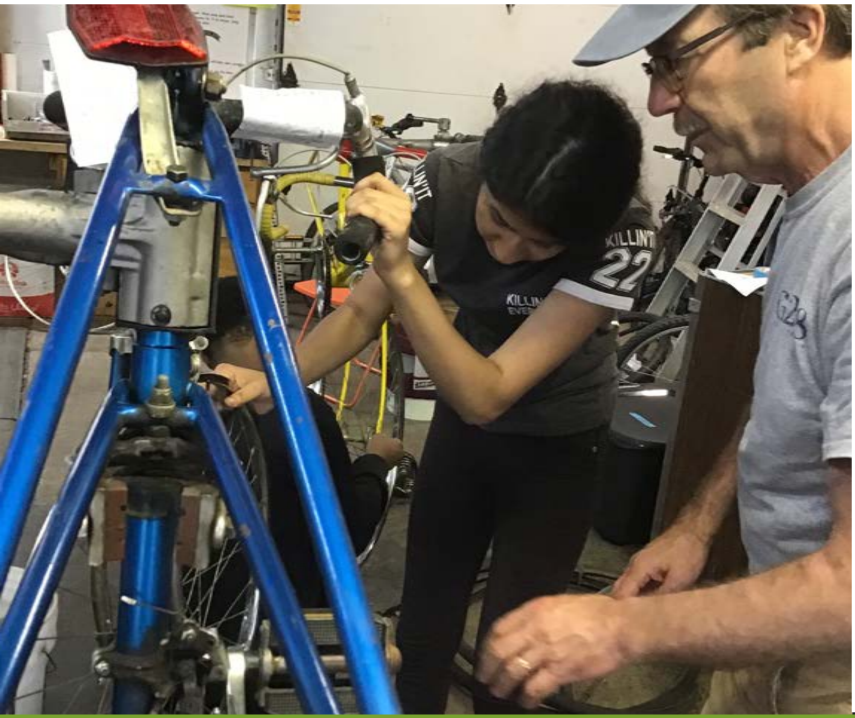
Trips for Kids
EARN-A-BIKE WORKSHOP PROGRAM
Lesson Guide for Instructors

FOR BEGINNER STUDENTS, AGES 15-17

PRODUCED IN COLLABORATION WITH TRIPS FOR KIDS MARIN

TABLE OF CONTENTS

Cover: Diego Gonzalez, 14, Earn-a-Bike program graduate and student mentor at Trip For Kids Marin



WELCOME
TO THE EARN-A-BIKE PROGRAM

The nation's oldest and largest youth cycling organization, Trips for Kids uses the power of the bicycle as a vehicle for change. Founded in 1988, what started out as a single program in the San Francisco Bay Area has become a national movement. Powered by independent, likeminded advocates with a common purpose, our affiliate chapters provide transformative cycling experiences that help kids shift gears. Serving youth from diverse communities across North America, especially those most in need, our programs combine lessons in personal responsibility, fitness, skill achievement and environmental awareness through development of practical skills and the simple act of having fun.

Our Earn-a-Bike program gives young people the opportunity to earn a bike of their own by attending after-school learning sessions for a designated number of hours. These sessions combine bicycle mechanic skills with hands-on STEM (Science, Technology, Engineering, Math) education, using the bicycle as the springboard for teaching STEM-related concepts and ideas.

Plus, with nearly 15 million bikes discarded by their owners every year, bike recycling keeps many of these bikes out of landfills, provides kids who don't have bikes with a means of transportation and exercise, and makes a positive impact on the environment.

Earn-a-Bike workshops are safe, positive, inclusive classrooms where youth learn how to work with their hands, develop vocational skills and knowledge, and earn a donated or recycled bike of their own.

WHY INCORPORATE STEM INTO THE EARN-A-BIKE PROGRAM?

Most careers today require a solid understanding of basic STEM concepts. According to the U.S. Department of Commerce, STEM occupations are growing at 17% while other occupations are growing at 9.8%. STEM degree holders have a higher income, even in non-STEM careers.

While a person's race, zip code or socioeconomic status should never determine their STEM fluency, it's a fact the lower-income students are substantially under-represented in STEM. Lower-income neighborhoods have significantly fewer opportunities for STEM education than more affluent neighborhoods.

Our Earn-a-Bike programs can help bridge this gap by directly connecting students with the STEM- related aspects of one of the world's greatest and most important inventions — the bicycle. By exposing students to STEM and giving them opportunities to explore STEM-related concepts, the hope is that they will develop a passion for it and possibly pursue a job in a STEM field. Research shows that STEM workers earn 26 percent more than similarly educated workers without a STEM background.

STEM-based education can teach more than science, technology, engineering, and mathematics concepts. In the Earn-a-Bike program, the combination of hands-on learning, theoretical knowledge and real-world applications helps students develop a variety of skill sets, including creativity, productivity, flexibility, and initiative. Other skills attained through STEM education include problem solving, critical thinking, decision making, leadership, acceptance of failure and more. These skills go a long way to preparing students for mainstream professional success, no matter their chosen career path.

HOW TO USE THIS GUIDE

Each lesson in the Earn-a-Bike Workshop is designed to be 1.5-2 hours long for beginner students in the 15-17 age range. The six lessons are broken down into different aspects of bike mechanics, and STEM components have been woven into the fabric of each lesson to work in tandem with the mechanics and skills being presented.

The Guide provides the goal and objectives for each lesson, the materials needed, a thorough lesson plan, plus ideas for friendly student check-ins and ways to evaluate the effectiveness of each lesson presented.

Know Your Icons

As the instructor, you should be able to follow the core lesson and, using the icon key below, present your students with interesting STEM concepts, applied technology theories, fun facts and safety tips. Hands-on activities and demonstrations are peppered throughout the lessons for your use, as are questions that can help keep students attentive and engaged.

- Ask Students
- Hands-on
- Evaluation Actions and Questions
- Did You Know?
- Safety
- Applied Technology

Content in blue boxes are deeper dives you use to flesh out the curriculum.

Links to video clips with information meant to solidify your understanding of different concepts or experiments are provided — and you can share them with students to help amplify their learning.

Use the Appendix

In the Appendix, you'll find an enlarged version of all of the visuals presented in this Guide. These are on separate pages to facilitate printing and viewing. Use them to illustrate some of the STEM concepts being taught, either by providing them as handouts for your students or allowing them to view the images directly from the Guide. There a re also two worksheets in the Appendix that should be distributed to students as part of their evaluation process.

Make the Lesson Your Own

Use your discretion and eliminate a section or two from a lesson if you don't think your timeframe will allow for the complete version. You should also schedule breaks as you see fit. Most of all, have fun with each lesson and enjoy the sense of accomplishment that comes with helping someone see the world in a new way — while learning all about bikes.

LESSON 1

Intro to the Bike and Tires, Tubes and Wheels

LESSON GOAL

Be able to identify a tire or tube in need of repair, describe all the major steps for fixing a flat, and complete those steps.

LESSON OBJECTIVES

During this class, students will:

- ✔ Learn a brief history of the bicycle
- ✔ Understand the anatomy of the bicycle
- ✔ Understand why wheel size matters
- ✔ Understand why — and how — tires, tubes and valves work
- ✔ Understand the concept of air pressure, PSI, and how to determine proper tire pressure
- ✔ Learn how to make scientific observations via a bicycle

MATERIALS NEEDED

- ✔ Textbooks and other course materials, which could include the Park Tool Big Blue Book of Bicycle Repair and a folder with printouts from the Appendix.
- ✔ An assortment of frames and wheels
- ✔ An assortment of tubes and tires, preferably ranging in sizes from 12.5”- 29”
- ✔ Three front wheels with tires and flat tubes
- ✔ New tubes for the flat tires
- ✔ 15mm open end or adjustable wrenches
- ✔ Patch kits
- ✔ New tire
- ✔ Pumps with easy-to-read pressure gauges
- ✔ Tire levers

LESSON PLAN

Provide an Overview of the Lesson:

Let students know that the bike is a perfect example of how scientific theory can be explained through a practical object. The invention of the bike began over 140 years ago with improvements in technology that are still being made today.

Over the next six weeks, as your students work toward earning a bike, they will learn how a bike is built and why a bike works through the application of STEM-based principles and ideas. Explain to them that STEM learning is a valuable educational component that can provide them with more than just science and math literacy — it can also help them learn skills that include problem solving, critical thinking, creativity, curiosity, decision making, acceptance of failure and more.

- Tell students that each lesson will be broken down by different sections of the bike, include hands-on building or fixing, and utilize STEM lessons to further bring the mechanics of the bike to life.
- Provide a brief overview of the six lessons planned (See Table of Contents) and explain that today’s lesson includes an intro to the bicycle, an overview of wheels, tires and tubes, and step-by-step instructions for fixing a flat tire.

Make Introductions:

Consider an ice-breaker name game to give students the opportunity to introduce themselves. You may want to ask each student to explain why they want to earn a bike and how they feel it will change their lives.

Share a Brief History of the Bike:

Since the first bicycle was invented in Germany in 1818, it has evolved considerably. Initially a pedal-less “running machine” with iron tires, it developed into what was called the “safety bicycle” in the 1880s, with pedals and a design that is a direct ancestor to the modern bike.

