your fitness, but it may change how you feel. Note honestly what you notice.
- Every person's numbers are different. Compare only your own stages and sessions.

Check your work

- ☐ I can explain what Lavoisier, Laplace and Seguin measured and concluded.
- ☐ I measured and graphed my breathing and heart rate from rest to heavy work and through recovery.
- ☐ I calculated the energy in a meal from its macronutrients and planned a snack to fuel training.

FITNESS JOURNAL

1. Draw the ice calorimeter: guinea pig, inner ice jacket, outer ice jacket, the drain collecting melted water. Label how heat flows.
2. Copy your rest-to-work table and graph. Write the ratio of heavy-work heart rate to resting heart rate.
3. Make a three-column chart of the energy systems: how fast, how long, an example from your own sport or play.
4. Show your breakfast energy calculation and write one sentence about why your body needs this fuel.

From history. Marie-Anne Paulze Lavoisier, Antoine's wife, worked beside him as translator, illustrator and recorder; she drew the laboratory scenes of his respiration experiments and engraved the plates for his famous chemistry textbook of 1789.

COMMON MISTAKES

- Thinking calories are something to fear. A calorie is a unit of energy; growing athletes need plenty of fuel.
- Believing fat or carbohydrate is “bad.” Both are fuels; the body uses a blend all day.
- Training on an empty stomach to “toughen up.” It lowers performance and recovery; eat beforehand.
- Saying the energy systems take turns. All three work at once; the blend changes with how hard and how long you work.

Make it a game · Energy System Quiz. Do a ten-second sprint, a one-minute hard effort and a five-minute easy jog, and name which energy system dominated each. Explain how food becomes ATP. Retell Lavoisier's ice calorimeter experiment. Your parent sneaks one wrong fact into her questions; catch it. Then plan a fueling snack for the next hard session.

Scripture. “Whether therefore ye eat, or drink, or whatsoever ye do, do all to the glory of God.” (1 Corinthians 10:31, KJV)

Eating is not a matter of indifference or fear; it is part of how we glorify God, receiving food with thanks and using its strength for good work.

3.2 WHOLE AND PROCESSED FOODS: APPERT'S BOTTLES AND A HOME-COOKED MEAL

OBJECTIVES

- Tell how Nicolas Appert invented canning and how Clarence Birdseye developed quick-freezing, and explain why processing can be helpful.
- Describe the processing spectrum from whole foods to ultra-processed products, and judge a food by its ingredient list and label.
- Calculate added sugar as a share of the Dietary Guidelines limit.
- Plan, prepare and safely cook a whole-food meal using proper knife skills and food-safety rules.

Warm-up. Kitchen-ready warm-up (5 minutes): 1 minute of brisk walking, 10 wall push-ups, 10 squats, 10 calf raises, wrist and finger circles, and 10 shoulder rolls. Then wash your hands with soap for 20 seconds. Think about it: of everything you ate yesterday, how much came straight from a plant or an animal, and how much came from a factory?

WATCH

Jacques Pépin Techniques: Proper Knife Skills for Cutting, Chopping and Slicing

KQED Food • 3:58

<https://www.youtube.com/watch?v=nffGuGwCE3E>

WHEN TO WATCH

Before Session 2. Watch how he holds the knife, curls the fingers of his other hand and keeps the blade against his knuckles.

Note: From the public-television series of the French chef Jacques Pépin. Practice slowly; speed comes later.

KEY TERMS

whole (minimally processed) food

Food eaten as it grows or with only simple changes such as washing, cutting, drying, freezing or pasteurizing: fruit, vegetables, eggs, milk, plain meat and fish, beans, oats, rice.

ultra-processed food

Industrial products made mostly from refined ingredients (sugars, starches, oils) plus additives such as flavorings, colors and emulsifiers, like most sodas, candy and many packaged snacks.

nutrient density

How many vitamins, minerals, fiber and protein a food supplies compared with its energy.

processed food

Food changed by cooking, canning, salting or combining a few ingredients, such as canned beans, cheese, fresh bread or canned fish.

added sugars

Sugars and syrups put into foods during processing or preparation, listed separately on the Nutrition Facts label; natural sugars in fruit and milk are not counted.

CORE IDEAS

The story. At the end of the 1700s, armies and navies lost more men to hunger and disease than to battle, and the French government offered a prize for a better way to preserve food. Nicolas Appert, a Paris confectioner and cook, began experimenting around 1795. He packed food into thick glass bottles, corked and wired them shut, and heated them in boiling water for a set time. Soups, vegetables, fruit and meat kept for months, even years. The French navy tested his bottles on voyages, and in 1810 the government awarded him 12,000 francs on the condition that he publish his method, which he did in *The Art of Preserving All Kinds of Animal and Vegetable Substances for Several Years*. The same year an Englishman, Peter Durand, patented the tin can. More than a century later, an American fur trader named Clarence Birdseye watched Inuit fishermen in Labrador catch fish at about -40°F ; the fish froze almost instantly, and when thawed months later they tasted fresh.

How they figured it out. Appert did not know why his method worked; that came in the 1860s, when Louis Pasteur showed that tiny living germs spoil food and heat destroys them. Birdseye figured out why fast freezing mattered: slow freezing forms large ice crystals that burst the food's cells and make it mushy, while very fast freezing forms tiny crystals that leave cells whole. In the 1920s he built machines that froze packaged food quickly between cold metal plates, and in 1930 Birds Eye frozen foods went on sale. These inventions show that **processing is not the enemy**: canned tomatoes, frozen peas, pasteurized milk and dried beans are safe, cheap and nutritious. In 2009–2010 a team led by Carlos Monteiro at the University of São Paulo proposed sorting foods by *how* they are processed, from whole foods, to cooking ingredients like oil and flour, to simply processed foods, to **ultra-processed** products built mostly from refined ingredients and additives.

How your body works. Whole foods come packaged by God with fiber, water, vitamins and minerals. Fiber slows digestion, so the sugar in an apple enters the blood more gradually than the sugar in apple-flavored candy, and it feeds the helpful bacteria in your gut; teens need about 25–31 grams a day. Many ultra-processed foods remove the fiber, add sugar, refined starch, salt and fat, and are designed to be eaten quickly. The *Dietary Guidelines for Americans* advise keeping **added sugars** below 10 percent of daily energy and sodium below 2,300 milligrams a day for ages 14 and up. For a teen who needs 2,400 kilocalories, 10 percent is 240 kilocalories, and $240 \div 4 = 60$ grams of added sugar. A flavored drink with 39 grams of added sugar uses $39 \div 60 = 65$ percent of that limit at once. None of this makes a birthday cake “bad”: treat foods have their place at feasts and celebrations, and nutrient-dense foods carry the everyday load.

Good form. Knife skills: put a damp towel under the cutting board so it cannot slide; hold the handle with three fingers and pinch the base of the blade with your thumb and forefinger; curl the fingertips of your other hand into a “claw,” knuckles against the flat of the blade; rock the knife forward and down. **Food safety:** wash hands for 20 seconds before cooking and after touching raw meat; use separate boards for raw meat and vegetables; cook poultry to 165°F, ground meat to 160°F and eggs until firm; refrigerate leftovers within 2 hours. A parent supervises knives and the stove, and everyone checks for food allergies first.

Try it. In Session 2 you will compare ingredient lists, practice knife skills and plan a whole-food dinner. In Session 3 you will shop with your family (or use what is in the

kitchen), cook the meal, time yourself and serve it.

PICTURE STUDY



The Kitchen Maid, Jean Siméon Chardin, 1738 · Oil on canvas · National Gallery of Art, Washington, D.C.

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

Jean Siméon Chardin painted ordinary people at ordinary tasks with great respect. Here a kitchen maid has paused in the middle of peeling turnips for the household's dinner. Everything in the scene is a whole food or a tool for preparing it.

Look closely

- Find every food in the painting. Which are whole foods? Is anything processed?
- Look at how she holds the knife and the turnip. Is she cutting toward or away from herself?
- Find the bowl of water at her feet. Why might peeled turnips be kept in water?
- Look at the chopping block, cleaver and pans. What will happen to these vegetables next?

Talk about it

1. This dinner took hours of hand work to prepare. What has processing (canning, freezing, washing machines for vegetables) given families since then?

2. What does a whole-food meal give your body that many ultra-processed foods do not?
3. Chardin made a humble kitchen task beautiful. Why is preparing food for others worthy work?

Safety first. A parent supervises all knife and stove work. Keep the board steady on a damp towel, use the claw grip, cut away from your body, and never try to catch a falling knife. Wash hands after touching raw meat, use separate boards, cook poultry to 165°F, turn pot handles inward, and check everyone's food allergies before choosing ingredients.

ACTIVITY

Plan, Shop and Cook a Whole-Food Dinner

You will become the cook. After comparing labels and practicing knife skills, you will plan and cook a dinner for your family built from whole and simply processed foods, then cook a second dish or improve the first.

You will need

- Two similar foods with labels, one whole or simply processed and one ultra-processed (for example plain oats and a frosted cereal, or plain yogurt and a dessert yogurt)
- A cutting board, a damp towel, a sharp chef's knife, a paring knife, measuring cups, a large skillet or sheet pan, an instant-read thermometer
- Ingredients for the meal, for example: chicken thighs or a can of beans, brown rice or potatoes, three or four colorful vegetables (onion, peppers, carrots, broccoli, zucchini), olive oil, salt, pepper, garlic and herbs
- Fitness journal with a planning page: menu, shopping list, time plan and a label-comparison table

Steps

1. **Label lab (Session 2).** For your two foods, copy the ingredient list, count the ingredients, and record serving size, added sugars, fiber and sodium. Calculate each food's added sugar as a percentage of a 60-gram daily limit. Which is more nutrient-dense?
2. **Knife practice.** With a parent watching, practice the claw grip on an onion, a carrot and a pepper: slice, dice and mince slowly. Aim for even pieces so they cook at the same speed.
3. **Plan the meal.** Choose a protein, a whole grain or potato, and at least two vegetables, plus a fruit for dessert. Write a shopping list and a time plan working backward from dinner time (for example, start rice 45 minutes before; chop for 15 minutes; sauté 20 minutes).
4. **Shop (or gather).** Go with your family or use what is in the kitchen. If you buy something canned or frozen, check the label for added sugar and sodium.

5. **Cook (Session 3).** Wash hands, set out every ingredient, cook the grain, prepare the protein (check chicken reaches 165°F with the thermometer), and sauté or roast the vegetables in a little oil with salt, pepper and herbs. Clean as you go.
6. **Serve and give thanks.** Time the whole job from start to table. Ask your family to rate taste and appearance from 1 to 5 and write down one suggestion.
7. **Improve.** Later in the week, cook the meal again (or a whole-food breakfast or lunch), using the suggestion and trying to cut 10 minutes from your time with better planning.

Tips

- Read the whole recipe and lay out every ingredient before you turn on the stove; good cooks call it “everything in its place.”
- Frozen vegetables and canned beans count as whole-food choices; they are quick, cheap and nutritious. Rinse canned beans to remove some salt.
- Season at the end and taste (cooked food only); a squeeze of lemon or a pinch of salt often makes the dish.

Check your work

- ☐ I can explain how Appert and Birdseye preserved food and why processing can help.
- ☐ I can sort foods along the processing spectrum and compare labels for added sugar, fiber and sodium.
- ☐ I planned, cooked and served a whole-food meal safely, with good knife skills.

FITNESS JOURNAL

1. Copy your label-comparison table and show the added-sugar percentage calculations.
2. Draw your dinner plate and label each food as whole, processed or ultra-processed, and as carbohydrate, protein, fruit or vegetable.
3. Write your time plan and, after cooking, note how long each step really took.
4. Record your family’s ratings and suggestions and what you will change next time.

From history. Appert opened one of the world's first commercial canneries near Paris, and the French honored him with the title "Benefactor of Humanity." Clarence Birdseye sold his frozen-food company in 1929 for about 22 million dollars; the Birds Eye name is still on freezer cases today.

COMMON MISTAKES

- Thinking all processed food is bad. Canned, frozen and dried foods are often excellent choices; read the ingredient list.
- Judging a food by the front of the package. "Natural," "made with fruit" or "multigrain" can mean little; read the back.
- Using a dull knife or a sliding board. Dull knives slip; a damp towel keeps the board steady.
- Guessing whether chicken is done. Use a thermometer: 165°F.

Make it a game • Label Courtroom. Put a processed food on trial. Your parent argues for it, you argue against, using the ingredient list, added sugars and nutrient density. Judge the case by a rubric of five points. Then tell how Appert's bottles and Birdseye's freezing helped. Sketch the whole-food alternative on paper and defend it in sixty seconds.

NUTRITION

Food is a gift and fuel. In this unit you will see how scientists discovered what “fuel” means. In 1782–83 Antoine Lavoisier and Pierre-Simon Laplace put a guinea pig inside a jacket of ice and measured how much ice its body heat melted, and they concluded that breathing is a slow, gentle kind of burning. You will follow the energy from a plate of food into ATP, the molecule every muscle cell spends, and learn the three energy systems that power a sprint, a 400-meter race and a long hike. Calories appear here only as a unit for measuring food energy; your growing body needs plenty of it, and under-fueling harms bones and growth.

Then you will look at what happens to food before it reaches the plate. Nicolas Appert won a French government prize in 1810 for preserving food in sealed, boiled bottles, and Clarence Birdseye learned to flash-freeze fish from the Inuit of Labrador. Processing can keep food safe and nutritious, or it can turn whole foods into products loaded with added sugar, refined starch and salt. You will learn to tell the difference on a label, and you will plan, shop for and cook a whole-food dinner for your family.

PREREQUISITES

- Knows that carbohydrate, protein and fat are the macronutrients and can read a Nutrition Facts label (earlier grades)
- Can multiply grams by 4 or 9 and find a percentage
- Has a parent available to supervise knives and the stove, and has checked for food allergies in the family

MASTERY CHECKLIST

- ☐ I can describe Lavoisier's ice calorimeter and his work with Seguin, and explain what they showed about breathing and work.
- ☐ I can explain how food energy becomes ATP and describe the phosphagen, glycolytic and aerobic energy systems.
- ☐ I can calculate the energy in a food from grams of carbohydrate, protein and fat, treating calories as units, not limits.
- ☐ I can explain the processing spectrum, using Appert and Birdseye as examples, and read an ingredient list and added-sugar line wisely.
- ☐ I can plan, prepare and safely cook a whole-food meal with good knife skills and food safety.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **"How to Understand and Use the Nutrition Facts Label" (U.S. Food and Drug Administration)**: Free. The FDA's guide to serving size, percent Daily Value, added sugars, sodium and fiber. Use with Lessons 3.1 and 3.2.
- **An instant-read kitchen thermometer**: For checking that meat, poultry and eggs are cooked to a safe temperature in Lesson 3.2. Many kitchens already have one.

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 Energy and Metabolism: Lavoisier's Ice Calorimeter

3 sessions of 45–50 minutes

3.2 Whole and Processed Foods: Appert's Bottles and a Home-Cooked Meal

UNIT 3 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Describe Lavoisier and Laplace's ice calorimeter experiment and their conclusion.

2. 10 pts

What did Lavoisier and Seguin measure in 1789–90, and what did they find?

3. 10 pts

Calculation. The latent heat of melting ice is about 80 calories per gram (0.08 kilocalories per gram). If an animal melted 330 grams of ice in 10 hours, how much heat did it produce in kilocalories, and how much per hour?

4. 10 pts

Compare the three energy systems: how fast each remakes ATP, about how long it can lead, and an example of each.

5. 10 pts

Calculation. A lunch has 85 g of carbohydrate, 35 g of protein and 22 g of fat. Calculate its energy in kilocalories and the percentage that comes from carbohydrate.

6. 10 pts

Why should growing athletes never try to under-eat for their training? Give two effects of low energy and two practical habits.

7. 10 pts

Tell how Nicolas Appert and Clarence Birdseye changed food preservation, and explain the science behind each method.

8. **10 pts**

Sort these foods into whole or minimally processed, processed, and ultra-processed: frozen peas, a sports candy bar, canned black beans, plain oats, cheese, a cola, fresh-baked bread from a bakery, an apple.

9. **10 pts**

Calculation. A teen needs about 2,400 kilocalories a day. (a) What is the added-sugar limit in grams under the 10 percent guideline? (b) A breakfast of flavored yogurt (15 g added sugar) and a frosted cereal (12 g added sugar) uses what percentage of that limit?

10. **10 pts**

Short written answer. Describe the whole-food meal you cooked: what you made, one food-safety rule and one knife-safety rule you followed, and what you would change next time.

ANSWER KEY

1. In 1782–83 they placed a guinea pig in a chamber surrounded by packed ice (with an outer ice jacket to block room heat) and measured how much ice its body heat melted in about ten hours. They compared this with the heat from burning charcoal that produced the same amount of carbon dioxide. The amounts were close, so they concluded that respiration is a slow combustion: the animal combines food with oxygen and releases heat.
2. They measured the oxygen Seguin used while resting before eating, after a meal, in the cold, and while lifting a weight repeatedly with his foot. Oxygen use rose with digestion and cold, and work raised it to roughly two to four times the resting amount, showing that the body uses more fuel and oxygen for work.
3. $330 \text{ g} \times 0.08 \text{ kcal/g} = 26.4$ kilocalories in 10 hours, or $26.4 \div 10 = 2.64$ kilocalories per hour.
4. Phosphagen system: fastest, leads for about the first 10 seconds; example, a 40-meter sprint or a heavy set of 3. Anaerobic glycolysis: fast, 2 ATP per glucose, leads from about 10 seconds to 2 minutes; example, a 400-meter race. Aerobic system: slower but huge capacity, about 30–32 ATP per glucose, uses glucose and fat with oxygen; leads beyond about 2 minutes; example, a soccer game, a long run or a hike. All three work at once.
5. Carbohydrate $85 \times 4 = 340$; protein $35 \times 4 = 140$; fat $22 \times 9 = 198$. Total = $340 + 140 + 198 = 678$ kilocalories. Carbohydrate share = $340 \div 678 \approx 0.50$, about 50 percent.
6. The body needs energy for growth, repair and training; too little energy harms performance and health. Effects (any two): weaker bones and more stress fractures, poorer growth, more injuries, slower recovery, tiredness, poorer concentration. Habits (any two): eat regular meals and snacks, eat a carbohydrate-rich snack 1–3 hours before training, eat carbohydrate and protein after training, include fruits and vegetables, drink water.
7. Appert, a Paris cook, sealed food in glass bottles and heated them in boiling water; he won a 12,000-franc government prize in 1810 and published his method. Heat destroys the germs that spoil food (explained later by Pasteur), and the seal keeps new ones out. Birdseye learned in Labrador that fish frozen very quickly stayed fresh; fast freezing forms tiny ice crystals that do not burst cells, and in the 1920s he built quick-freezing machines; Birds Eye frozen foods went on sale in 1930.
8. Whole or minimally processed: frozen peas, plain oats, an apple. Processed: canned black beans, cheese, fresh-baked bakery bread. Ultra-processed: the

candy bar and the cola. (Canned beans may be called minimally processed; either answer with a reason earns credit.)

9. (a) 10% of $2,400 = 240$ kilocalories; $240 \div 4 = 60$ grams of added sugar. (b) $15 + 12 = 27$ g; $27 \div 60 = 0.45$, or 45 percent of the daily limit at breakfast.

10. Answers will vary. A strong answer names the dishes and their food groups, states a correct food-safety rule (hand washing for 20 seconds, separate boards, chicken to 165°F , refrigerate leftovers within 2 hours) and a correct knife rule (damp towel under the board, claw grip, cut away from the body, never catch a falling knife), and gives a specific improvement.

UNIT CHALLENGE: A FAMILY DINNER FROM WHOLE FOODS

Plan, shop for, cook and serve a complete dinner for your family made from whole and simply processed foods: a protein, a whole grain or potato, at least two vegetables and fruit. Prepare a planning sheet with the menu, shopping list and time plan; calculate the approximate energy and the carbohydrate, protein and fat of one serving from labels or a food database, treating calories as fuel units; and photograph or draw the plate. After the meal, write a reflection with your family's ratings, what went well, what you would change, and a short prayer or note of thanks for the meal.

LOOK FOR	WHAT IT MEANS
Planning	A complete menu, shopping list and realistic time plan, with whole-food choices and allergies checked.
Safe, skilled cooking	A parent confirms good knife skills, hand washing, separate boards and safe cooking temperatures.
Nutrition analysis	Correct energy and macronutrient calculations for one serving, with working shown and a sentence about what the meal supplies.
Reflection	Family ratings, honest notes on what went well and what to change, and thanks for the meal. Effort and growth count, not perfection.

UNIT 4

STRENGTH

How does a muscle actually pull? For centuries no one knew. On May 22, 1954, the journal *Nature* printed two papers side by side: one by Andrew Huxley and Rolf Niedergerke in Cambridge, the other by Hugh Huxley and Jean Hanson, working at the Massachusetts Institute of Technology. Using different microscopes and different muscles, both teams saw the same thing: muscle shortens because two sets of protein filaments slide past each other. You will build a scale model of a sarcomere and measure what they measured, and learn how nerves, motor units and training make muscles stronger.

Then you will learn to design a strength program the way the modern field began: with Thomas DeLorme, an army doctor who in 1945 rebuilt the strength of wounded soldiers with carefully counted sets of ten. You will learn sets, reps, rest, load and progression, practice the squat, hinge, push, pull and carry patterns with body weight, household loads or light dumbbells, and write a four-week program. Free weights are used only with a knowledgeable adult present and a spotter for any pressing lift, and we never test a one-repetition maximum.

PREREQUISITES

- Can perform a bodyweight squat, push-up and plank with good form (earlier grades and Unit 1)
- Knows the role of ATP and the energy systems (Unit 3)
- Has a knowledgeable adult available to supervise every session with loads

MASTERY CHECKLIST

- ☐ I can tell the story of the 1954 sliding-filament papers and describe the bands of a sarcomere and what changes when it contracts.
- ☐ I can explain the cross-bridge cycle and the roles of calcium and ATP, and describe motor units and the size principle.
- ☐ I can explain how strength grows: early nerve adaptations, then muscle growth, with rest, food and sleep.
- ☐ I can tell how DeLorme developed progressive resistance exercise and calculate a three-sets-of-ten workout from a 10-rep load.
- ☐ I can design a safe four-week program with sets, reps, rest and progression for the five movement patterns.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Strength Training” (Nemours TeensHealth):** Free. A teen article on the benefits of strength training, supervision, good form and why to avoid maximal lifts and supplements. Read with Lesson 4.2.
- **A pair of light, adjustable or fixed dumbbells:** Optional. Water jugs, a backpack with books and body weight do the same job in every activity.

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 How a Muscle Contracts: The Sliding-Filament Discovery of 1954

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Who published the two sliding-filament papers in 1954, what did each team study, and what did they observe about the A band and the I band?

2. 10 pts

Calculation. A sarcomere shortens from 2.4 μm to 1.9 μm . The thick filaments are 1.6 μm long. (a) What is the I band length (total) before and after? (b) A muscle fiber is 8 cm long at a sarcomere length of 2.4 μm . How many sarcomeres are in series, and how much does the fiber shorten?

3. 10 pts

Describe the cross-bridge cycle, including the roles of calcium and ATP.

4. 10 pts

What is a motor unit? Explain the size principle using the example of picking up an empty mug and then a full gallon jug.

5. 10 pts

Why do beginners gain strength so quickly in the first few weeks, and what produces gains after that? Name three things muscles need to grow.

6. 10 pts

Tell how Thomas DeLorme developed progressive resistance exercise, and describe the DeLorme–Watkins three-set method.

7. **10 pts**

Calculation. Your 10-rep load for the one-arm row is 18 lb. (a) Give DeLorme's three loads. (b) Calculate the volume load if you do 10, 10 and 11 reps. (c) You do 12 reps in the third set two workouts in a row. What is a 5–10 percent increase, and what is your new 10-rep load?

8. **10 pts**

Name the five movement patterns and give an exercise and one form cue for each.

9. **10 pts**

List four safety rules for high-school strength training in this course and explain why we estimate strength from a 10-rep set instead of a one-rep maximum.

10. **10 pts**

Short written answer. Describe the four-week program you designed: days, exercises, sets and reps, rest and how you will progress, and explain how it follows DeLorme's principle.