Resource video: **YouTube: The Evolution of the Bicycle**

Explore the Anatomy of the Bike:

Hands-on:

Find out how much your students know about bike anatomy. Have a bike or two in stands with Velcro attached to different parts. Next to each bike, place a bowl with the names of the parts of the bike on laminated paper with Velcro on the back. Give students time to work together and match the cards to the bike parts, then see how everyone did.

Explore the Design of the Frame:

Discuss the frame and show examples. Explain that the most common frame design is known as the diamond or double-triangle and has changed very little since the advent of the safety bicycle. The structure of the frame is incredibly strong and distributes a rider's weight between the front and back wheels. The frame will be explored in further detail in Lesson 2.

Assorted Frame Materials:

- **Carbon Steel**
  Strong, long-lasting steel is the most commonly used material in bike frames, although it is difficult to machine and less pliable than other steels.
- **Chromoly Steel**
  A workhorse of the industry, chromoly is light and strong. It can deliver a fairly light frame that will withstand hard use. It offers good flex while maintaining its form.
- **Aluminum**
  It's light, strong, stiff and comes in different alloys. With proper design, aluminum frames are good for climbing or easy handling in tight situations.
- **Titanium**
  Lighter than steel but just as strong, this expensive metal is found on high-end road or cross-country mountain bikes. It flexes so well that some bikes use the metal itself as a shock absorber.
- **Carbon Fiber**
  Used on higher-end bikes, it is significantly lighter than aluminum, steel or titanium. Carbon frames do a better job of absorbing road vibration for a more comfortable ride, but they are easily damaged.
- **Bamboo**
  Bamboo bikes were first introduced in 1894 but never attained large-scale use. With higher tensile strength than steel, bamboo is lightweight, vibration damping and sustainable.

Discuss the Evolution of Wheels:

Have examples of road and mountain bike tires and wheels on hand. Explain the differences and let students come to a central location to observe and feel.

- Why do modern bike wheels and tires look the way they do? The first pedal-powered bikes weighed over 65 pounds and had wooden wheels. The "tires" were simply metal strips tacked onto a wooden rim.
- In 1887, the pneumatic — or air-filled — tire was invented when linen sleeves were fitted onto and around a tricycle's wooden wheels, and a rubber tube was inserted between the linen and the wood and inflated with air through a valve.
    - Pneumatic — or air-filled — tires are still used on bikes and cars today. They are made of an airtight inner core filled with pressurized air. The pressure of the air inside the tire is greater than atmospheric pressure so the tire remains inflated despite the weight of the bike and the person on top of it. The tire's air pressure provides resistance against external forces that try to deform the tire and it compresses, providing a cushioning effect over bumpy surfaces.

- Explain that today's bicycle wheels vary in size but, in general, the circumference of a racing bike wheel is larger than that of a mountain bike. Why? Because smaller wheels tend to be more agile, making them great for short, steep climbs and fast-flowing, quick-turning trails.

Dive Into Tires and Tubes:

Have examples of bike tires with tubes inside. Explain how they work together and pass samples around.

Explain that when someone says they have a flat tire, they mean that they have a flat tube.

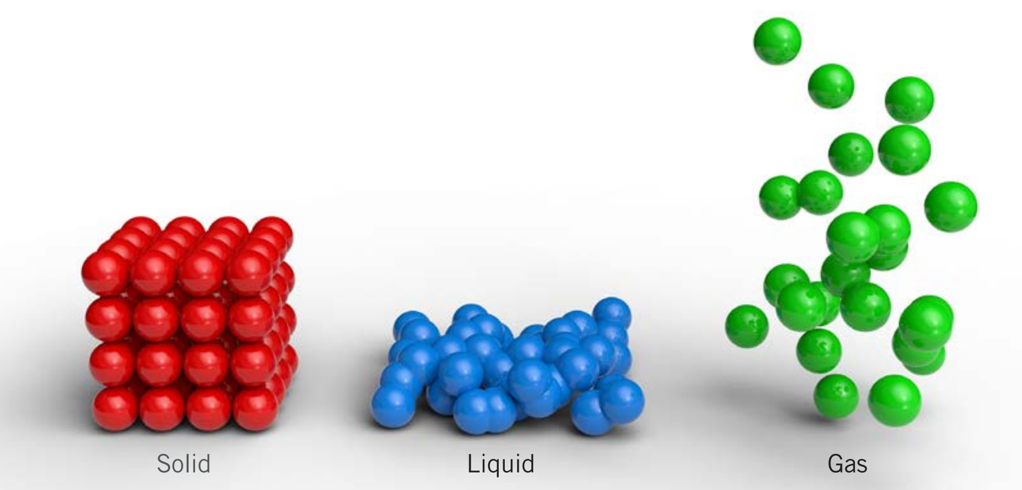
- Show that bike tires contain important information on the sidewall that includes the diameter and width of the tire and inflation recommendations in PSI.
- PSI, which stands for "pounds per square inch," relates to the recommended air pressure for a particular tire. The right pressure inside the bike tube ensures that the bike will roll quickly, ride smoothly, and avoid flats.

Ask students: Can you think of an example of gas under pressure other than a tire?

Answer: Balloons, soft drinks.

Focus on the Pressure of Gases:

Explain that gas is a state of matter that has no fixed shape and no fixed volume. Unlike solids and liquids, gases can expand and compress. Gases have lower density than other states of matter, such as solids and liquids. There is a great deal of empty space between molecules, which have a lot of kinetic energy. The molecules move very fast and collide into one another, causing them to diffuse, or spread out, until they are evenly distributed throughout the volume of the container.



Relative Density of Particles

DID YOU KNOW?

The Weight of Air

Did you know that air weighs 14.7 pounds per square inch at sea level? That means that every square inch of your body is being pressed on by 14.7 pounds of pressure. All the molecules in the atmosphere above your head weigh something. And the combined weight of these molecules causes a pressure of 10,000 kg per square meter. This means that the mass of the air above the 0.1 square meter cross section of your body is 1,000 kg or one ton. Result? The weight pressing down on your head and shoulders is equivalent to the weight of a small car.

When more gas enters a container, there is less space for the molecules to spread out, so they become compressed and exert more force on the interior volume of the container. This force is called pressure. Then explain:

- Air is a mixture of gas molecules composed of atoms constantly in motion
- The way a gas like air exerts pressure inside a container like a tire or balloon is through the action of the air molecules colliding with each other and the sides of their container.
- The more gas atoms you put in the container, the more collisions you get and the greater the pressure they exert on the sides of the container.
- When you pump up a bike tire or blow into a balloon, you're placing more molecules into a constant volume, so the pressure increases.

Hands-on:

Explain to students that they'll be taking part in a balloon experiment to experience an easy demonstration of how gas and pressure work.

- ✔ Give each student a balloon to blow up (but not pop). Explain that when they force air from their lungs into the balloon, the air molecules hit the inside walls of the balloon and create enough pressure to force the rubber of the balloon to expand, inflating the balloon.
- ✔ Explain that the collision of these particles with the walls creates a high-pressure environment inside the balloon relative to the atmospheric pressure around it. This is why when a balloon is released, the high-pressure air flows out of the balloon to the low-pressure air surrounding it.

Resource video: One Side of a Car is Held up by a Group of Inflated Balloons

And Now for Tires…

Have examples of tires with different treads and let students observe and touch them.

Why Do Tires Have Different Tread Patterns?

Explain that bicycle tread patterns serve one of two purposes. Knobby treads on off-road tires provide better "bite" on loose surfaces such as dirt, sand, and gravel. Grooved treads on road tires push some of the water on the road to the side, reducing the amount of water that is sprayed up behind the wheel.

Over time, mechanical engineers and designers have developed the best tread designs for various cycling applications.

Let's Fix a Flat:

Ask students for a show of hands of who's had a flat tire or seen someone with a flat bike tire.

What's A Pinch Flat?

Pinch flats are caused when you ride into something that causes a sharp impact — a rock, railroad track or edge of a pothole are prime culprits. The impact compresses the tire so much that the tube is pinched between it and the edge of the rim.

> ? **Ask students: What do you think the main causes of a bike flat are?**
>
> **Answer:** See sidebar.

Know Your Bike Valves

For such a small component, the bike tire valve plays a significant role in ensuring the overall success of a ride.

There are two kinds of bikes valves, each engineered to work differently: Presta and Schrader

The **Schrader valve** is a spring-loaded check valve that controls airflow. Its inner pin needs to be depressed to let air in or out.

The **Presta valve** seals entirely based on the pressure in the tube or tire. The valve seals closed when there is sufficient air pressure in the tube to push against the inside of the valve.

Demo: Approximately 30 Minutes

Have a bike with a deflated tire. Explain that it's important to determine the cause of the flat so you don't damage the tube you install.

1. **Show students the tools needed to change a flat tire: pump, tire levers, a patch kit, a new tube, and tools to remove the wheel from the bicycle.**
   a. Explain each side of the tire lever and its intended uses.
   b. Explain parts of the pump, including the gauge, barrel and head.
2. **Show students the process for flat repair.**
   a. Demonstrate how to remove and reinstall a wheel with a quick release lever.
   b. Demonstrate how to remove and reinstall a rear bolt-on wheel.
3. **Remove one side of the tire using tire levers.**
   a. Explain the importance of only removing a single tire bead unless the tire needs to be replaced.
   b. Beginning opposite the valve stem, demonstrate inserting one tire lever and securing it on the spokes. When applicable, show students how to roll the tire off without any tools using your thumbs to aid in removing one bead of the tire.
   c. Demonstrate using the second tire lever how to remove one side of the tire. Explain the process of sliding the lever around the wheel until the tire comes off freely.
4. **Remove the inner tube.**
   a. Demonstrate the removal of the inner tube, making note of how to remove the tube when you get to the valve stem. A torn valve stem is unrepairable.