ANSWER KEY

1. Andrew Huxley and Rolf Niedergerke studied living frog muscle fibers with an interference microscope in Cambridge; Hugh Huxley and Jean Hanson studied rabbit myofibrils with phase-contrast and electron microscopes at MIT. Both papers appeared in *Nature* on May 22, 1954. Both saw that the A band stayed the same length while the I band and H zone shortened during contraction, so the filaments slide past each other rather than shrinking.
2. (a) Before: $2.4 - 1.6 = 0.8 \mu\text{m}$. After: $1.9 - 1.6 = 0.3 \mu\text{m}$. The A band stays $1.6 \mu\text{m}$.
(b) $8 \text{ cm} = 80,000 \mu\text{m}$; $80,000 \div 2.4 \approx 33,333$ sarcomeres. Each shortens by $0.5 \mu\text{m}$, so the fiber shortens by about $33,333 \times 0.5 \approx 16,667 \mu\text{m} \approx 1.7 \text{ cm}$.
3. A nerve impulse releases calcium inside the fiber. Calcium binds troponin, which moves tropomyosin off actin's binding sites. A cocked myosin head attaches to actin and performs the power stroke, pulling the thin filament toward the center. A new ATP binds so the head releases; splitting the ATP re-cocks the head for the next cycle. When nerve signals stop, calcium is pumped back (using ATP) and the muscle relaxes.
4. A motor unit is one motor nerve cell and all the muscle fibers it controls. By the size principle, the nervous system recruits small motor units first and adds larger ones as more force is needed. Lifting the empty mug recruits only a few small units; lifting the heavy jug recruits many more, including large ones, and they fire faster.
5. In the first 4–8 weeks, most gains come from the nervous system: recruiting more motor units, firing them faster and coordinating muscles better. After that, the fibers add more actin and myosin and grow thicker (hypertrophy). Muscles need progressive work, food (especially protein and enough energy) and rest with sleep (8–10 hours for teens).
6. DeLorme, an army medical officer at Gardiner General Hospital in Chicago, treated soldiers with leg injuries in World War II by having them lift heavy loads with weighted boots for sets of ten, increasing the load as they grew stronger; they recovered faster, and he published in 1945. With Arthur Watkins in 1948 he refined it: set 1, 10 reps at 50% of the 10-rep maximum; set 2, 10 reps at 75%; set 3, as many reps as possible at 100%; the 10RM is raised as strength increases.
7. (a) 50% = 9 lb, 75% = 13.5 lb (about 13–14 lb), 100% = 18 lb. (b) $10 \times 9 + 10 \times 13.5 + 11 \times 18 = 90 + 135 + 198 = 423 \text{ lb}$. (c) 5–10% of 18 = 0.9–1.8 lb, so the new 10-rep load is about 19–20 lb.

8. Squat: goblet squat; chest up, knees over toes. Hinge: Romanian deadlift or hip bridge; flat back, push the hips back. Push: push-up or dumbbell floor press; body straight (push-up) or elbows about 45 degrees from the body, with a spotter (press). Pull: one-arm row; flat back, pull to the hip. Carry: farmer's carry; stand tall, shoulders down, walk steadily.
9. Rules (any four): a knowledgeable adult is present whenever free weights are used; a spotter stands ready for any pressing lift; learn technique first with a broom handle or very light load; never test a one-repetition maximum; stop a set when form breaks; warm up; rest between sessions for the same muscles; use stable equipment and a clear floor; stop at sharp pain, joint pain, dizziness or chest pain. A one-rep maximum puts the body under its greatest load with the highest risk of form breaking down and injury; a 10-rep set is safer and gives enough information to plan loads, as DeLorme's method shows.
10. Answers will vary. A strong answer lists three nonconsecutive days, the five patterns (plus core), 2–3 sets of about 8–15 reps with 1–2 minutes' rest, a clear progression rule (for example add 5–10 percent when two extra reps are done twice), a lighter week if needed, and explains that load increases gradually as strength grows: progressive resistance exercise.

UNIT CHALLENGE: A FOUR-WEEK STRENGTH PROGRAM, TRAINED AND RECORDED

Using the program you wrote in Lesson 4.2, train three nonconsecutive days a week for at least two weeks (continue all four if you can), with a knowledgeable adult present for every session with loads. Record every set: load, reps, rest and effort. At the end, repeat your 10-rep load check for the goblet squat, row and press (never a one-rep maximum) and compare with your first loads. Make a graph of weekly squat volume load and write a one-page report on what improved, what you learned about form, rest and food, and how you will continue.

LOOK FOR	WHAT IT MEANS
Faithful training	At least six dated sessions on nonconsecutive days, with every set recorded and an adult's initials for each session with loads.
Safe, good form	A parent or knowledgeable adult confirms good technique on all five patterns, spotting for pressing, and no maximal testing.
Calculations and graph	Correct volume-load calculations, a clear weekly graph and before-and-after 10-rep loads.
Report	A thoughtful report on progress, form, recovery and next steps. Effort, consistency and improvement count, not the size of the loads.

4.1 HOW A MUSCLE CONTRACTS: THE SLIDING-FILAMENT DISCOVERY OF 1954

OBJECTIVES

- Tell how two teams discovered the sliding-filament mechanism in 1954 and what each measured.
- Describe the structure of a sarcomere (Z lines, A band, I band, H zone) and explain which bands change length during contraction.
- Explain the cross-bridge cycle, the roles of calcium and ATP, motor units and the size principle.
- Build a scale sarcomere model, take measurements, and feel motor-unit recruitment in a tempo strength session.

Warm-up. Five-minute warm-up: 1 minute of jogging in place, 10 arm circles each way, 10 bodyweight squats, 10 glute bridges, 5 inchworms with a push-up, and 20 seconds of fast punches in the air. Think about it: when you bend your elbow, the biceps gets shorter and fatter. What is happening inside it?

WATCH

Muscle Tissues and Sliding Filament Model

Amoeba Sisters • 8:20

<https://www.youtube.com/watch?v=dpxalWAC07k>

WHEN TO WATCH

After “How they figured it out.” Watch for the three kinds of muscle tissue, the sarcomere, actin and myosin, and the roles of troponin and tropomyosin.

Note: A cartoon biology lesson for high-school students.

BACKUP VIDEO

Muscle Contraction - Cross Bridge Cycle, Animation.

Alila Medical Media • 2:49

<https://www.youtube.com/watch?v=BVcgO4p88AA>

For a close-up animation of the cross-bridge cycle step by step.

KEY TERMS

sarcomere

The smallest contracting unit of a muscle fiber, about 2–2.5 micrometers long, running from one Z line to the next.

A band and I band

The dark band (the length of the thick myosin filaments) and the light band (thin filaments only); in contraction the A band stays the same length while the I band shortens.

motor unit

One motor nerve cell and all the muscle fibers it controls; small units make fine movements and large units make powerful ones.

actin and myosin

The two main contractile proteins: thin actin filaments anchored at the Z lines, and thick myosin filaments in the middle whose heads pull on the actin.

cross-bridge

The attachment of a myosin head to actin; each cycle of attach, pull (power stroke), release (using ATP) and re-cock moves the filaments a few nanometers.

size principle

The rule, described by Elwood Henneman in 1957, that motor units are recruited from smallest to largest as more force is needed.

CORE IDEAS

The story. By the early 1950s, scientists knew that muscle fibers are packed with long threads called myofibrils, striped with dark and light bands, and that two proteins, actin and myosin, do the work. Most believed the proteins themselves crumpled or coiled up, like a spring, to make the muscle shorter. Two pairs of scientists set out to look. In Cambridge, England, Andrew Huxley, a physiologist who had already helped explain the nerve impulse, built an interference microscope with the German physiologist Rolf Niedergerke to watch single living fibers from frog muscle as they contracted. At the Massachusetts Institute of Technology, the young English biophysicist Hugh Huxley (no relation to Andrew) and Jean Hanson, a biophysicist from King's College London, studied myofibrils from rabbit muscle with phase-contrast and electron microscopes. On May 22, 1954, *Nature* published both papers back to back.

How they figured it out. Both teams measured the bands as the muscle shortened or was stretched. The dark **A band** stayed the same length. The light **I band** and the pale

H zone in the middle of the A band got shorter. If the proteins were crumpling, every band should shrink. The only explanation that fit was that the filaments themselves stayed the same length and **slid past one another**: the thin actin filaments were pulled in toward the center of the thick myosin filaments, like interlacing fingers sliding together. Three years later Andrew Huxley proposed how: tiny bridges from myosin grab actin, pull, let go and grab again. Electron microscopes later photographed these cross-bridges. Andrew Huxley shared the 1963 Nobel Prize for his work on nerves; Hanson and Hugh Huxley went on to map the structure of muscle in great detail.

How your body works. A nerve impulse arrives at the muscle fiber and spreads into it, releasing **calcium** from storage sacs inside the fiber. Calcium binds to troponin, which moves tropomyosin off the binding sites on actin. Myosin heads, already “cocked” with energy from ATP, attach to actin and swing (the **power stroke**), pulling the thin filaments about 5–10 nanometers. A new ATP lets each head release and re-cock. Thousands of heads cycling out of step in millions of sarcomeres in series shorten the whole muscle. When the nerve stops firing, calcium is pumped back (this uses ATP too) and the muscle relaxes. Your brain grades force through **motor units**: lifting a cup recruits a few small units; lifting a heavy jug adds larger and larger ones (the **size principle**), and they fire faster. In the first 4–8 weeks of training, most strength gain comes from the nervous system learning to recruit more units and coordinate them; after that, the fibers themselves add more actin and myosin and grow thicker. During the teen years, growth hormones make this muscle growth easier than it was in childhood, as long as you give it work, food (especially protein), rest and sleep (8–10 hours for teens).

Think it through. Suppose a sarcomere shortens from 2.5 to 2.0 micrometers while the thick filaments stay 1.6 micrometers long. The A band is still 1.6 μm ; the I band (the total length of thin-filament-only regions) shrinks from $2.5 - 1.6 = 0.9 \mu\text{m}$ to $2.0 - 1.6 = 0.4 \mu\text{m}$. A muscle fiber 10 cm long holds about $100,000 \mu\text{m} \div 2.5 \mu\text{m} = 40,000$ sarcomeres in a row; if each shortens by 0.5 μm , the fiber shortens by $40,000 \times 0.5 \mu\text{m} = 20,000 \mu\text{m}$, or 2 cm. Tiny slides added up make visible movement.

Try it. In Session 2 you will build a scale sarcomere model and reproduce the 1954 measurements, then feel the size principle and train with a slow tempo. In Session 3 you will repeat the tempo session and add a rep or a little load.

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 clearing rough, thistly ground pauses, leaning his whole weight on his hoe. Millet showed the honest cost of hard work: tired muscles, a bent back, a moment to breathe.

Look closely

- Look at how he leans on the hoe. Which muscles are resting, and which are still working to hold him up?
- Find the stones and thistles in the field. How hard would it be to dig this ground? What movements would he repeat all day?
- Look at his face and open mouth. What is happening to his breathing?
- Find the smoke and the distant figure. What other work is going on in this field?

Talk about it

1. Hoeing uses the hinge pattern again and again. Which muscles would be strongest in a man who did this every day? Which might be overused?
2. In your own words, what is happening inside his muscle fibers as he swings the hoe and as he rests?

3. Millet painted this worker with dignity. How is strong, faithful work for others a good use of the body God gave you?

Safety first. Warm up first and move slowly with control, breathing out as you lift; never hold your breath for long. Use only loads you can lift 10 or more times with good form; if you use dumbbells, a knowledgeable adult must be present. Stop and tell an adult if you feel sharp pain, joint pain, dizziness or chest pain.

ACTIVITY

The Sarcomere Model and a Tempo Strength Session

First you will make a scale model and measure what Huxley, Niedergerke, Huxley and Hanson measured. Then you will feel motor units at work and train with a slow tempo, which makes every rep count.

You will need

- Card stock or cereal-box cardboard, scissors, a ruler, markers in two colors, tape, a paper clip
- Household loads: an empty mug, a full gallon jug of water (about 8.3 lb), two full jugs in a sturdy bag; light dumbbells optional
- A towel or mat, a sturdy chair, a timer
- Fitness journal with a model-measurement table and a training log (exercise, tempo, reps, load, effort 1–10)

Steps

1. **Build the model (scale: 10 cm = 1 μ m).** Cut two long strips for the Z lines' positions on a base card 30 cm long. Cut one thick filament (myosin) 16 cm long and color it dark. Cut two thin filaments (actin) 10 cm long each and color them light. Tape one actin strip to each Z-line card so they point toward each other, and lay the myosin strip in the middle, overlapping both.
2. **Relaxed.** Slide the Z lines to 25 cm apart (2.5 μ m). Measure and record: sarcomere length, A band (myosin length), I band (Z line to the start of myosin, both sides added), and H zone (the gap in the middle where actin does not reach).
3. **Contracted.** Slide the Z lines to 20 cm apart (2.0 μ m) and measure again. Then 18 cm. Which bands changed? Which stayed the same? Write a sentence comparing your results with the 1954 papers.
4. **Feel the size principle.** Warm up. Stand and hold each load with your elbow bent at 90 degrees for 10 seconds: the empty mug, one full jug, then the bag with two jugs. With your other hand, feel the firmness of the biceps each time, and rate effort from 1 to 10.

5. **Tempo session.** Do 3 sets of each exercise with a 3-1-1 tempo (3 seconds lowering, 1 second pause, 1 second up), resting 90 seconds between sets: (1) squats or goblet squats holding one jug at the chest, 8–12 reps; (2) push-ups at your level, 6–12 reps; (3) glute bridges, 10–15 reps; (4) one-arm rows with a jug, other hand and knee on a sturdy chair, 8–12 reps each side; (5) plank, 20–40 seconds.
6. Record reps and effort for every set. Stop each set when you have about 2 good reps left in reserve; never grind to failure with broken form.
7. **Cool down:** walk 2 minutes and stretch thighs, hips, chest and back for 20–30 seconds each.
8. **Session 3:** repeat the tempo session. On each exercise, add 1 rep per set, or if you reached the top of the rep range in all 3 sets, use a slightly heavier load (for example, add water to the jug or a book to the backpack).