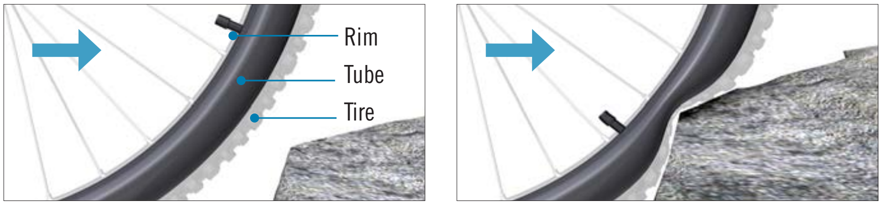
DID YOU KNOW?

Causes of punctures include:

- Punctures by a sharp object, like glass and nails
- Failure or damage to the valve stem
- Rubbed or ripped tire
- Over pumped tires (blowouts)
- Road hazards (potholes, debris)
- Slow leaks
- Pinch flats (snake bite)
- Tire quality and/or wear
- Inner tube quality and/or wear
- Damaged tire liner
- Sharp edges from the rim drilling (spoke holes)

5. **Identify the cause and patch the inner tube.**

    a. Determine if it's a patchable flat or if it requires a new tube. If it's a pinch flat, it can't be patched. If it's a puncture flat, it can.



Hitting an edge with enough force for the rim to come into contact with the surface can pin the tube in the middle, ripping the tube. Snake bite flats are also called pinch flats.

    b. Explain how to look for the hole using either water or blowing up the tire and using your hand to feel where the air is escaping.

    c. Patch the tube using normal patching procedures. Explain that the tube needs to dry if water was used or returned to a normal size if the hand method was used.

    d. Explain how to inspect for and remove any foreign objects. If these are not removed, another flat is inevitable.

6. **Replace the inner tube.**

    a. Confirm that there is a rim strip present. If not, it will need to be replaced prior to reinstalling the inner tube.

    b. Start with the valve stem and work around the rim until the tube is completely inside the tire.

7. **Reinstall the tire.**

    a. Reinstall the single side of the tire by hand, taking care not to pinch the tube.

    b. Confirm that the valve stem is pulled all the way through and make sure it is perpendicular to the rim. If it's crooked, this could lead to unnecessary pressure on the base of the valve stem and could lead to premature failure.

8. **Inflate tire to proper PSI.**

    a. Discuss how to properly use a pump by identifying the pressure gauge. Demonstrate how to lock or thread pump head on valve.

    b. Show how to keep the valve from being pushed back into the rim while securing the pump head.

Hands-on:

Separate students into groups of two and have them recreate the steps you just showed them.

Evaluation Actions and Questions:

1. Point to a part of the bike and ask students to name it.
2. What's the purpose of the knobby tread on off-road bikes?
3. What's happening inside a tire when you inflate it with an air pump?

Final Check-in:

Ask students to share something they learned today and what they are most interested in learning about. Then do a final check-in to make sure everyone is in good spirits. You might want to do "fist to five," where a closed fist is 0 (signifying a bad day) and five fingers means it was an awesome day. Thank the students for their participation and introduce the next week's class subject.

LESSON 2

Intro to Frames, Handlebars, Stems, Saddles and Controls

LESSON GOAL

Learn how to install handlebars on a bicycle.

LESSON OBJECTIVES

During this class, students will:

- ✔ Learn about the history of the bike frame, its structure, and some recent variations
- ✔ Understand torque and its importance to making a bicycle safe and stable
- ✔ Understand how different parts of the bike attach to the frame using torque
- ✔ Learn how levers work and the concept of leverage
- ✔ Gain an understanding of the concept of aerodynamics
- ✔ Learn about mechanical advantage

MATERIALS NEEDED

- ✔ A quill stem and standard stem
- ✔ 25.4 mm handlebars and 31.8 mm handlebars
- ✔ Saddle (loose) and seat post
- ✔ Brake controls and shift controls
- ✔ Isolated bike frame, if possible
- ✔ Y-wrenches, 5 mm Allen wrenches, torque wrenches plus nuts and bolts
- ✔ Ruler, fulcrum and pennies

LESSON PLAN

Provide an Overview of the Lesson:

Let students know that in this lesson they'll be learning about the frame of the bike, parts that attach to the frame, and controls.

They will learn about the contribution of each part of the bike to the bike as a whole, plus how to properly fasten these parts to the bike using torque. They'll also learn how levers work and gain a working knowledge of mechanical advantage.

Go around the room and ask students to tell you one thing they learned in Lesson 1. Ask them why they think it's something they remember.

Let's Explore the Frame:

Show some examples of frames. Explain any differences between them.

Explain that the bicycle frame is the skeleton of the bicycle and that it's required to be strong, stiff, and light. As described in Lesson 1, the most common modern frame design consists of two triangles — a main triangle and a rear triangle — and is known as the diamond frame.

- The diamond frame structure, generally made from tubular steel or lighter alloys based on steel or aluminum, is incredibly strong and distributes a rider's weight between the front and back wheels.
- While the diamond design is the core of most bicycles built today, some frame builders are experimenting with new variations on this classic design.

? Ask students: What other structures use the triangle for support?

Answer: Bridges, truss ceilings, radio towers, high-voltage power poles, etc.

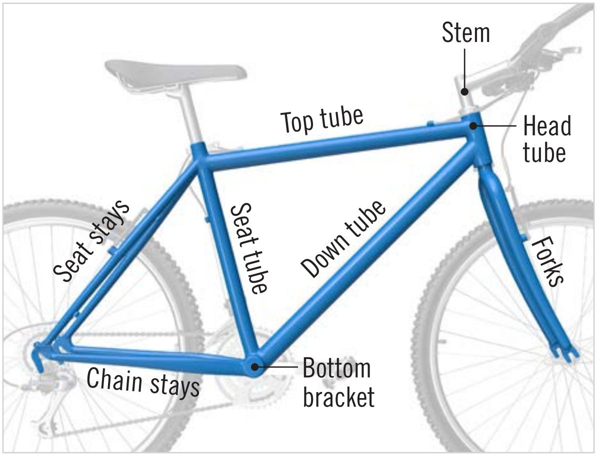
What is Triangulation?

Triangulation — at the core of engineering for over 2,000 years — involves the use of triangular shapes to give structures stability. Triangles are the strongest geometric shape because they have fixed angles. In other words, when pressure is applied to one edge of a triangle, its force is evenly distributed to the other two sides which then transmit pressure to adjacent triangles. That's why the shape is used in building supports and trusses.

In bikes, the lengths of the sides of the triangle and its angles also help determine how a bike rides.

Add to the Frame:

Explain that handlebars, stems, seats and seat posts are all parts of the bike that get fastened to the frame. Before getting into a discussion of nuts, bolts, screws and torque, explain what each of these parts do.



Handlebars:

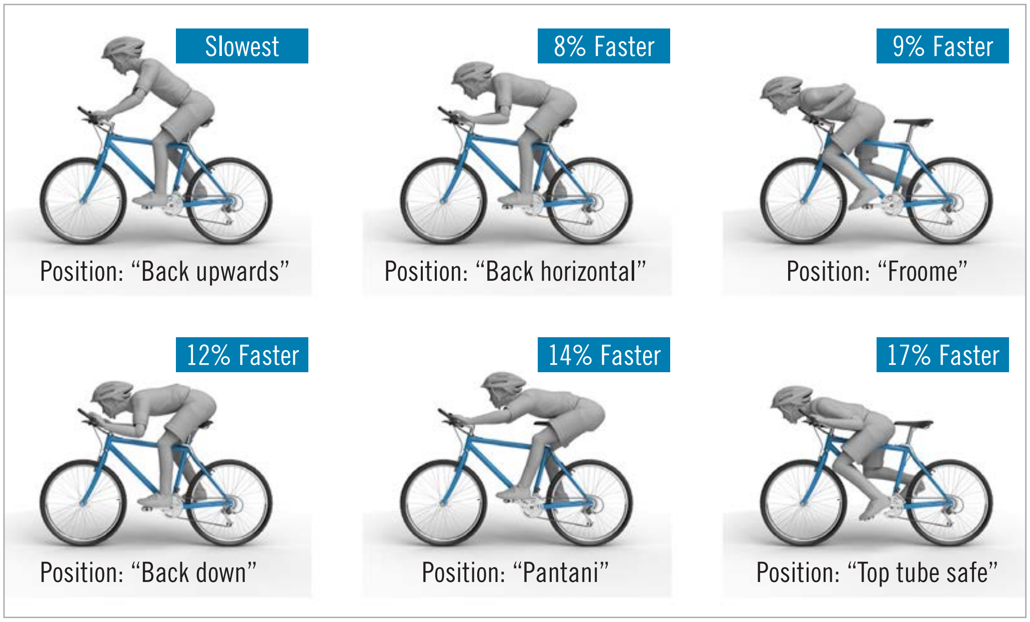
Have examples of different types of handlebars on hand. Explain the differences and pass around.

Explain that handlebars allow you to steer the bike.

- Road bikes typically use narrow drop bars to provide better aerodynamic positioning on the bike and allow for multiple riding positions.
- Commuter bikes have flat handlebars so the rider will use a more upright position on the bike and have better visibility of the road ahead.
- Mountain bikes use wider riser handlebars to assist with control around tight bends and over obstacles. In recent times, mountain bike handlebars have gotten much wider, similar to dirt bike bars, which can be as wide as 32 inches.

What Does Aerodynamic Mean?

When a cyclist pedals into a stiff headwind, the cyclist encounters wind resistance, which causes *aerodynamic drag*, or inefficiency. *Aerodynamic efficiency* occurs when a streamlined shape can smoothly move through the air. For bike racers, aerodynamic efficiency can make a huge difference in terms of speed and resistance. Different riding positions change a rider's body profile and center of gravity to maximize aerodynamic efficiency and stability, which affects handling and speed. (See diagram below.)



DID YOU KNOW?

- Some carbon-fiber frames are made with oval and tear-drop profile tubing to make the bicycle more aerodynamic.
- Frame makers use tube shape and design to build ride characteristics into their frames.
- New full-suspension bikes have altered the diamond design to mount a large rear shock to the rear triangle that allows the rear wheel to move up and down.
- Most changes to conventional frames are designed to improve performance for different types of terrain or uses.

Stem:

Have examples of a quill stem and a standard stem on hand. Pass samples around.

Explain that the stem is the component of the bike that connects the handlebars to the steerer tube of the bicycle fork. Make it clear that stems come in different lengths so they can be adjusted to a riding position that suits the rider.

- In general, a shorter stem gives you quicker, more responsive steering but requires a less aerodynamic body position.
- A longer stem gives you a more stretched out and aerodynamic position on the bike.
- Let them know that there are two types of stems, which represent design evolution:
  - Quill stems, which were developed first, are held in place by a wedge inside the fork's steerer tube. These are usually used on older and less-expensive bikes.
  - Standard stems, which are stronger, safer, and can handle more load and force, clamp around the outside of the steerer tube on a threadless headset design.

? Ask students: What's a bicycle fork and what does it do?

Answer: A bicycle fork is the part of the bicycle that holds the front wheel in place.

Seat Post:

Have examples of seat posts on hand.

The seat post fixes the saddle to the bike frame. Adjustable up and down, you can set the seat post to the height that best suits your riding and desired positioning — whether a more upright or aerodynamic racing position. You can also adjust the saddle's angle and fore/aft position on the seat post mount.

Saddle:

Have examples of different types of saddles on hand. Show how saddles attach differently to different kinds of seat posts.

Saddles come in lots of different shapes: wide, narrow, long, short, cut out.
As a general rule:

- A flat, narrow saddle suits a more aggressive, stretched-out riding position, as you tend to move your legs quickly and tend to place less weight on the saddle itself.
- A wide, curved saddle is best suited to a more upright riding position, as its width supports your weight more evenly.

All About Torque:

Have nuts and bolts on hand to pass around.

Now that all of the parts have been introduced, it's time to learn how to attach them to the frame. Each of these parts is fastened to the frame by nuts and bolts.

Explain that bolts have ridges called threads on the outside and nuts have threads on the inside. When they are threaded together, the tension created by that threading is measured in torque.

Torque is the application of force exerted at a radial distance to tighten a screw or bolt.

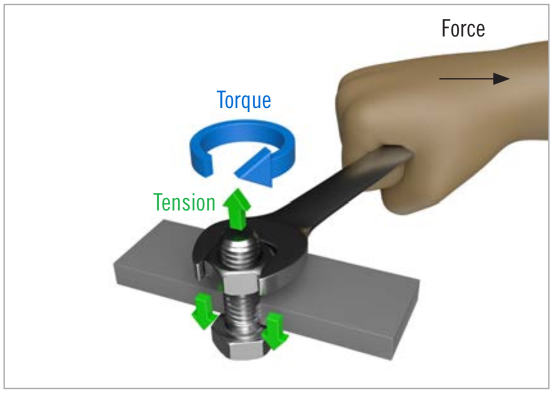
Torque = Lever Arm Length x Force

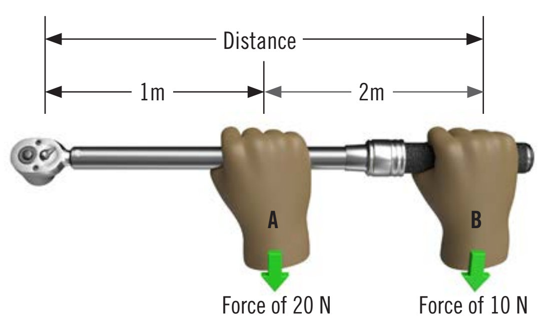
Mountain bikes use longer handlebars to give riders more torque for better steering and control over rough terrain.

Simply put, the torque is the amount of force you can apply to a lever arm — such as a torque wrench — multiplied by the distance from the pivot point where you're applying that force.

When the nut and bolt are tightened, the two plates are clamped together — and the thread converts the applied torque into tension in the bolt shank. The standard unit for measuring torque is Newton-meters (Nm).

A Newton is a measure of force and a meter is a measure of distance.





Example:
10 Newtons x 1 Meter = 10 Nm (Newton-meters)

Let: T = Torque
F = Force
L = Length of lever or wrench

Then: **T = F x L**

Ask students: If you have a force of 10 Newtons and a wrench that's 2 meters long, what's the torque?

Answer: 20 Nm

The Importance of Using the Correct Torque

The amount of tension created in the bolt is critical. Using the right torque when tightening nuts and bolts is important for both bike safety and structural stability.

Ask students: What do you think happens if you don't tighten the bolt enough?

Answer: By not tightening to the correct torque, you risk that it will come loose.

Ask students: What do you think happens if you "over torque," or tighten it too much?

Answer: Cracking, deformation, stripped threads, and stripped bolt heads can be a direct result of over torquing.

How to Use a Click-type Torque Wrench:

Demonstrate how this kind of wrench works.

A click-type torque wrench can be set to a specific torque and clicks when the correct torque is reached. Many have a spring-loaded system that releases when you apply more force than is required for the torque rating.

Hands-on:

Let students use the torque wrench and tighten a nut and bolt to an established torque value.

Let's Get to Work:

It's time to put what you've been talking about into practice. Explain to students that now they'll get to add some of the hard parts to the frame.

Hands-on:

Make sure enough front wheel/fork combos are set up in stands for students to work in pairs or small groups.

- ✔ First, give each student the opportunity to try to install a handlebar onto a stem.
- ✔ Next, have them install a saddle on a seat post, first off the bike and then with the seat post attached to the bike.
- ✔ Next, show students how to make small adjustments to the handlebars and saddle.
- ✔ Point out how small changes in handlebar, stem and post position affect the position of the rider.

The Front End of the Bike:

The front end of the bike is where all of the controls are located. Here you'll find the controls for steering, braking and shifting/gear selection. Explain that today's lesson will lightly focus on brake and shift/gear levers. Lessons 3 and 4 in this series include a deeper exploration of brakes and gears.

Introducing Bike Controls: Brake Levers and Shift Levers

Explain that brake levers activate the brake system and shift levers, or "shifters," derail the chain from the current gear and shift it to a new gear. Both sets of controls are mounted on to the handlebars with nuts and bolts.

DID YOU KNOW?

Torque is also involved in pedaling a bike!

If we take the same formula:

Torque =
Lever Arm Length X Force

and understand that the pedal is a crank (or lever arm), you can see that torque can be measured by the amount of force you apply to the pedals.

In addition:

Power = Torque X Crank Speed

So power is a product of how hard you press on the pedals and how fast you turn them!

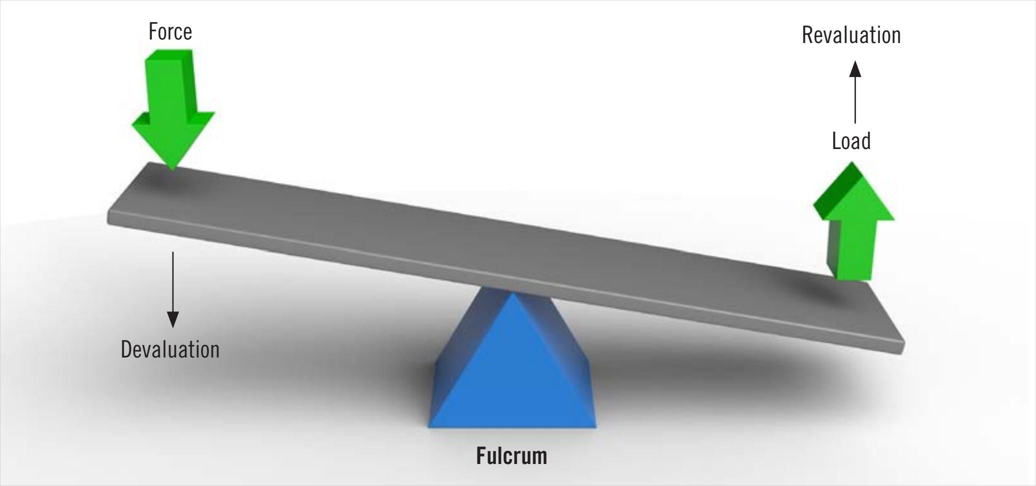
Learning About Levers

It's time to talk about levers, but first find out how much your students know about them.