Tips

- The slow lowering phase is where control is learned. Count “one-thousand, two-thousand, three-thousand.”
- Breathe in as you lower, out as you lift. Brace your middle as if about to be nudged.
- Your effort ratings matter as much as your reps: they tell you whether the load is right.

Check your work

- ☐ I can explain the sliding-filament theory and show with my model which bands change length.
- ☐ I can explain motor units and the size principle from what I felt.
- ☐ I completed two tempo sessions with good form and recorded progress.

FITNESS JOURNAL

1. Draw a sarcomere relaxed and contracted, labeling Z lines, actin, myosin, A band, I band and H zone, with your measured lengths.
2. Draw the cross-bridge cycle in four steps: attach, power stroke, release with ATP, re-cock.
3. Copy your training log and circle the sets where you added a rep or load in Session 3.

4. Write a paragraph: why do beginners get stronger so quickly in the first few weeks, and what takes over after that?

From history. Jean Hanson was one of the leading women scientists of her time in Britain; she was elected a Fellow of the Royal Society in 1967. Andrew Huxley later served as President of the Royal Society and Master of Trinity College, Cambridge.

COMMON MISTAKES

- Saying the filaments shrink. The filaments stay the same length; they slide past each other.
- Rushing reps. Fast, bouncing reps use momentum instead of muscle and risk injury; use a controlled tempo.
- Training to failure every set. Leaving about 2 reps in reserve builds strength with less risk and better form.
- Forgetting recovery. Muscles rebuild during rest, with food and sleep; train the same muscles hard on non-consecutive days.

Make it a game · Sarcomere Build. Model a sarcomere with two bundles of pens or spoons sliding between pegs. Move the filaments and call out which bands shorten: I band and H zone, not the A band. Do a slow-tempo squat set of five while narrating each phase. Your parent grades your explanation of cross-bridges and the size principle.

4.2 PROGRAM DESIGN: DELORME’S THREE SETS OF TEN

OBJECTIVES

- Tell how Thomas DeLorme developed progressive resistance exercise for injured soldiers and how his method became three sets of ten.
- Define and use repetitions, sets, load, rest, volume, frequency and progression, and estimate working loads from a 10-rep set without maximal testing.
- Perform the squat, hinge, push, pull and carry patterns with good form, using body weight, household loads or light dumbbells with an adult present and a spotter for pressing.
- Design and begin a safe four-week, three-day-a-week strength program.

Warm-up. Movement-prep warm-up (6 minutes): 1 minute of brisk marching or skipping; 10 bodyweight squats; 10 hip hinges with a broom handle held along your back (touching head, upper back and tailbone); 10 wall push-ups; 10 band or towel pull-aparts; 20-meter walking lunges; then one light practice set of each lift in today’s session. Think about it: why might a doctor in 1945 count every rep his patients did?

WATCH

Delorme & Watkins Training Systems

Discovery Learning • 7:56

<https://www.youtube.com/watch?v=deCk1bYeTSU>

WHEN TO WATCH

After “How they figured it out.” Watch how the coach finds the 10-rep load, works out 50, 75 and 100 percent of it, and stands ready to spot the dumbbell press.

Note: A small educational channel with few views, chosen because it demonstrates the exact DeLorme–Watkins method and correct spotting. The trainer and lifter wear T-shirts and shorts.

BACKUP VIDEO

How to Make a Strength Training Program | Sets, Reps, and Volume Explained

The Movement System • 6:30

<https://www.youtube.com/watch?v=sEdyG01QKPI>

For more on sets, reps and volume, after the “How your body works” paragraph.

KEY TERMS

repetition and set

A repetition (rep) is one complete movement; a set is a group of reps done without resting.

volume load

Sets × reps × load for an exercise, a simple measure of how much total work was done.

rest interval

The time between sets, usually 1–2 minutes for general strength, to let the phosphagen energy system recover.

10-repetition load (10RM)

The heaviest load you can lift 10 times with good form; DeLorme based his whole method on it. We estimate it by stopping at 10 good reps, never by testing a single maximal lift.

progressive overload

Gradually increasing load, reps or sets as the body adapts; DeLorme called his method progressive resistance exercise.

spotter

A trained helper who stands ready to assist with a pressing lift if the lifter cannot finish a rep safely.

CORE IDEAS

The story. During the Second World War, many young soldiers came home with leg injuries, especially to the knee. The usual treatment was light exercise with many repetitions, and it was slow. Captain Thomas DeLorme, an army medical officer at Gardiner General Hospital in Chicago, had rebuilt his own strength through weight training after illness as a young man. He tried something new: he strapped weighted boots to his patients' feet and had them lift heavy loads for sets of ten repetitions, increasing the weight as they grew stronger. The soldiers recovered strength much faster than with the old methods. In 1945 he published his results as “heavy-resistance exercise,” and in 1948, with Dr. Arthur Watkins, he refined it into **progressive resistance exercise**.

How they figured it out. DeLorme's first programs had patients lift seven to ten sets of ten. He measured and recorded every session and found that fewer, better sets worked as well. His refined method used the **10-repetition maximum**: set 1, ten reps at 50 percent of the 10RM; set 2, ten reps at 75 percent; set 3, as many reps as possible (aiming for ten) at 100 percent. As strength rose, the 10RM was raised. The

two lighter sets served as a built-in warm-up. Nearly every strength program since, from rehabilitation clinics to high-school weight rooms, descends from DeLorme's counted sets of ten. Today's youth guidelines from the National Strength and Conditioning Association recommend that beginners do 1–3 sets of about 8–15 reps of each exercise, 2–3 nonconsecutive days a week, with qualified supervision and technique first.

How your body works. A program has a few dials. **Load and reps:** lighter loads for 12–15 reps build endurance and are best for learning; loads you can lift about 8–12 times build strength and muscle. **Sets:** 2–3 per exercise for teens. **Rest:** 1–2 minutes lets the phosphagen energy system refill. **Frequency:** each muscle group 2–3 times a week, with at least a day between, because muscles rebuild during recovery.

Progression: when you can do two more reps than your target in the last set for two workouts in a row, raise the load by about 5–10 percent. **Patterns:** a balanced program trains the squat (goblet squat), hinge (Romanian deadlift or hip bridge), push (push-up or dumbbell floor press), pull (one-arm row) and carry (farmer's carry). **Worked example:** if your 10-rep goblet squat load is 24 lb, DeLorme's workout is 10 reps at 12 lb, 10 at 18 lb and 10 at 24 lb. $\text{Volume load} = 10 \times 12 + 10 \times 18 + 10 \times 24 = 120 + 180 + 240 = 540 \text{ lb}$. A 5–10 percent increase on 24 lb is 1.2–2.4 lb, so the next 10-rep load is about 25–26 lb.

Good form. Use only light free weights, and **only with a knowledgeable adult present.** Learn every lift first with a broom handle or very light load. For any pressing lift (push-up variations excepted), a spotter kneels or stands ready with hands near the lifter's wrists. **Never test a one-repetition maximum.** Find your working load by doing a set of 10: if 10 good reps were easy with 4 or more left in reserve, go a little heavier next set; if form broke before 10, go lighter. Do your work with all your might, as Ecclesiastes says, but with wisdom: good form first, load second.

Try it. In Session 2 you will learn the five patterns, find a safe 10-rep load for each and complete a DeLorme workout. In Session 3 you will repeat it, apply the progression rule and write a four-week program.

PICTURE STUDY



Astronaut Koichi Wakata Exercising on the Advanced Resistive Exercise Device, International Space Station, NASA, February 2014 · Digital photograph · NASA (U.S. government photograph, public domain)
Image: [Wikimedia Commons](#), public domain

In space, muscles and bones carry almost no load, and without exercise astronauts can lose about 1 to 1.5 percent of the mineral in their hip and spine bones each month. To fight this, crews on the International Space Station exercise about two hours a day. The Advanced Resistive Exercise Device uses vacuum cylinders to create up to about 600 pounds of resistance, so astronauts can squat, deadlift and press as if lifting weights on Earth. Here Japanese astronaut Koichi Wakata trains a squat during Expedition 38.

Look closely

- Look at his position. Which movement pattern is he training? Where are his feet, hips and back?
- Find the bar and the arms that connect it to the machine. Where does the resistance come from, since nothing has weight in orbit?
- Look at his face. How hard does this set look? Do you think he is near the end of it?
- Look at all the equipment around him. Why must every piece be strapped or stored?

Talk about it

1. Why do astronauts need strength training to keep strong bones, according to Wolff's law from Unit 1?
2. NASA trainers plan sets, reps and loads for each astronaut and track progress. How is that like DeLorme's method?
3. If astronauts train two hours a day in space just to stay strong, what does that suggest about how much our bodies depend on daily load on Earth?

Safety first. Free weights are used only with a knowledgeable adult present, and a spotter stands ready for any pressing lift. Learn each lift with a broom handle or very light load first, keep a neutral spine, never test a one-repetition maximum, and stop a set when form breaks. Clear the floor, use sturdy equipment that cannot slide, and stop at sharp pain, joint pain, dizziness or chest pain.

ACTIVITY

DeLorme's Workout and Your Four-Week Program

You will train like DeLorme's patients: find a safe 10-rep load for each pattern, do three counted sets of ten, record everything and progress. Then you will write a four-week program that you begin this week and continue in the unit challenge.

You will need

- A broom handle; two water or milk jugs (one gallon $\approx$ 8.3 lb; half full $\approx$ 4 lb), a backpack with books; light dumbbells if available
- A sturdy bench or chair that will not slide, a mat, a timer
- A knowledgeable adult present for the whole session, and a spotter for the floor press
- Fitness journal with a log table: exercise, 10-rep load, set 1 (50%), set 2 (75%), set 3 (100%), reps, rest, notes

Steps

1. **Learn the five patterns (Session 2, 15 minutes).** With a broom handle or no load, practice 2 sets of 8 slow reps of each: (1) goblet squat: chest up, knees track over toes, hips down to about knee height; (2) Romanian deadlift (hinge): soft knees, push hips back with a flat back until the load is just below the knees, stand by squeezing the seat; (3) floor press: lying on the floor, press up from elbows resting on the floor, with the spotter kneeling behind your head; or push-ups; (4) one-arm row: one hand and knee on the bench, flat back, pull the load to your hip; (5) farmer's carry: a load in each hand, stand tall, walk 20 meters.
2. **Find your 10-rep loads.** For each lift, choose a light load and do 10 reps. If all 10 were smooth and you had 4 or more reps left, rest 2 minutes and try a slightly heavier load. Stop at the load where the 10th rep is challenging but your form is still perfect. Record it. Never try a single maximum lift.
3. **Calculate.** For each lift, work out 50 and 75 percent of your 10-rep load, rounding to what you can actually use (add or pour out water; add or remove books).

4. **DeLorme workout.** For the squat, hinge, press and row: 10 reps at 50 percent, rest 90 seconds; 10 reps at 75 percent, rest 90 seconds; as many good reps as possible (up to 12) at 100 percent. Finish with 3 farmer's carries of 20 meters, resting 60 seconds.
5. **Record** every set and calculate the volume load for your squat.
6. **Session 3:** repeat the workout. Apply the rule: if you did 12 good reps in the 100 percent set, raise that lift's 10-rep load by about 5–10 percent next time.
7. **Write your four-week program:** three nonconsecutive days a week (for example Monday, Wednesday, Friday), the five patterns plus a plank, the sets, reps and rest for each, and your planned progression. Add a deload in week 4 if needed (fewer sets) and list your rest-day activities.

Tips

- Film one set of each lift from the side and compare with the form cues; a coach's eye, even your own on video, catches what you cannot feel.
- Small jumps win. Adding a cup of water (about half a pound) to a jug is real progress.
- Protein at each meal and 8–10 hours of sleep do more for your progress than any extra set.

Check your work

- ☐ I can tell the DeLorme story and calculate a three-sets-of-ten workout from a 10-rep load.
- ☐ I performed the five patterns with good form, with an adult present and a spotter for pressing.
- ☐ I wrote a safe four-week program with sets, reps, rest, frequency and progression.

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1. Copy your training log for both sessions, with the volume-load calculation for one lift.
2. Draw a stick figure for each of the five patterns with two form cues beside each.
3. Write out your four-week program as a table: week, day, exercise, sets × reps, load, rest.

4. Write a paragraph: Why does this course never test a one-repetition maximum, and how do 10-rep loads give you the information you need?