Ask students: Other than brake levers and shift levers, can you think of other examples of a lever?

Answer: Seesaw, nutcracker, scissors, brake lever

Remind them that a traditional seesaw is a great example of a lever. It's a long, rigid arm that hinges on a pivot point called a fulcrum. Strictly speaking, a lever works by using mechanical advantage. It is a device that redirects a force from one end and transfers it to the other end as load force or load output.



Ask students: What is mechanical advantage?

Answer: See below.

Mechanical Advantage

In simple terms, mechanical advantage is the amount of help you get from using a machine instead of just using your own strength. It's a measure of the force amplification achieved by using a tool, mechanical device or machine system.

Hands-on:

Leverage and mechanical advantage with a ruler

- ✔ You'll need a lever, fulcrum and weights. The seesaw is made simply by using a 15" ruler. Make the fulcrum using an index card folded and taped into a triangle. Use double-sided tape underneath the midpoint of the ruler and along the top. Use three pennies for two weights, taping two together. Another construction option is online at: https://www.youtube.com/watch?v=PBQarKVKLfQ

- ✔ With your ruler and fulcrum setup,
  - Place one penny at the 5” point.
  - Now place two pennies at the 10” point and watch as the smaller weight is lifted into the air.

Ask students: What can we do with the lighter weight to lift the heavier weight into the air?

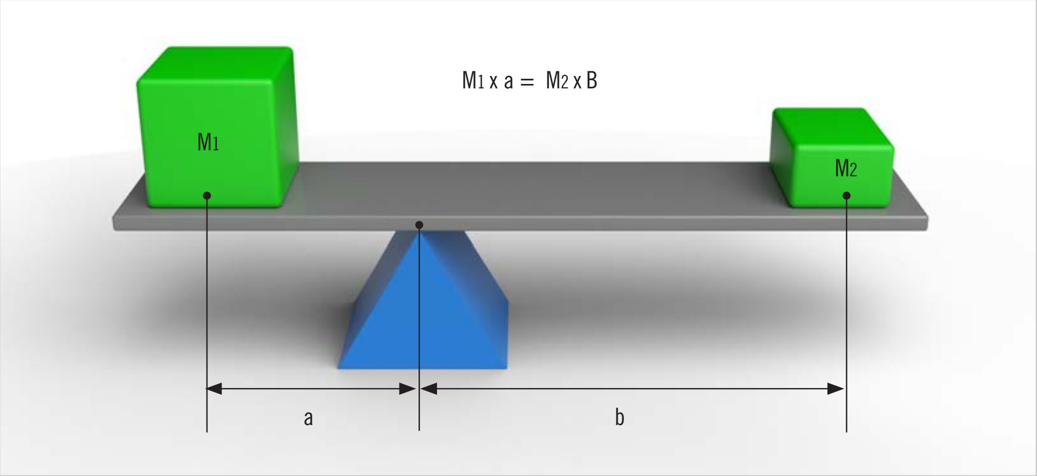
Give everyone time to respond to the question.

- ✔ Now have a student move the single penny away from the fulcrum until he or she finds the spot that balances the two. Mark that spot on the ruler.
- ✔ Then keep moving the single penny in the same direction until the heavier magnet is lifted into the air.
- ✔ You've used mechanical advantage to lift the heavier weight.

Resource video: Mathematics of the Lever

Measuring Mechanical Advantage

Using a whiteboard or the image in the Appendix, create an illustration like the one below. Explain to students that, like the hands-on exercise they just completed, this illustration demonstrates that the longer the leverage (or section of ruler), the less mass needed to move a greater mass.



The formula is:

Mechanical Advantage (MA) = $\frac{\text{Input Arm Distance}}{\text{Output Arm Distance}}$

Divide the length of the lever's effort arm, which represents the input force (“b” in illustration), by the length of its resistance arm, which represents the output force (“a” in illustration).

Ask students: If a = 6 meters and b = 9 meters, then what is the mechanical advantage

MA = $\frac{9}{6}$ or a mechanical advantage of 1.5.

How Does Mechanical Advantage Apply to Brake Levers?

In a bike brake system, you pull the brake lever, which pulls the brake cables, which in turn pulls the brake pads into the rim of the tire and stops the wheel.

In the case of bicycle brakes, the mechanical advantage of the system represents the ratio between the amount of force that presses the brake shoes against the rim and the amount of force that the rider's fingers have to apply to the brake levers to create this braking force.

If a particular braking system has a mechanical advantage of 8, then squeezing the brake lever with 10 pounds of force will cause the brake shoes to apply 80 pounds of force against the rim.

$$\text{MA} = \frac{\text{Force applied by brake shoes} \quad 80}{\text{Force applied to brake shoes} \quad 10} = 8$$

Shift Levers

Explain to students that shift levers shift the gears on the bike. Their mechanical advantage will be discussed in a later lesson.

Hands-on:

Give students the opportunity to install brake levers and shift levers on to the handlebars.

Evaluation Actions and Questions:

1. Using a blank version of the frame structure (in the Appendix), identify the parts of the frame on the worksheet.
2. Teach the person sitting next to you how to apply the proper torque to a nut and bolt.
3. What is mechanical advantage?
4. How does a lever work?

Final Check-in:

Ask students to share something they learned today and what they found most interesting. What "new fact" stands out? Then do a final check-in to make sure everyone is in good spirits. You might want to do "fist to five," where a closed fist is 0 (signifying a bad day) and five fingers means it was an awesome day. Thank the students for their participation and introduce the next week's class subject.

LESSON 3

Brakes and the Braking System

LESSON GOAL

Know how to properly adjust brakes and perform a brake safety check.

LESSON OBJECTIVES

During this class, students will:

- ✔ Learn the different types of brakes and which bicycles use them
- ✔ Understand why — and how — each type of braking system works
- ✔ Be able to name basic parts of the two main braking systems: rim and disc
- ✔ Learn about friction, forces and materials involved in braking
- ✔ Understand the connection between friction and slowing down a bicycle wheel

MATERIALS NEEDED

- ✔ Samples of different braking systems
- ✔ No. 1 Phillips head screwdriver
- ✔ 5 mm T-handle wrench
- ✔ 3-way Allen wrench tool with 4mm, 5mm, and 6mm sizes
- ✔ 2-foot flat piece of plywood
- ✔ Test items: wooden block, rubber eraser, metal spoon, small plastic container, toy car, etc.
- ✔ Sandpaper
- ✔ Measuring tape
- ✔ Water

LESSON PLAN

Provide an Overview of the Lesson:

Tell students that in this lesson, they'll be learning about brakes and braking systems. Through their understanding of how brakes work, they will also learn about friction, heat and frictional force.

They'll do hands-on brake adjustments and learn the importance of brake safety.

Group Check-in and Connect:

To open the class and get students checked in and connected, try a short exercise. Consider having each student tell a six-word story about something positive in their lives or give a simple fist-to-five signal of how they're feeling today with fist = 0 (or terrible day) up to five fingers = 5 (or best day ever).

Share a Brief History of Braking Systems:

Have examples of different braking systems on hand and explain how each system works. Show students the different kinds of brakes on various bike types or pass parts around.

Explain that while brakes are needed to stop a bicycle, it's important to understand that they are also used to control speed, especially when riding with a group, making a turn, or descending a slope. All of these things factor into brake design.

Next, share some of the history of brakes. Explain that over time, braking systems have undergone many changes, even though the basics remain the same. In the very early days, when bicycles were slow, dragging your feet along the ground to stop them worked pretty well. But with increases in speed and performance, brake designs have had to get better and better.

Remind students that all brake systems are based on the principle of mechanical advantage that was discussed in the last lesson.

Coaster brakes were invented in the 1890s. They became the standard "safety bike" brake and have been in continuous use ever since.

Coaster Brakes

Included in the rear hub, this is the most common type of brake for basic, single speed bikes — like beach cruisers. Coaster brakes have high efficiency and low maintenance. They work similarly to car drum brakes. When you back-pedal, two brake shoes inside the hub push against an internal cylindrical brake surface.

Even earlier, in 1887, English inventors patented the first caliper braking system — and versions of those are still used as well.

Caliper Brakes

Brake arms extend around the tire with brake shoes that press against the rim. The entire brake assembly is attached to the center of the fork.

U-Brakes

Essentially these are the same as center pull caliper brakes, except the two arm pivots attach directly to the frame or fork. They're mainly used on BMX bikes.

In the 1940s, cantilever brakes were developed. They got popular in the 1980s, when mountain bikes became common.

Cantilever Brakes

Two pivoting arms are connected by a cable. When a lever is pulled, hangers engage the two pivoting arms via the connecting cable. They have very good mud clearance, which is why they are used on cyclocross bikes.

Linear-Pull V-Brakes

V-brakes improve on the cantilever by lengthening the pivoting arms for better leverage and placing the connecting cable in line with the direction of the braking forces. They're used on cyclocross, city and mountain bikes.

Disc brakes for bicycles were popularized in the 1990s, and today's disc brakes are the cutting edge of precision stopping.

Disc Brakes

Disc brakes can be hydraulic or mechanical. Disc brakes rely on a caliper with two or sometimes four brake pads that squeeze the rotor (or disc) attached to the wheel's hub.

Discuss Mechanics and Anatomy:

Explain that bicycle braking systems consist of three main components:

1. A mechanism that allows riders to apply force, such as levers or pedals
2. A mechanism for sending that force into the system — typically via cables, hydraulic hoses, or the bicycle chain
3. A mechanism such as a caliper to press surfaces together

All bicycle brakes, no matter their mechanisms, work by using friction. Without getting too technical, friction can be described as a rubbing force that reduces motion between objects as they slide past each other while in contact. So, the friction caused by braking stops or slows down the bike.

- For example, when a rider applies force by pulling the brake lever on a caliper brake, that force is transmitted through the system via brake cables that connect the lever to the caliper. Then a pair of rubber brake pads clamp onto the metal rims of the wheels. As the brake pads rub tightly against the rims, they create friction.

Ask students: Can you think of other examples of friction?

Answer: A sled sliding across snow, a person sliding down a slide, a coaster sliding across a table.

All types of caliper and cantilever brakes are known as rim brakes because their brake pads squeeze wheel rims. With disc brakes, pads squeeze discs that are attached to the wheel's hub to create friction and slow the bike.

Explore the Science of Friction and Heat:

Braking creates kinetic friction, which is also known as dynamic friction — the resistance that one object encounters when moving over another — and this slows things down. But creating friction has another effect.

Hands-on:

Kinetic Friction Experience – Exercise 1 – Heat Production

Ask students to rub their hands together very rapidly. What happens?

Explain: The friction you created converted kinetic energy into thermal energy!

So, the friction of the brake pads against the wheel rim takes energy out of the forward spin of the wheel and transforms it into heat — which dissipates into the rim and the air around it. Point out how that's exactly what happened after students stopped rubbing their hands together — the heat went away.

DID YOU KNOW?

Friction Produces Heat

But do you know why? It's because no surface is perfectly smooth. There are always rough spots, even if they're microscopic. When surfaces rub against each other, the rough spots on both sides catch and grab each other. This causes the molecules on each surface to move faster. The added energy raises their temperature. In general, the rougher the surfaces are, the more friction and heat produced.

What's Kinetic Energy?

Simply put, kinetic energy is the energy of motion. An object in motion is using kinetic energy, whether it's a thrown baseball, a moving car or a charged particle in an electrical field. Objects that are not in motion possess potential energy, which is converted to kinetic energy when some force, such as gravity, acts upon the object to set it in motion. The formula to measure kinetic energy is:

KE = 1/2mv2

In cycling, this means that the kinetic energy is based on the weight of the bike and the rider and the velocity, or speed, at which they're moving.

Ask students: Where do caliper braking systems get hot?

Answer: Primarily the rim.

How to Brake Correctly:

When braking a bicycle, balancing the braking between the front and rear tire is very important. You want to stop quickly, in control, and not go over the handlebars. As you ride along on the bicycle and apply the brakes, your body has momentum — the tendency to continue moving in the same direction. That shifts your weight forward onto the front wheel. However, if you do too much braking with the front wheel, you can wind up going over the handlebars. The idea is to balance your braking between the front and the back brakes to achieve the maximum effect.

Momentum is Mass in Motion

Momentum = Mass x Velocity

Momentum can be thought of as the "power" when a body is moving, meaning how much force it can have on another body. For example, a bowling ball (large mass) moving very slowly (low velocity) can have the same momentum as a baseball (small mass) that is thrown fast (high velocity).

Deep dive into brake pads

Explain that while brake pads don't get a lot of attention, they deserve it. Brake pads literally save lives. With disc or rim brake pads, there are lots of important scientific and technical choices to be made in their design and manufacture. Decisions about durability, speed modulation and rim compatibility can all make a huge difference in the quality and safety of a ride.

Of course, the major problem every brake pad has to overcome is heat dissipation from all the friction created. A secondary problem is how the brake pad materials interact with the braking surface (wheel rim or disc) materials. With different types of wheel rims (such as steel, carbon, aluminum or blends) and different types of brake pads (such as rubber, metal or organic), it's important to make sure that both materials work well together so the brakes perform as desired.

DID YOU KNOW?

Energy Can Never Be Destroyed

There's even a "law" about it and it's called the first law of thermodynamics. This law says that energy can't be created or destroyed — it can only be transferred or changed from one form to another. So, the kinetic energy of braking gets changed into thermal energy and some sound energy and is transferred into the atmosphere!

SAFETY TIPS

Tip 1

Explain that, especially on long downhill runs when there's a tendency to "ride the brakes," it's possible for brakes to get too hot because heat can't dissipate fast enough. In extreme cases, this overheating can even cause a blowout. It's important to stay off the brakes for periods of time in between using the brakes so wheel rims can cool down.

Tip 2

Explain that water reduces friction on the braking surface. So, if you are riding in the rain with rim brakes, their stopping power is diminished.

For example, with rim brakes, temperatures generated during braking depend on the material of the rim. Brake pads for some metal wheels are rated up to 180° Celsius (356° F). But pads for carbon wheels need to sustain temperatures up to 320° Celsius (608° F), so they're made of harder rubber designed for higher temperatures.

Explore Frictional Force

As explained earlier, kinetic friction is a force that acts between two moving surfaces. Smoother surfaces create less friction when rubbed together. Rougher surfaces will produce more friction and heat. The angles of the surfaces and the weights of the objects can also affect the amount of friction. Another consideration is whether the surfaces are dry or wet.

Hands-on:

Let's dig a bit deeper into kinetic friction.

Kinetic Friction Experience – Exercise 2 – Sliding

Materials:

- ✔ Flat piece of plywood about two feet long
- ✔ Test items: wooden block, rubber eraser, metal spoon, plastic container, toy car, etc.
- ✔ Sandpaper
- ✔ Measuring tape
- ✔ Water

Testing:

1. Start by making an inclined ramp at a moderate angle.
2. Place each item at the top of the ramp – no pushing.
3. Measure how far each item moves down the ramp on its own.
4. Affix sandpaper to the ramp and repeat with each item.
5. Wet the ramp with water and repeat again.

Ask students: What did you observe? Why did the speed and distance travelled by each item change with the different circumstances created?

Answer: Rougher surfaces produce friction.

SAFETY TIP

It's very important to make sure you always check that any replacement brake pads you buy are made of the right materials for the wheel rims or discs being used on your bike.

DID YOU KNOW?

Materials Science and Engineering (MSE) is the field for creating the "stuff" that makes everything work!

MSE combines principles of engineering, physics, and chemistry in order to solve real world problems — including innovations in bicycle braking systems. Getting the right performance out of a braking system depends in part on finding or making the right materials, especially when it comes to brake pads. You need something that can produce a decrease in speed but also quickly disperses the heat created. Within MSE, there's an entire field devoted to friction materials!

Brake Safety and Adjustments:

Explain that over time, the stopping power of bicycle brakes can change. Brake pads wear out or can start dragging on the rims, the brake housing wears down and compresses, and hydraulic brake fluid degrades. Since a rider's safety depends on optimum brake performance, being able to make common adjustments to bicycle brakes is an important skill for every rider to have.

- Make sure students know how to do a safety check of bike brakes:

Safety Check

As part of every pre-ride safety inspection, checking the brakes is a must.

- Spin each wheel to check for rubbing
- Squeeze the brake levers to make sure the brakes engage smoothly and release fully
- Check the brake pads for excessive wear
- Check the brake cables and housing for fraying and splitting

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Demo: Approximately 30 Minutes

Move to bike stands and bring out fork/front wheel combos with different types of braking systems. If possible, include various brake types as well as mechanical disc brakes.

1. **Show students the required tools necessary to adjust brakes.**
   a. Number 1 Phillips head screwdriver
   b. 5 mm T-handle wrench
   c. Multi-tool 4mm, 5mm, 6mm, and Phillips screwdriver
   d. 3-Way Allen wrench tool with 4mm, 5mm, and 6mm sizes
2. **Demonstrate how to check that brakes are working safely and properly.**
   a. Are brake pads in alignment? How worn are they?
   b. What is the condition of the wheel rims?
   c. How is the cable tension?
   d. What is the condition of cables and housing? Any rust or breakage?
   e. Are the adjuster screws too loose? Too tight?
3. **Show how brake pads are attached on different braking systems and demo how to reposition or replace brake pads properly.**
4. **Show students the process for removing and replacing cables on different types of brakes.**

   Demonstrate how to lube at entry and exit points.
5. **Show how to re-center a brake using the mechanisms on different braking systems.**

Hands-on:

If time and tools allow, break students up into pairs or small groups and have them work independently to take one style of braking system apart and put it back together.

Evaluation Actions and Questions:

1. Using a blank version of the brake chart (in the Appendix), name the bicycle brake systems featured.
2. How do brakes work?
3. What is friction?
4. How do you do a brake safety check?

Final Check-in:

Ask students to share something they learned today and what they are most interested in learning more about. Then do a final check-in to make sure everyone is in good spirits. You might want to do "fist to five," where a closed fist is 0 (signifying a bad day) and five fingers means it was an awesome day. Thank the students for their participation and introduce the next lesson's subject.

LESSON 4

Chains, Chainrings and Cassettes

LESSON GOAL

Know how to examine a chain for wear and properly clean and lubricate a chain.