From history. DeLorme's methods spread quickly to civilian hospitals and to athletics. In 1951 the British physician A. N. Zinovieff tried the opposite order, starting each workout with the heaviest set and decreasing the load, known as the Oxford technique; both methods work, because both apply progressive overload.

COMMON MISTAKES

- Choosing a load by ego instead of form. If the back rounds or knees cave, the load is too heavy.
- Skipping the lighter sets. DeLorme's first two sets are both warm-up and work.
- Training without an adult or spotter. Free weights require a knowledgeable adult present and a spotter for pressing.
- Changing the program every week. Keep the same exercises long enough to see progress, at least four weeks.

Make it a game • Program Design Duel. Each of you writes a four-week program for one lift using sets, reps, load, rest, volume and progression, estimating loads from a ten-rep set. Swap papers and find one flaw in the other's plan. A parent supervises any load. Defend your plan in sixty seconds. Most valid critiques wins the round.

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

Training faithfully is a small picture of a larger calling: to give our full effort to the work God sets before us, for His glory and the good of others.

STRENGTH

How does a muscle actually pull? For centuries no one knew. On May 22, 1954, the journal *Nature* printed two papers side by side: one by Andrew Huxley and Rolf Niedergerke in Cambridge, the other by Hugh Huxley and Jean Hanson, working at the Massachusetts Institute of Technology. Using different microscopes and different muscles, both teams saw the same thing: muscle shortens because two sets of protein filaments slide past each other. You will build a scale model of a sarcomere and measure what they measured, and learn how nerves, motor units and training make muscles stronger.

Then you will learn to design a strength program the way the modern field began: with Thomas DeLorme, an army doctor who in 1945 rebuilt the strength of wounded soldiers with carefully counted sets of ten. You will learn sets, reps, rest, load and progression, practice the squat, hinge, push, pull and carry patterns with body weight, household loads or light dumbbells, and write a four-week program. Free weights are used only with a knowledgeable adult present and a spotter for any pressing lift, and we never test a one-repetition maximum.

PREREQUISITES

- Can perform a bodyweight squat, push-up and plank with good form (earlier grades and Unit 1)
- Knows the role of ATP and the energy systems (Unit 3)
- Has a knowledgeable adult available to supervise every session with loads

MASTERY CHECKLIST

- ☐ I can tell the story of the 1954 sliding-filament papers and describe the bands of a sarcomere and what changes when it contracts.
- ☐ I can explain the cross-bridge cycle and the roles of calcium and ATP, and describe motor units and the size principle.
- ☐ I can explain how strength grows: early nerve adaptations, then muscle growth, with rest, food and sleep.
- ☐ I can tell how DeLorme developed progressive resistance exercise and calculate a three-sets-of-ten workout from a 10-rep load.
- ☐ I can design a safe four-week program with sets, reps, rest and progression for the five movement patterns.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **“Strength Training” (Nemours TeensHealth):** Free. A teen article on the benefits of strength training, supervision, good form and why to avoid maximal lifts and supplements. Read with Lesson 4.2.
- **A pair of light, adjustable or fixed dumbbells:** Optional. Water jugs, a backpack with books and body weight do the same job in every activity.

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 How a Muscle Contracts: The Sliding-Filament Discovery of 1954

3 sessions of 45–50 minutes

UNIT 4 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Who published the two sliding-filament papers in 1954, what did each team study, and what did they observe about the A band and the I band?

2. 10 pts

Calculation. A sarcomere shortens from 2.4 μm to 1.9 μm . The thick filaments are 1.6 μm long. (a) What is the I band length (total) before and after? (b) A muscle fiber is 8 cm long at a sarcomere length of 2.4 μm . How many sarcomeres are in series, and how much does the fiber shorten?

3. 10 pts

Describe the cross-bridge cycle, including the roles of calcium and ATP.

4. 10 pts

What is a motor unit? Explain the size principle using the example of picking up an empty mug and then a full gallon jug.

5. 10 pts

Why do beginners gain strength so quickly in the first few weeks, and what produces gains after that? Name three things muscles need to grow.

6. 10 pts

Tell how Thomas DeLorme developed progressive resistance exercise, and describe the DeLorme–Watkins three-set method.

7. **10 pts**

Calculation. Your 10-rep load for the one-arm row is 18 lb. (a) Give DeLorme's three loads. (b) Calculate the volume load if you do 10, 10 and 11 reps. (c) You do 12 reps in the third set two workouts in a row. What is a 5–10 percent increase, and what is your new 10-rep load?

8. **10 pts**

Name the five movement patterns and give an exercise and one form cue for each.

9. **10 pts**

List four safety rules for high-school strength training in this course and explain why we estimate strength from a 10-rep set instead of a one-rep maximum.

10. **10 pts**

Short written answer. Describe the four-week program you designed: days, exercises, sets and reps, rest and how you will progress, and explain how it follows DeLorme's principle.

ANSWER KEY

1. Andrew Huxley and Rolf Niedergerke studied living frog muscle fibers with an interference microscope in Cambridge; Hugh Huxley and Jean Hanson studied rabbit myofibrils with phase-contrast and electron microscopes at MIT. Both papers appeared in *Nature* on May 22, 1954. Both saw that the A band stayed the same length while the I band and H zone shortened during contraction, so the filaments slide past each other rather than shrinking.
2. (a) Before: $2.4 - 1.6 = 0.8 \mu\text{m}$. After: $1.9 - 1.6 = 0.3 \mu\text{m}$. The A band stays $1.6 \mu\text{m}$.
(b) $8 \text{ cm} = 80,000 \mu\text{m}$; $80,000 \div 2.4 \approx 33,333$ sarcomeres. Each shortens by $0.5 \mu\text{m}$, so the fiber shortens by about $33,333 \times 0.5 \approx 16,667 \mu\text{m} \approx 1.7 \text{ cm}$.
3. A nerve impulse releases calcium inside the fiber. Calcium binds troponin, which moves tropomyosin off actin's binding sites. A cocked myosin head attaches to actin and performs the power stroke, pulling the thin filament toward the center. A new ATP binds so the head releases; splitting the ATP re-cocks the head for the next cycle. When nerve signals stop, calcium is pumped back (using ATP) and the muscle relaxes.
4. A motor unit is one motor nerve cell and all the muscle fibers it controls. By the size principle, the nervous system recruits small motor units first and adds larger ones as more force is needed. Lifting the empty mug recruits only a few small units; lifting the heavy jug recruits many more, including large ones, and they fire faster.
5. In the first 4–8 weeks, most gains come from the nervous system: recruiting more motor units, firing them faster and coordinating muscles better. After that, the fibers add more actin and myosin and grow thicker (hypertrophy). Muscles need progressive work, food (especially protein and enough energy) and rest with sleep (8–10 hours for teens).
6. DeLorme, an army medical officer at Gardiner General Hospital in Chicago, treated soldiers with leg injuries in World War II by having them lift heavy loads with weighted boots for sets of ten, increasing the load as they grew stronger; they recovered faster, and he published in 1945. With Arthur Watkins in 1948 he refined it: set 1, 10 reps at 50% of the 10-rep maximum; set 2, 10 reps at 75%; set 3, as many reps as possible at 100%; the 10RM is raised as strength increases.
7. (a) 50% = 9 lb, 75% = 13.5 lb (about 13–14 lb), 100% = 18 lb. (b) $10 \times 9 + 10 \times 13.5 + 11 \times 18 = 90 + 135 + 198 = 423 \text{ lb}$. (c) 5–10% of 18 = 0.9–1.8 lb, so the new 10-rep load is about 19–20 lb.

8. Squat: goblet squat; chest up, knees over toes. Hinge: Romanian deadlift or hip bridge; flat back, push the hips back. Push: push-up or dumbbell floor press; body straight (push-up) or elbows about 45 degrees from the body, with a spotter (press). Pull: one-arm row; flat back, pull to the hip. Carry: farmer's carry; stand tall, shoulders down, walk steadily.
9. Rules (any four): a knowledgeable adult is present whenever free weights are used; a spotter stands ready for any pressing lift; learn technique first with a broom handle or very light load; never test a one-repetition maximum; stop a set when form breaks; warm up; rest between sessions for the same muscles; use stable equipment and a clear floor; stop at sharp pain, joint pain, dizziness or chest pain. A one-rep maximum puts the body under its greatest load with the highest risk of form breaking down and injury; a 10-rep set is safer and gives enough information to plan loads, as DeLorme's method shows.
10. Answers will vary. A strong answer lists three nonconsecutive days, the five patterns (plus core), 2–3 sets of about 8–15 reps with 1–2 minutes' rest, a clear progression rule (for example add 5–10 percent when two extra reps are done twice), a lighter week if needed, and explains that load increases gradually as strength grows: progressive resistance exercise.

UNIT CHALLENGE: A FOUR-WEEK STRENGTH PROGRAM, TRAINED AND RECORDED

Using the program you wrote in Lesson 4.2, train three nonconsecutive days a week for at least two weeks (continue all four if you can), with a knowledgeable adult present for every session with loads. Record every set: load, reps, rest and effort. At the end, repeat your 10-rep load check for the goblet squat, row and press (never a one-rep maximum) and compare with your first loads. Make a graph of weekly squat volume load and write a one-page report on what improved, what you learned about form, rest and food, and how you will continue.

LOOK FOR	WHAT IT MEANS
Faithful training	At least six dated sessions on nonconsecutive days, with every set recorded and an adult's initials for each session with loads.
Safe, good form	A parent or knowledgeable adult confirms good technique on all five patterns, spotting for pressing, and no maximal testing.
Calculations and graph	Correct volume-load calculations, a clear weekly graph and before-and-after 10-rep loads.
Report	A thoughtful report on progress, form, recovery and next steps. Effort, consistency and improvement count, not the size of the loads.

AEROBIC TRAINING

How much oxygen can your body use, and what limits it? In 1870 the German physiologist Adolf Fick wrote down a simple equation that answers the question: the oxygen your body uses equals the blood your heart pumps times the oxygen your tissues take out of each liter. You will follow oxygen from the air to the mitochondria, learn what cardiac output, stroke volume and VO_2 max mean, work Fick's equation with real numbers, and estimate your own aerobic fitness with Kenneth Cooper's 12-minute run.

Then you will learn to train by heart rate. In 1957 the Finnish physiologist Martti Karvonen found that training improved fitness only when the heart rate rose past about 60 percent of the way from resting to maximum. His formula, using **heart-rate reserve**, is still how coaches set training zones. You will calculate your own zones, check them with the talk test and perceived effort, plan a four-week aerobic training block, and finish the quarter by leading your family in a family fitness day.

PREREQUISITES

- Can take a pulse accurately and convert a 15-second count to beats per minute (Unit 1)
- Knows the aerobic and anaerobic energy systems (Unit 3)
- Has a PACER or mile baseline from Lesson 1.2

MASTERY CHECKLIST

- ☐ I can trace oxygen from the lungs to the mitochondria and explain cardiac output, stroke volume and the a-v oxygen difference.
- ☐ I can use Fick's equation to calculate oxygen uptake at rest and during exercise.
- ☐ I can explain VO_2 max, estimate mine from a 12-minute run, and describe how training improves it.
- ☐ I can calculate heart-rate reserve and training zones with the Karvonen formula and check them with the talk test and perceived effort.
- ☐ I can plan a four-week aerobic training block and lead a family fitness day.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A stopwatch or phone timer with a lap button:** For the 12-minute run, pulse counts and interval timing. A heart-rate monitor is a nice extra but never needed.
- **A measured running loop:** A local 400-meter track is ideal; otherwise measure a safe loop with a car odometer or a map app and mark every 100 meters with chalk.

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 The Cardiorespiratory System: Fick's Equation and VO₂ Max

3 sessions of 45–50 minutes

5.2 Heart-Rate Zones and the Karvonen Formula

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. 10 pts

Trace the path of oxygen from the air to a muscle mitochondrion, naming at least six structures.

2. 10 pts

State Fick's principle and tell the story of how it was first used in people.

3. 10 pts

Calculation. At rest a student's stroke volume is 75 mL and heart rate 68 bpm, and the a–v oxygen difference is 50 mL O₂ per liter. (a) Find cardiac output in L/min. (b) Find oxygen uptake. (c) In hard exercise, Q = 18 L/min and the a–v difference is 140 mL/L. Find oxygen uptake and how many times the resting value it is.

4. 10 pts

What is VO₂ max? Describe how A. V. Hill and Hartley Lupton first measured it.

5. **10 pts**

Calculation. A student runs 2,650 meters in the Cooper 12-minute test. Estimate VO_2 max using $\text{VO}_2 \text{ max} \approx (\text{distance} - 504.9) \div 44.73$. Four weeks later she runs 2,780 meters. What is the new estimate and the percentage improvement?

6. **10 pts**

Name three ways aerobic training changes the body, and explain why a trained athlete's resting heart rate is lower.