LESSON OBJECTIVES

During this class, students will:

- ✔ Learn about the history of the bike drivetrain and be able to identify each of its components
- ✔ Understand how chains, chainrings and cassettes work together
- ✔ Know how to size a chain for a given drivetrain — and understand why size matters
- ✔ Understand how gears work
- ✔ Learn how to "break" a chain with a chain breaker and by using master link pliers

MATERIALS NEEDED

- ✔ Chains of different speeds and lengths
- ✔ Cassettes and freewheels to show the variance of chain size
- ✔ Master link pliers
- ✔ Degreaser
- ✔ Chain lubricant
- ✔ Chain breaker tool
- ✔ Chain wear indicator: Park Tool CC 3.2
- ✔ Gloves
- ✔ Paper, pen, clipboard, picture

LESSON PLAN

Provide an Overview of the Lesson:

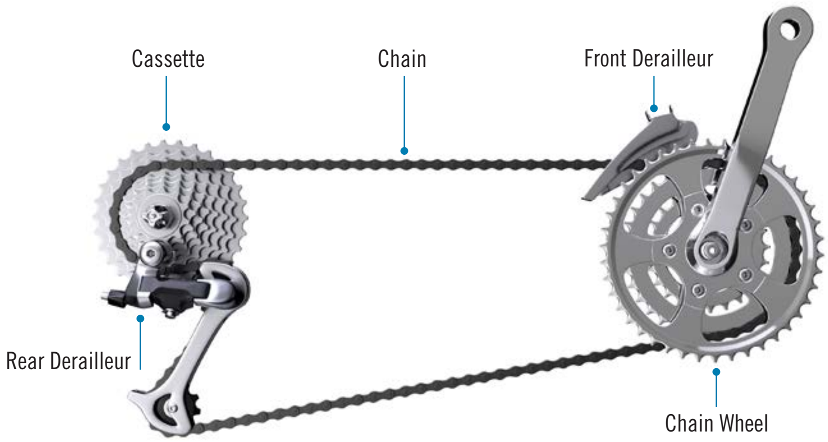
Let students know that in this lesson they'll be learning about the drivetrain of the bike, specifically the chain, chainrings and cassette and how they create gearing. Explain that the class will be very "hands-on." Students will learn how to examine chains for wear as well as how to break a chain, clean a chain and lubricate a chain. Let them know that this class will be their most messy and that they will need to wear gloves at all times to limit their exposure to chain oil and grime.

Group Check-in and Connect:

Ask students to spread out and form a "human chain" with some space between each person. Then, show the first person a picture. That student must tell the person next to them what it is. This continues until the last person receives the description and must then attempt to recreate the picture on paper. The aim is to try and match the original picture, showing that information was transmitted along a chain. In a bike, its chain and mechanism transmit your energy from the pedals to its wheels.

Bicycle Drivetrain 101:

Explain that the "drivetrain" of the bike consists of multiple parts that work together to transfer power from your legs to the wheels so that the bike can move. The primary components of the drivetrain are the cranks, chainrings (or chain wheel), chain, cassette, and front and rear derailleurs.



Repeat that this lesson will focus on how the chain, chainrings and cassette work together. The other components of the drivetrain will be explored in Lesson 5.

Explain that before we begin, we'll need a quick vocabulary lesson so this section of the class doesn't become confusing. We're going to talk about cogs, sprockets, and teeth as they pertain to the drivetrain and the gears of your bike.

Let's Go Over It

Gear: A metal disc with teeth that interlocks with the chain to drive the bike forward

Cogs: The individual gears that make up the cassette

Sprocket: A single, stand-alone gear (e.g., chainring)

Teeth: The engagement points for the chain on the cog, sprocket or chainring

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? Ask students: What do your bike chain, the odometer, and the Mona Lisa have in common?

Answer: Leonardo DaVinci

Review the History of the Bicycle Chain and Chain Drive

Leonardo DaVinci was an inventor, scientist, astronomer, map maker and painter who lived 500 years ago. (Who has heard of the Mona Lisa?) He is credited with developing the idea of the chain and cog in the 15th century. However, it took nearly 400 years for the idea to become a practical aspect of bicycle design.

By the 1880's, the chain drive was commonplace, effectively eliminating the need to have the cyclist directly above the wheel. Instead, the cyclist could be positioned between the two wheels for better balance.

? Ask students: Why is a chain better than a belt?

Answer: Because a chain is more precise, doesn't slip, and doesn't require tension to work.

Let's Begin with the Bicycle Chain:

Show some examples of chains. Explain any differences between them.

Place a number of chains in front of the students and ask them to observe them.

? Ask students: What are some of the differences you notice between the chains?

Write down some of the differences they note and refer back to them as you move through the lesson.

Explain that a bicycle chain is a roller chain that propels your bike forward. It is a simple, reliable and efficient means of power transmission.

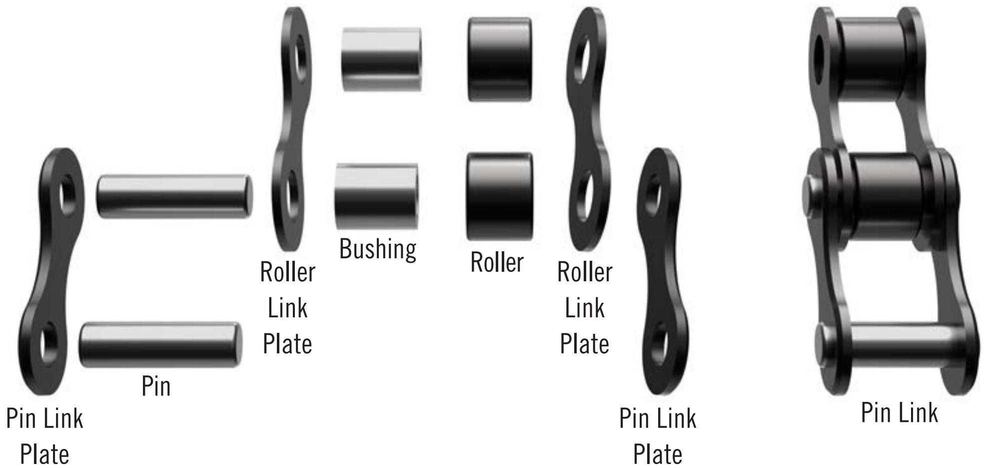
Ask students: What is a roller chain?

Answer: A roller chain is the type of chain most commonly used for transmission of mechanical power. It consists of a series of short cylindrical rollers held together by side links. It's driven by a toothed wheel called a sprocket.

More About Roller Chains

The roller chain consists of 5 basic components:

- Pins
- Bushings
- Rollers
- Pin link plates
- Roller link plates



Each of these components is manufactured and assembled to precise tolerances and heat treated to optimize performance with regard to wear resistance, fatigue strength (the highest stress a material can withstand without breaking), and tensile strength (the resistance of a material to breaking under tension). Explain to students how these pieces fit together to form a chain. Let them compare the image to the chains in their hands.

How Chains Work with Gears:

With a bicycle in a stand, demonstrate how the pieces of the drivetrain work together.

On a bicycle, the chain is looped around the main gear wheel between the pedals. At its other end, it shifts between a series of bigger or smaller toothed wheels when you change gears.

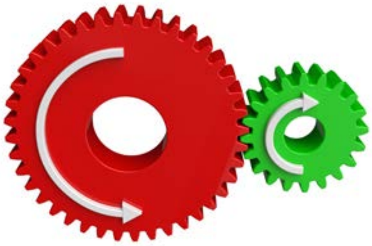
Explain that a typical bicycle may have anywhere from 3 to 30 different gears that can be used to increase a rider's speed or pedaling force. Using them correctly can make the bike faster on flat terrain and easier to pedal when going uphill.

Explain that being able to change gears based on terrain and conditions is a truly amazing leap forward in bicycle engineering. The clever combination of two different sized cogs and a chain is what makes all this possible.

Demonstrate the lessons below with gears on a bike in a stand.

Most geared bikes have one, two or three chainrings in the front and anywhere from seven to 12 gears in the back (or the cassette attached to the rear wheel). Each time you pass power from one gear wheel to another, you can:

- **Increase speed:** If you connect two gears together and the first one has more teeth than the second one, the second one has to turn round much faster to keep up. So, this means the second wheel turns faster than the first one but with less force. Turning the red wheel with 24 teeth would make the green wheel with 12 teeth go twice as fast but with half as much force.



- **Increase force:** If the second wheel in a pair of gears has more teeth than the first one, it turns slower than the first one but with more force. Turn the red wheel and the green wheel goes slower but has more force.

Newton's Second Law of Motion

Some of the oldest and most basic laws of physics help explain how bicycles work. For example, Newton's second law of motion says that:

Force (F) = Mass (M) x Acceleration (A)

Applied to bicycling, that means that when you exert force by pushing down on the pedals, the bike will accelerate proportionately, depending on the mass (weight) of the bike and rider

What Are Cassettes?

Explain that the gear pieces on the rear wheel are a modernized version of the "cogs" invented by DaVinci. When a few of them are put together in ascending size and attached onto the back wheel of a bike, they are referred to as a "freewheel" or a "cassette," depending on the mechanism that engages the wheel. Most bikes built in the last few years have between 8 and 11 cogs in the cassette. The largest are closest to the wheel and the gears are numbered from the inside out. The larger the cog, the "lower" the gear and the easier it will be to pedal, but the slower you will go.