7. **10 pts**

Describe Karvonen's 1957 study and its main finding.

8. **10 pts**

Calculation. A 14-year-old has a resting heart rate of 70. (a) Estimate maximum heart rate with $220 - \text{age}$ and with $208 - 0.7 \times \text{age}$. (b) Using $220 - \text{age}$, find heart-rate reserve and target heart rates at 60% and 85%. (c) Convert the 60% target to a 15-second count.

9. **10 pts**

Describe the easy, steady and interval zones: about what percent of heart-rate reserve, how each feels (talk test and RPE), and what each trains. What is the rule for increasing training time?

10. **10 pts**

Short written answer. Describe your family fitness day and your retest results compared with your baselines from Lessons 1.2 and 5.1. What habit from this quarter will you keep, and why?

ANSWER KEY

1. Air enters the nose or mouth, passes down the trachea and bronchi to the alveoli; oxygen diffuses across the alveolar and capillary walls into the blood and binds to hemoglobin in red blood cells; the blood returns to the left side of the heart, and the left ventricle pumps it through the aorta and arteries to the muscle capillaries; oxygen diffuses into the muscle fiber and on to the mitochondria, where it is used in aerobic respiration.
2. Oxygen uptake equals cardiac output times the arterial-venous oxygen difference ($VO_2 = Q \times a-vO_2 \text{ diff}$). Adolf Fick stated it in Würzburg in 1870 but could not measure the oxygen in blood returning to the heart. Werner Forssmann passed a catheter into his own heart in 1929, and in the 1940s André Cournand and Dickinson Richards used catheters to measure cardiac output in patients by Fick's method; all three shared the 1956 Nobel Prize.
3. (a) $Q = 75 \text{ mL} \times 68 = 5,100 \text{ mL/min} = 5.1 \text{ L/min}$. (b) $VO_2 = 5.1 \times 50 = 255 \text{ mL O}_2/\text{min}$. (c) $VO_2 = 18 \times 140 = 2,520 \text{ mL O}_2/\text{min}$; $2,520 \div 255 \approx 9.9$, about ten times the resting value.
4. $VO_2 \text{ max}$ is the greatest rate at which the body can take in and use oxygen during hard exercise, usually in mL per kg per minute, and is the best single measure of aerobic fitness. In 1923 Hill and Lupton had runners run faster and faster on a grass track while collecting their breath in bags; oxygen uptake rose with speed and then leveled off at a maximum.
5. First: $(2,650 - 504.9) \div 44.73 = 2,145.1 \div 44.73 \approx 48.0 \text{ mL/kg/min}$. Second: $(2,780 - 504.9) \div 44.73 = 2,275.1 \div 44.73 \approx 50.9 \text{ mL/kg/min}$. Improvement = $(50.9 - 48.0) \div 48.0 \approx 0.06$, about 6 percent.
6. Any three: the left ventricle grows larger and stronger, raising stroke volume; blood volume increases; muscles grow more capillaries; muscles grow more and larger mitochondria and extract more oxygen (wider a-v difference); $VO_2 \text{ max}$ rises. Resting heart rate falls because the heart pumps more blood per beat, so it can supply the same resting cardiac output (about 5 L/min) with fewer beats.
7. Martti Karvonen, E. Kentala and O. Mustala at the University of Helsinki had six young men run on a treadmill for 30 minutes, four or five times a week, for four weeks, each at a controlled heart rate. Only those whose training heart rate rose above a threshold improved, and the threshold was about 60 percent of the way from resting to maximum heart rate (heart-rate reserve), giving the formula $\text{target HR} = \text{resting HR} + \text{intensity} \times (\text{max HR} - \text{resting HR})$.

8. (a) $220 - 14 = 206$; $208 - 0.7 \times 14 = 208 - 9.8 = 198.2 \approx 198$. (b) $HRR = 206 - 70 = 136$.
60%: $70 + 0.60 \times 136 = 70 + 81.6 \approx 152$ bpm. 85%: $70 + 0.85 \times 136 = 70 + 115.6 \approx 186$ bpm. (c) $152 \div 4 = 38$ beats in 15 seconds.
9. Easy: about 50–70% of HRR, full sentences, RPE about 10–12; builds stroke volume, capillaries and mitochondria and allows recovery; most training. Steady or tempo: about 70–80%, short phrases, RPE about 13–15; raises the pace you can sustain. Intervals: about 80–90% and above, only a few words, RPE about 16–18; pushes VO_2 max higher, needs rest days after. Increase total training time by no more than about 10 percent a week.
10. Answers will vary. A strong answer describes the warm-up, stations from each unit, the family run or walk and the snack; reports retest numbers with units beside the baselines and the change; and names a specific habit (such as three aerobic sessions a week, a strength program, a fluid plan, cooking whole-food meals), with a reason that reflects stewardship of the body and thankfulness.

UNIT CHALLENGE: A FOUR-WEEK AEROBIC TRAINING BLOCK

Carry out the four-week block you wrote in Lesson 5.2 (complete at least the first two weeks during the quarter and the rest afterward). Log every session: date, type, duration, distance if known, average or end heart rate, zone and RPE. Each week, record your heart rate at your fixed easy pace from Lesson 5.1 and your morning resting heart rate. At the end, retest the 12-minute run or the PACER and calculate your new VO₂ max estimate. Graph weekly training minutes and your heart rate at the fixed pace, and write a report on what changed and what you learned about patient training.

LOOK FOR	WHAT IT MEANS
Sound plan	Zones calculated correctly with working shown; sessions mostly easy with one hard session a week; weekly increases of about 10 percent or less.
Faithful training log	Every session dated and recorded with duration, zone, heart rate and RPE, and safety rules followed.
Graphs and retest	Clear graphs of training minutes and fixed-pace heart rate, and a correctly calculated retest estimate compared with the baseline.
Report and reflection	A thoughtful report on progress and lessons learned. Effort, consistency and personal improvement count, never comparison with others.

5.1 THE CARDIORESPIRATORY SYSTEM: FICK'S EQUATION AND VO₂ MAX

OBJECTIVES

- Trace oxygen's path from the air to the mitochondria and describe the roles of the lungs, heart, blood and muscles.
- Explain Fick's principle and calculate oxygen uptake from cardiac output and the arterial-venous oxygen difference.
- Define VO₂ max, explain how A. V. Hill first measured it and how training raises it, and estimate your own with the Cooper 12-minute run.
- Measure resting heart rate and heart-rate recovery and record them as fitness markers.

Warm-up. Five-minute warm-up for running: 2 minutes of easy jogging, then 10 high knees, 10 butt kicks, 10 leg swings each leg, 10 walking lunges and 3 relaxed 50-meter strides at a quick but comfortable pace. Think about it: your breathing doubled in the last two minutes. Where is all that extra oxygen going?

WATCH

Oxygen's surprisingly complex journey through your body - Enda Butler

TED-Ed • 5:09

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

WHEN TO WATCH

After the “How your body works” paragraph. Follow oxygen through the alveoli, the red blood cells and the capillaries into the cells.

Note: The cartoon shows a simple skeleton and organs to explain the path of oxygen.

BACKUP VIDEO

Cardiovascular System Physiology - Cardiac Output (stroke volume, heart rate, preload and afterload)

Armando Hasudungan • 5:13

<https://www.youtube.com/watch?v=hpQFToprIH8>

For a deeper look at cardiac output = stroke volume × heart rate, drawn by hand.

KEY TERMS

cardiac output (Q)

The volume of blood the heart pumps each minute: stroke volume $\times$ heart rate; about 5 L/min at rest and 20 L/min or more in hard exercise.

a-v oxygen difference

The difference between the oxygen in arterial blood and in venous blood returning to the heart: how much oxygen the tissues took out of each liter.

VO₂ max

The greatest rate at which the body can take in and use oxygen during hard exercise, usually given in milliliters per kilogram per minute; the best single measure of aerobic fitness.

stroke volume

The volume of blood pumped by one ventricle in one beat, about 70 mL at rest in a teen and higher in trained athletes.

Fick principle

Oxygen uptake = cardiac output $\times$ a-v oxygen difference ($VO_2 = Q \times a-vO_2$ diff), stated by Adolf Fick in 1870.

heart-rate recovery

How much the heart rate falls in the first minute after hard exercise; a faster fall is a sign of better aerobic fitness.

CORE IDEAS

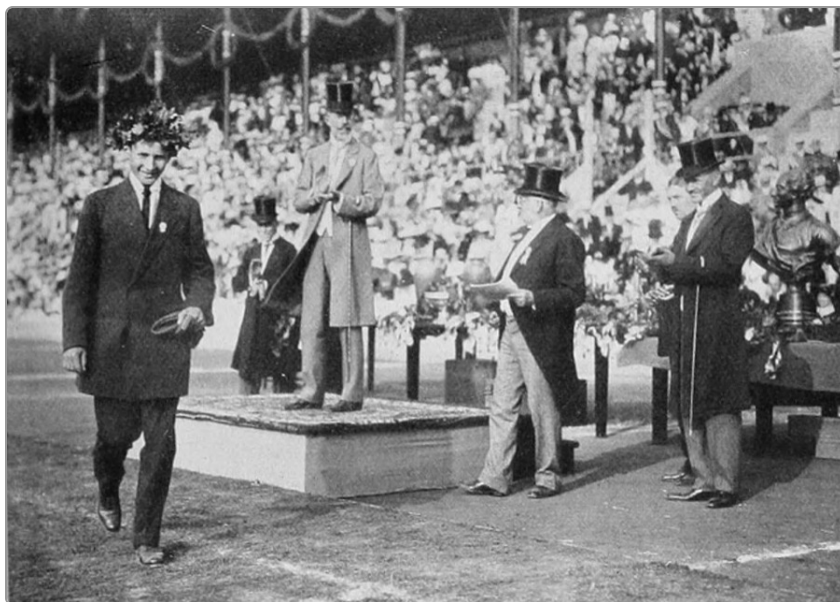
The story. On July 9, 1870, Adolf Fick, the professor of physiology at the University of Würzburg in Germany, gave a very short talk to the city's medical and scientific society. He pointed out that if you know how much oxygen a person takes in each minute, and how much oxygen is in the blood going into and coming out of the lungs, you can calculate how much blood the heart pumps. The idea was simple, but no one could yet measure the oxygen in blood returning to the heart. It was decades before doctors could do it in people: in 1929 the German surgeon Werner Forssmann passed a narrow tube into his own heart, and in the 1940s André Cournand and Dickinson Richards in New York used such catheters to measure cardiac output by Fick's method. All three shared the 1956 Nobel Prize. Meanwhile, in 1923, the British physiologist A. V. Hill and Hartley Lupton had runners go faster and faster on a grass track while they collected their breath in bags, and found that oxygen uptake rose with speed until it reached a ceiling: the **maximal oxygen uptake**, or VO₂ max.

How they figured it out. Fick's equation is $VO_2 = Q \times (a-v \text{ O}_2 \text{ difference})$. At rest a teen's heart might pump 5 liters of blood a minute ($Q = 70 \text{ mL per beat} \times 70 \text{ beats per minute} \approx 4.9 \text{ L/min}$), and the tissues take about 50 mL of oxygen from each liter: $5 \text{ L/min} \times 50 \text{ mL/L} = 250 \text{ mL of oxygen per minute}$. In all-out exercise the heart rate might reach 200 and the stroke volume 100 mL, so $Q = 20 \text{ L/min}$, and the working muscles pull out about 150 mL per liter: $20 \times 150 = 3,000 \text{ mL}$, or 3 liters of oxygen a minute, twelve times the resting rate. Dividing by body mass gives the familiar units: $3,000 \text{ mL} \div 60 \text{ kg} = 50 \text{ mL/kg/min}$. Untrained teens are often in the 35–50 range; the greatest endurance athletes reach the 70s and 80s. Kenneth Cooper showed in 1968 that the distance a person covers in 12 minutes of running tracks $VO_2 \text{ max}$ closely, giving the estimate $VO_2 \text{ max} \approx (\text{distance in meters} - 504.9) \div 44.73$. A student who covers 2,400 m: $(2,400 - 504.9) \div 44.73 \approx 42.4 \text{ mL/kg/min}$.

How your body works. Air reaches about 300–500 million tiny air sacs (**alveoli**) in the lungs, where oxygen crosses a wall finer than a soap bubble into the blood and binds to hemoglobin in red blood cells. The left ventricle pumps this oxygen-rich blood through the arteries to the capillaries, where oxygen moves into the muscle fibers and their mitochondria. Aerobic training improves almost every link. The heart's left ventricle grows larger and stronger, so **stroke volume** rises; that is why a trained athlete's resting heart rate falls (the same 5 L/min with fewer, bigger beats). Blood volume increases. Muscles grow more capillaries and more mitochondria, so they extract more oxygen and the a–v difference widens. In previously untrained people, $VO_2 \text{ max}$ often rises by around 10–20 percent over a few months of training, though people differ in how much they respond. Isaiah promised strength renewed to those who wait upon the Lord; training teaches in a small way that strength is built, not wished for.

Try it. In Session 2 you will measure your resting heart rate, run the Cooper 12-minute test on a measured course, estimate your $VO_2 \text{ max}$ and record your heart-rate recovery. In Session 3 you will do a steady aerobic run at conversational pace and track your heart rate at a fixed speed, a baseline for the training block in Lesson 5.2.

PICTURE STUDY



Hannes Kolehmainen after Receiving His Olympic Medal, Stockholm, Unknown photographer, 1912 · Photograph · Public domain photograph (Olympic Stadium, Stockholm)

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

At the 1912 Olympic Games in Stockholm, the Finnish runner Hannes Kolehmainen won the 5,000 meters, the 10,000 meters and the individual cross-country race. In the 5,000 meters he beat France's Jean Bouin in a world-record finish. He was the first of the "Flying Finns," a line of great distance runners that included Paavo Nurmi. Here, in his suit and laurel wreath, he walks away from the prize ceremony.

Look closely

- Find the laurel wreath. Why might the Olympic organizers have chosen this ancient sign of victory?
- Look at the officials in top hats and frock coats. What does their dress tell you about the time and the occasion?
- Look at the size of the crowd. How might a runner use the noise and excitement in a long race, and how might it hurt his pacing?
- Look at Kolehmainen's face and posture. How does he seem to carry his victory?

Talk about it

1. Kolehmainen won three races of 5,000 meters or more in a week. What qualities of his heart, blood and muscles, from this lesson, made that possible?
2. Using Fick's equation, explain two ways a distance runner's body can use more oxygen per minute than an untrained person's.
3. Kolehmainen trained for years in Finland's long winters. What do victories like this teach about patient, faithful training?

Safety first. Run the 12-minute test only if you have done some running in the past few weeks and have no illness or injury; anyone with a heart or lung condition follows the doctor's advice. Warm up, run on a safe measured course away from traffic with a buddy or adult, in cool weather or the cool part of the day, and drink water. Pace yourself; slow to a walk if needed, and stop at once and tell an adult at chest pain, dizziness, fainting or unusual breathlessness.

ACTIVITY

The Cooper Test and a Heart-Rate Baseline

You will measure three markers of your aerobic fitness: resting heart rate, an estimated VO₂ max and heart-rate recovery. In Session 3 you will add a fourth: your heart rate at a fixed, easy pace. You will retest them after the training block.

You will need

- A measured course: a 400-meter track, or a flat loop marked every 100 meters
- A stopwatch with a lap button, a whistle or phone alarm set for 12 minutes
- A helper to count laps and note your final position
- Fitness journal with a test table: resting heart rate, laps, distance, VO₂ max estimate, heart rate at 0 and 1 minute after, effort 6–20

Steps

1. **Resting heart rate.** On the morning of the test (and for two more mornings this week), before getting out of bed, count your pulse for 60 seconds. Record the average of the mornings.
2. **Warm up** for 8–10 minutes: easy jogging, the dynamic moves from the lesson warm-up and three relaxed strides.
3. **The 12-minute run (Session 2).** Start the watch and run (walking when you must) as far as you can in 12 minutes, aiming for an even pace. Your helper counts laps and marks your exact position when the alarm sounds.
4. Immediately take a 15-second pulse ($\times 4$), and again exactly 1 minute later. The drop is your heart-rate recovery.
5. **Calculate** your distance in meters and estimate VO₂ max $\approx$ (distance – 504.9) $\div$ 44.73. Rate your effort on the 6–20 scale (6 = no effort, 20 = maximal).
6. **Cool down** with 5 minutes of walking and gentle stretches, and drink water.
7. **Session 3: the steady run.** Warm up, then run for 20–25 minutes at a pace where you can speak in full sentences. Each 5 minutes, check your pace

(time per lap) and take a 15-second pulse. Record heart rate at a fixed pace (for example, 2:30 per 400 meters); in Lesson 5.2 you will watch this number fall as you get fitter.

Tips

- Even pacing wins. Divide your target distance by 12 to get your meters per minute, and check your lap times.
- Fitness markers change slowly. Your first test is a baseline, not a judgment.
- Retest under the same conditions: same course, same time of day, similar weather, rested and fed.

Check your work

- ☐ I can explain Fick's equation and calculate oxygen uptake at rest and in exercise.
- ☐ I completed the 12-minute run, estimated my VO_2 max and recorded my heart-rate recovery.
- ☐ I recorded my resting heart rate and my heart rate at a fixed easy pace as baselines.

FITNESS JOURNAL

1. Draw the path of one oxygen molecule from the air to a mitochondrion: nose, trachea, alveolus, capillary, red blood cell, left heart, artery, muscle capillary, muscle fiber.
2. Work Fick's equation for rest and for maximal exercise using your own assumptions, and show every step.
3. Record your Cooper test, VO_2 max estimate and heart-rate recovery, and your average resting heart rate.
4. Write a paragraph on how aerobic training changes the heart, the blood and the muscles.

From history. A. V. Hill shared the 1922 Nobel Prize for discoveries about heat production in muscle, and he loved to run himself; some of his early experiments used his own body as the subject. Adolf Fick is also remembered for Fick's laws of diffusion, which describe how oxygen crosses the walls of the alveoli.

COMMON MISTAKES

- Starting the 12-minute run too fast. A sprint start leads to walking later; even pacing covers more ground.
- Thinking VO_2 max is fixed. Training raises it, though people respond differently.
- Taking resting heart rate after moving around. Measure lying in bed right after waking.
- Comparing your estimate with a friend's. Use it only to measure your own progress.

Make it a game • Oxygen Path Race. Trace oxygen's journey from air to mitochondria out loud in under forty seconds, naming lungs, heart, blood and muscles. Then compute VO_2 from sample cardiac output and a-v difference in a worked Fick problem. Your parent times you. Do the Cooper test or a shortened version and beat your distance next time.

5.2 HEART-RATE ZONES AND THE KARVONEN FORMULA

OBJECTIVES

- Tell how Martti Karvonen's 1957 study led to training by heart-rate reserve.
- Estimate maximum heart rate with two formulas and calculate personal training zones with the Karvonen formula.
- Check heart-rate zones against the talk test and the Borg scale of perceived exertion.
- Plan a four-week aerobic training block with easy, steady and interval sessions, and lead a family fitness day.

Warm-up. Five-minute warm-up with a pulse check: take your resting pulse for 15 seconds, then do 1 minute of marching, 1 minute of easy jogging, 10 skips, 10 lateral shuffles each way and 1 minute of brisk jogging. Take your pulse again. Think about it: how many beats per minute did your heart rise, and what percentage of the way to your maximum is that?

WATCH

The Karvonen Formula for Target Heart Rate Calculation

[Physiotutors](#) · 3:43

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

WHEN TO WATCH

After “How they figured it out.” Work along on paper as he calculates heart-rate reserve and a target range.

Note: A physiotherapy teaching channel. The final screen advertises its courses and app; stop when the calculation ends.

BACKUP VIDEO

Target heart rate explained | Karvonen Method | How to compute target heart rate?

[Physical Education Videos For All](#) · 6:31

<https://www.youtube.com/watch?v=4ufSQ7mjikQ>

For a second worked example for a 15-year-old.

KEY TERMS

maximum heart rate

The highest heart rate a person reaches in all-out effort; estimated as $220 - \text{age}$, or more accurately for many people as $208 - 0.7 \times \text{age}$ (Tanaka, 2001).

Karvonen formula

Target heart rate = resting heart rate + (intensity $\times$ heart-rate reserve), from Martti Karvonen's 1957 study.

rating of perceived exertion (RPE)

How hard exercise feels on Gunnar Borg's 6–20 scale (6 = no effort, 20 = maximal effort); multiplied by 10, it roughly matches heart rate in many young adults.

heart-rate reserve (HRR)

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

training zones

Bands of intensity, such as easy (about 50–70% of HRR), steady or tempo (about 70–80%) and hard intervals (about 80–90% or more), each used for a different purpose.

training block

A planned period of training, usually 3–6 weeks, with a clear goal and a gradual increase in load.

CORE IDEAS

The story. In the 1950s, doctors and coaches knew that endurance training lowered the heart rate during exercise, but no one knew how hard a person had to train to get the benefit. At the University of Helsinki, the physiologist Martti Karvonen and his colleagues E. Kentala and O. Mustala designed a study with six young men, medical students, who ran on a treadmill for 30 minutes, four or five times a week, for four weeks. Each trained at a different, carefully controlled heart rate. They published the results in 1957.

How they figured it out. The men who trained at low heart rates showed little change. Those whose training heart rate went above a threshold improved: the heart rate needed for the same treadmill work fell. Karvonen noticed that the threshold was not a fixed number of beats but a fraction of each person's range: training had to raise the heart rate past about **60 percent of the way from resting to maximum**. This gave the formula: **target heart rate = resting HR + intensity $\times$ (maximum HR –**

resting HR). **Worked example:** a 15-year-old with a resting heart rate of 64. Using $220 - \text{age}$, maximum HR = 205, so $\text{HRR} = 205 - 64 = 141$. At 60 percent: $64 + 0.60 \times 141 = 64 + 84.6 \approx 149$ bpm. At 80 percent: $64 + 0.80 \times 141 = 64 + 112.8 \approx 177$ bpm. Using the newer Tanaka formula, maximum HR = $208 - 0.7 \times 15 = 197.5$, $\text{HRR} \approx 134$, and the 60–80 percent range is about 144–171 bpm. Formulas are only estimates; real maximums vary by 10 beats or more either way, so check zones against how you feel.

How your body works. Each zone trains something different. **Easy** running (about 50–70 percent of HRR, RPE 10–12, full sentences) builds the heart’s stroke volume, capillaries and mitochondria and allows recovery; most endurance training is done here. **Steady or tempo** running (about 70–80 percent, RPE 13–15, short phrases) raises the pace you can hold before lactate builds up rapidly. **Intervals** (about 80–90 percent and above, RPE 16–18, a few words), such as Emil Zátopek’s repeated laps, push VO_2 max higher; they are hard and need rest days after. A good block for a teen might be three or four aerobic sessions a week: mostly easy, one steady or interval session, a longer easy run, and an increase in total running time of no more than about 10 percent a week. Over weeks, your heart rate at a fixed pace falls, a sure sign of progress. Scripture calls the Christian life a race to be run “with patience”; patient, steady training is the same lesson in the body.

Try it. In Session 2 you will calculate your zones, run a zone-check session to compare heart rate, talk test and RPE, and write your four-week block. In Session 3 you will complete the first interval session, and in the last week you will plan and lead the family fitness day and retest your baseline.

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 the Elder painted this winter scene as one of a series of the seasons for a merchant in Antwerp. Weary hunters return through the snow, while in the valley below the whole village is out on the ice: skating, sledding, sweeping stones and playing. It is a picture of hard work and of shared winter play.

Look closely

- Count the hunters and the dogs. How do their postures show that they have been out a long time?
- Look at the frozen ponds. List every activity you can find: skating, curling, sledding, pulling a sled, a game with sticks.
- Find the people by the fire outside the inn on the left. What are they doing, and how does it help in the cold?
- Find the woman pulling a child on a sled near the bottom right, and the figure carrying a bundle of sticks across the bridge.

Talk about it

1. Which activities in the painting would be in the easy zone, and which in the hard zone?

2. The whole village is moving together on the ice. What would a family fitness day look like if Bruegel painted your family?
3. The hunters return tired after long, patient work in the cold. How is that like a training block?

Safety first. Use estimated maximum heart rates only to set zones; never try to reach your maximum heart rate on purpose. Warm up before intervals, train on a safe course with a buddy away from traffic, avoid the hottest part of the day, drink water, and take at least one easy day after each hard session. Stop and tell an adult at chest pain, dizziness, fainting or unusual breathlessness.

ACTIVITY

Your Zones, a Four-Week Block and the Family Fitness Day

You will calculate your own training zones, check them in a real run, and plan four weeks of aerobic training. Then you will finish the quarter by leading your family in a fitness day that brings together everything you have learned.

You will need

- Your average resting heart rate from Lesson 5.1, a calculator
- A stopwatch with a lap button and your measured course
- A printed or hand-drawn Borg scale (6–20)
- Fitness journal with a zone table and a four-week plan; for the family day, stations from each unit, water and a whole-food snack

Steps

1. **Calculate your zones.** Find your maximum heart rate with both formulas, your HRR for each, and target heart rates at 50, 60, 70, 80 and 90 percent. Convert each to a 15-second count ($\div 4$) for checking on the run.
2. **Zone check (Session 2).** Warm up. Run 4 minutes easy, 4 minutes steady and 2 minutes hard, with 2 minutes of walking between. At the end of each, take a 15-second pulse, try to say a sentence, and rate RPE. Compare: did your heart rate, talk test and RPE agree?
3. **Write your four-week block.** Three or four sessions a week on nonconsecutive or alternating days: (1) an easy run of 20–30 minutes; (2) an interval session, for example 6×2 minutes at about 80–90 percent of HRR with 2 minutes of easy jogging between; (3) a longer easy run of 30–40 minutes; (4) optional cross-training (cycling, swimming, a game). Increase total time by no more than about 10 percent a week, and make week 4 a little lighter before your retest.
4. **First interval session (Session 3).** Warm up 10 minutes, run the intervals, cool down 5–10 minutes. Record your heart rate at the end of each interval and RPE. Note whether your heart rate drops into the easy zone during each recovery jog.

5. **Plan the family fitness day (final week).** Choose a time and place. Plan: a 10-minute warm-up you lead; stations from each unit (a bone-builder jump station, a PACER or relay, a cooling-and-water table, a strength station with body weight or household loads, a heart-rate station where everyone checks a pulse before and after); a family walk or run where each person chooses his or her own pace and zone; a cool-down; and a whole-food snack you prepare.
6. **Lead the day.** Teach each station, keep everyone safe (water, shade, good form, no one pushed beyond his or her ability), and encourage effort. Retest your own PACER or mile and your resting heart rate, and compare them with your Lesson 1.2 and 5.1 baselines.
7. **Give thanks and reflect.** End with a prayer of thanks for strong bodies and good food, and write a reflection on the quarter.

Tips

- On intervals, the first repeat should feel too easy. Hold the same pace on the last one, and you paced it right.
- Most of your running should feel easy. Running every session hard leads to fatigue and injury, not faster progress.
- At the family fitness day, match stations to the youngest and oldest members; every body can join at its own level.

Check your work

- ☐ I can calculate my heart-rate reserve and training zones with the Karvonen formula.
- ☐ I checked my zones with the talk test and RPE and wrote a safe four-week block.
- ☐ I planned and led a family fitness day and compared my retest with my baselines.

FITNESS JOURNAL

1. Make your zone table: percent of HRR, beats per minute, 15-second count, talk test, RPE, purpose.
2. Graph your heart rate during the interval session (time on the x-axis, heart rate on the y-axis) and shade your zones.

3. Copy your four-week block as a calendar with total minutes for each week and the percentage increase.
4. Write a one-page reflection on the quarter: your baselines and retests, the habit you are most thankful for, and what you will keep doing.

From history. Martti Karvonen later helped lead Finland's part in the Seven Countries Study, one of the first large international studies of eating habits, activity and heart disease. Gunnar Borg, a Swedish psychologist, introduced his 6–20 scale of perceived exertion in the early 1970s; the numbers were chosen so that, times ten, they roughly match heart rate in young adults.

COMMON MISTAKES

- Treating $220 - \text{age}$ as exact. It is an estimate that can be off by 10 or more beats; check against how you feel.
- Running every session in the hard zone. Most aerobic training should be easy.
- Increasing training time too quickly. About 10 percent a week is a safe limit.
- Forgetting resting heart rate. The Karvonen method uses it; measure it carefully in bed in the morning.

Make it a game • Karvonen Zone Calculator. Find your resting heart rate, estimate maximum two ways, then calculate heart-rate reserve and each training zone using the Karvonen formula. Race your parent to finish the math. Do a ten-minute run and check your pulse to see which zone you hit. Retell Karvonen's 1957 study. Fewest errors wins.

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

Endurance is built by steady, faithful training, not sudden bursts. The writer of Hebrews uses the runner's patience as a picture of the Christian life, run looking to Jesus.

AEROBIC TRAINING

How much oxygen can your body use, and what limits it? In 1870 the German physiologist Adolf Fick wrote down a simple equation that answers the question: the oxygen your body uses equals the blood your heart pumps times the oxygen your tissues take out of each liter. You will follow oxygen from the air to the mitochondria, learn what cardiac output, stroke volume and VO_2 max mean, work Fick's equation with real numbers, and estimate your own aerobic fitness with Kenneth Cooper's 12-minute run.

Then you will learn to train by heart rate. In 1957 the Finnish physiologist Martti Karvonen found that training improved fitness only when the heart rate rose past about 60 percent of the way from resting to maximum. His formula, using **heart-rate reserve**, is still how coaches set training zones. You will calculate your own zones, check them with the talk test and perceived effort, plan a four-week aerobic training block, and finish the quarter by leading your family in a family fitness day.

PREREQUISITES

- Can take a pulse accurately and convert a 15-second count to beats per minute (Unit 1)
- Knows the aerobic and anaerobic energy systems (Unit 3)
- Has a PACER or mile baseline from Lesson 1.2

MASTERY CHECKLIST

- ☐ I can trace oxygen from the lungs to the mitochondria and explain cardiac output, stroke volume and the a-v oxygen difference.
- ☐ I can use Fick's equation to calculate oxygen uptake at rest and during exercise.
- ☐ I can explain VO_2 max, estimate mine from a 12-minute run, and describe how training improves it.
- ☐ I can calculate heart-rate reserve and training zones with the Karvonen formula and check them with the talk test and perceived effort.
- ☐ I can plan a four-week aerobic training block and lead a family fitness day.

OPTIONAL BOOKS AND GEAR FOR THIS UNIT

- **A stopwatch or phone timer with a lap button:** For the 12-minute run, pulse counts and interval timing. A heart-rate monitor is a nice extra but never needed.
- **A measured running loop:** A local 400-meter track is ideal; otherwise measure a safe loop with a car odometer or a map app and mark every 100 meters with chalk.

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 The Cardiorespiratory System: Fick's Equation and VO₂ Max

3 sessions of 45–50 minutes

5.2 Heart-Rate Zones and the Karvonen Formula

3 sessions of 45–50 minutes

UNIT 5 REVIEW

Answer each question in complete sentences. Show all working for calculations. The review is worth 100 points.

1. **10 pts**

Trace the path of oxygen from the air to a muscle mitochondrion, naming at least six structures.

2. **10 pts**

State Fick's principle and tell the story of how it was first used in people.

3. **10 pts**

Calculation. At rest a student's stroke volume is 75 mL and heart rate 68 bpm, and the a–v oxygen difference is 50 mL O₂ per liter. (a) Find cardiac output in L/min. (b) Find oxygen uptake. (c) In hard exercise, Q = 18 L/min and the a–v difference is 140 mL/L. Find oxygen uptake and how many times the resting value it is.

4. **10 pts**

What is VO₂ max? Describe how A. V. Hill and Hartley Lupton first measured it.

5. **10 pts**

Calculation. A student runs 2,650 meters in the Cooper 12-minute test. Estimate VO_2 max using $\text{VO}_2 \text{ max} \approx (\text{distance} - 504.9) \div 44.73$. Four weeks later she runs 2,780 meters. What is the new estimate and the percentage improvement?

6. **10 pts**

Name three ways aerobic training changes the body, and explain why a trained athlete's resting heart rate is lower.

7. **10 pts**

Describe Karvonen's 1957 study and its main finding.

8. **10 pts**

Calculation. A 14-year-old has a resting heart rate of 70. (a) Estimate maximum heart rate with $220 - \text{age}$ and with $208 - 0.7 \times \text{age}$. (b) Using $220 - \text{age}$, find heart-rate reserve and target heart rates at 60% and 85%. (c) Convert the 60% target to a 15-second count.

9. **10 pts**

Describe the easy, steady and interval zones: about what percent of heart-rate reserve, how each feels (talk test and RPE), and what each trains. What is the rule for increasing training time?

10. **10 pts**

Short written answer. Describe your family fitness day and your retest results compared with your baselines from Lessons 1.2 and 5.1. What habit from this quarter will you keep, and why?

ANSWER KEY

1. Air enters the nose or mouth, passes down the trachea and bronchi to the alveoli; oxygen diffuses across the alveolar and capillary walls into the blood and binds to hemoglobin in red blood cells; the blood returns to the left side of the heart, and the left ventricle pumps it through the aorta and arteries to the muscle capillaries; oxygen diffuses into the muscle fiber and on to the mitochondria, where it is used in aerobic respiration.
2. Oxygen uptake equals cardiac output times the arterial-venous oxygen difference ($VO_2 = Q \times a-vO_2 \text{ diff}$). Adolf Fick stated it in Würzburg in 1870 but could not measure the oxygen in blood returning to the heart. Werner Forssmann passed a catheter into his own heart in 1929, and in the 1940s André Cournand and Dickinson Richards used catheters to measure cardiac output in patients by Fick's method; all three shared the 1956 Nobel Prize.
3. (a) $Q = 75 \text{ mL} \times 68 = 5,100 \text{ mL/min} = 5.1 \text{ L/min}$. (b) $VO_2 = 5.1 \times 50 = 255 \text{ mL O}_2/\text{min}$. (c) $VO_2 = 18 \times 140 = 2,520 \text{ mL O}_2/\text{min}$; $2,520 \div 255 \approx 9.9$, about ten times the resting value.
4. $VO_2 \text{ max}$ is the greatest rate at which the body can take in and use oxygen during hard exercise, usually in mL per kg per minute, and is the best single measure of aerobic fitness. In 1923 Hill and Lupton had runners run faster and faster on a grass track while collecting their breath in bags; oxygen uptake rose with speed and then leveled off at a maximum.
5. First: $(2,650 - 504.9) \div 44.73 = 2,145.1 \div 44.73 \approx 48.0 \text{ mL/kg/min}$. Second: $(2,780 - 504.9) \div 44.73 = 2,275.1 \div 44.73 \approx 50.9 \text{ mL/kg/min}$. Improvement = $(50.9 - 48.0) \div 48.0 \approx 0.06$, about 6 percent.
6. Any three: the left ventricle grows larger and stronger, raising stroke volume; blood volume increases; muscles grow more capillaries; muscles grow more and larger mitochondria and extract more oxygen (wider a-v difference); $VO_2 \text{ max}$ rises. Resting heart rate falls because the heart pumps more blood per beat, so it can supply the same resting cardiac output (about 5 L/min) with fewer beats.
7. Martti Karvonen, E. Kentala and O. Mustala at the University of Helsinki had six young men run on a treadmill for 30 minutes, four or five times a week, for four weeks, each at a controlled heart rate. Only those whose training heart rate rose above a threshold improved, and the threshold was about 60 percent of the way from resting to maximum heart rate (heart-rate reserve), giving the formula $\text{target HR} = \text{resting HR} + \text{intensity} \times (\text{max HR} - \text{resting HR})$.

8. (a) $220 - 14 = 206$; $208 - 0.7 \times 14 = 208 - 9.8 = 198.2 \approx 198$. (b) $HRR = 206 - 70 = 136$.
60%: $70 + 0.60 \times 136 = 70 + 81.6 \approx 152$ bpm. 85%: $70 + 0.85 \times 136 = 70 + 115.6 \approx 186$
bpm. (c) $152 \div 4 = 38$ beats in 15 seconds.
9. Easy: about 50–70% of HRR, full sentences, RPE about 10–12; builds stroke volume, capillaries and mitochondria and allows recovery; most training. Steady or tempo: about 70–80%, short phrases, RPE about 13–15; raises the pace you can sustain. Intervals: about 80–90% and above, only a few words, RPE about 16–18; pushes VO_2 max higher, needs rest days after. Increase total training time by no more than about 10 percent a week.
10. Answers will vary. A strong answer describes the warm-up, stations from each unit, the family run or walk and the snack; reports retest numbers with units beside the baselines and the change; and names a specific habit (such as three aerobic sessions a week, a strength program, a fluid plan, cooking whole-food meals), with a reason that reflects stewardship of the body and thankfulness.

UNIT CHALLENGE: A FOUR-WEEK AEROBIC TRAINING BLOCK

Carry out the four-week block you wrote in Lesson 5.2 (complete at least the first two weeks during the quarter and the rest afterward). Log every session: date, type, duration, distance if known, average or end heart rate, zone and RPE. Each week, record your heart rate at your fixed easy pace from Lesson 5.1 and your morning resting heart rate. At the end, retest the 12-minute run or the PACER and calculate your new VO₂ max estimate. Graph weekly training minutes and your heart rate at the fixed pace, and write a report on what changed and what you learned about patient training.

LOOK FOR	WHAT IT MEANS
Sound plan	Zones calculated correctly with working shown; sessions mostly easy with one hard session a week; weekly increases of about 10 percent or less.
Faithful training log	Every session dated and recorded with duration, zone, heart rate and RPE, and safety rules followed.
Graphs and retest	Clear graphs of training minutes and fixed-pace heart rate, and a correctly calculated retest estimate compared with the baseline.
Report and reflection	A thoughtful report on progress and lessons learned. Effort, consistency and personal improvement count, never comparison with others.