What Are Chainrings?

Explain that the front gears on the bike are referred to as chainrings, or a crankset. Actually, the whole assembly with the crank arms and the front gears together is properly known as the "crankset." Most cranksets have either two or three chainrings.

Single chainrings are used on almost all mountain bikes made since 2017. Single chainrings or "one by" drivetrains are used on mountain and cyclocross bikes because the chain is less likely to fall off the single front chainring.

Explain Chain Sizing/Speed:

Show some examples of chains of different speeds and sizes.

Explain that there are two basic types of bicycle chains: "one-speed" chains and derailleur chains. You must choose the right chain for the bike or the chain will not function the way it's supposed to and the bike will not be operable.

- **Single-speed chains:**
  The common single-speed chain is designed for bikes with one sprocket on the crankset and a single sprocket on the wheel. The width of the roller is 1/8" wide (3.3mm). The one-speed chains are not designed to shift on the multiple rear cassette cogs on bikes that use derailleurs.
- **Multi-speed chains:**
  Multi-speed chains that use derailleurs are designed to be moved from cog to cog and come in many different design standards. When selecting a chain, the first consideration is the number of rear sprockets. The rear cassettes are made with 5-12 cassettes.
  - As the number of cogs on the rear hub increases, the spacing between cogs tends to be reduced. Consequently, chains tend to get narrower as the number of rear cogs increases.

Hands-on:

In small groups, let students get up close and personal with bikes in stands, seeing for themselves what different chain speeds look like.

Now, Let's Discuss the Importance of Chain Maintenance:

Periodically Check for Wear

Explain that as your chain goes through its range of motion over the course of months of riding, the surfaces inside the link rollers wear down, effectively making the chain slightly longer. This is sometimes referred to as "chain wear." As the rollers and bushings on the chain become worn and loose, their ability to stay between the teeth at the appropriate length diminishes. As the chain wears, space between the links no longer matches up exactly with the space between each tooth on your gears. At this point, your chain starts wearing down your gears.

- Explain that it's important to change out a worn chain before it does damage to your cassette or chainrings.

Explain that you can do a visual check for chain wear but a simple and effective way to measure chain wear is using a chain-wear indicator. This tool measures wear in the chain as a function of a gap space between two rollers. The way you use it is to insert the tool in the space between two rollers.

- The Park Tool CC 3.2 chain wear indicator accurately indicates when a chain reaches either 0.5% or 0.75% wear, the point at which most chain manufacturers suggest replacement.

Resource video: How to Use A Chain Wear Indicator

NICE TO TEACH, IF YOU HAVE TIME

Rear derailleurs are precision engineered for shifting performance and durability.

Some of the nominal widths measured across the chain pin between chains are:

- 12 rear cogs – 5.3 mm
- 11 rear cogs – 5.5 mm
- 10 rear cogs – 6 mm
- 9 rear cogs – 6.5 to 7 mm
- 6, 7 and 8 rear cogs – 7 mm

Resource video: How to Size a Bicycle Chain

Hands-on:

With bikes set up in stands, have students first do a visual check of the chain for wear and tell you if they think it needs to be changed. Then let them use the chain wear indicator to see if their visual examination was accurate.

Keep it Clean

Explain that the lifespan of the bike chain depends mostly on how well it is cleaned and lubricated as well as how it is used. Constant hard shifts and high torque loads on the chain will cause the chain to wear faster. As a result, well-maintained chains that are cleaned frequently will consistently last longer than dirty chains with too much lube that pick up grit and grime that cause premature chain wear.

- **Note:** The sheer force to which your chains, chainrings and cassettes are subjected make them high-wear items at any time of year, but grime, road salt and rain are additional stressors.

Hands-on:

First demonstrate how to effectively clean and lubricate a chain and then let your students — in pairs or small groups — follow your example.

- ✔ For the cleaning, demonstrate how to do a quick and easy cleaning using a rag and degreasing solvent.
- ✔ With the bike in a stand, pour or spray a generous amount of degreaser on a rag.
- ✔ Wrap the rag around the lower part of the chain and hold it in place with your left hand while you pedal the drivetrain backwards using your right hand.
- ✔ Hold the rag firmly enough to wipe the gunk, but loosely enough that the chain is able to move freely.
- ✔ Remove and reapply the rag so that you reposition the chain to a clean area of the rag.
- ✔ Repeat this process several times until the chain appears about as clean as it's going to get.
- ✔ Then add lubricant. With your left hand, hold the tip of the chain lubricant bottle over the chain near the gears, and pedal backwards with your right hand.
- ✔ Squeeze the lube bottle to make a light but steady stream onto the chain.
- ✔ You want to lube the chain only; it's important not to put lube on the gears. Keep spinning the pedals until you're sure you've gotten lube on the whole length of the chain. Then, take a clean rag and wipe away excess lube from the outside of the chain. It is just as important to get lubricant on the chain as it is to remove the excess, wipe the chain until it is not oily to the touch on the outside.

Breaking a Chain:

Explain that while bicycle chains can break on their own, there may be times that you choose to break it to put on a new one or fix a broken link. In this case, there's a tool called a chain breaker that is just perfect for the job.

Hands-on (15-20 minutes):

First demonstrate how to break a chain with a chain breaker and then have one student at a time break a segment of the chain.

Convey the importance of trying to break the chain without pushing the pin all the way out.

Resource video: How to Use a Chain Tool to Break a Chain

Hands-on (15-20 minutes):

Next, demonstrate how to break a chain without a chain breaker and pushing the pin all the way out — and then have one student at a time try it.

Resource video: Remove a Quick Link, Master Link on Your Chain Without Tools

Evaluation Actions and Questions:

1. Name the parts of the bike's drivetrain.
2. Name two or three components of a roller chain.
3. How many gears are on a cassette?
4. Is pedaling easier on the largest or smallest cassette gear?

Final Check-in:

Ask students to share something they learned today and what they are most interested in learning more about. Then do a final check-in to make sure everyone is in good spirits. You might want to do "fist to five," where a closed fist is 0 (signifying a bad day) and five fingers means it was an awesome day. Thank the students for their participation and introduce the next week's class subject.

LESSON 5

Shifters, Shifting and Front/Rear Derailleurs

LESSON GOAL

Understand how front and rear derailleurs function.

LESSON OBJECTIVES

During this class, students will:

- ✔ Learn to identify the main drivetrain components including shifters, derailleurs, cranks, cable and housing
- ✔ Understand how front and rear derailleurs function
- ✔ Understand how a shifter works, including ratchet and gear systems, spring and cable tension
- ✔ Understand gear ratios and how they affect performance
- ✔ Learn how to test derailleurs for proper shifting, including cable/housing check

MATERIALS NEEDED

- ✔ A few front and rear derailleurs as examples to show students
- ✔ One or more bicycles with complete drivetrains
- ✔ A piece of shift housing and a shift cable
- ✔ Bikes in stands with varying levels of functional drivetrains
- ✔ Tools, including
  - Box wrenches and Allen wrenches
  - Flathead and Phillips head screwdrivers
  - Fourth hand tool
  - Pliers

LESSON PLAN

Provide an Overview of the Lesson:

Let students know that in this lesson they'll be learning about how the front and rear derailleurs function, how they fit into the drivetrain system and how gear ratios can affect performance. They'll also learn how to test derailleurs for proper shifting and adjust them as needed.

Group Check-in and Connect:

Ask each student to share a story about having to change gears on a bicycle ride. When did they need to? Was it easy? Did it help the ride? Were there any problems?

Talk About Derailleurs and Gear Shift History:

Explain that being able to shift gears allows riders to power up hills, cruise on flats, and safely descend a mountainside. And it's the invention of the derailleur that made shifting gears possible. Derailleurs guide the chain between gears so that riders can shift into different gear ratios or "speeds."

- On the earliest bicycles, the only way to switch speeds was to stop and change the size of the wheels. Imagine doing this during a race!

By the late 1930s and 40s, derailleurs began appearing, although these early versions were hard to use. In 1937, the Tour de France allowed derailleurs for the first time. That year's winner had the enormous advantage of being able to shift gears without needing to dismount and change wheels.

By the 1950s, derailleurs began to look and function pretty much as they do today. Now you can get a bike with up to 30 speeds while early cyclists were lucky to have more than three. Controls are positioned at a rider's fingertips, and there are options for electronic systems and even computer-controlled automatic shifting. So, derailleurs, and the drivetrain system they belong to, have come a long way in a few decades.

Explore Derailleurs:

Have examples of front and rear derailleurs on hand and talk about how they work. Show students examples on a bike stand or pass parts around so they can observe and feel.

Front Derailleur

The front derailleur shifts the chain up and down on the front gears — the crankset — that make up the front half of the drivetrain. They are designed to work with two or three chainrings and are actuated by shifters mounted on the left-hand side of your handlebars as you look forward while riding.

Rear Derailleur

Actuated by shifters mounted on the right-hand side of the handlebars, the rear derailleur is constructed as parallelograms. It moves the chain up and down on the gears and diagonally across the rear half of the drivetrain. It also keeps the chain tensioned via a mobile pulley arm. A second pulley called an "idler" adjusts tension to keep the chain tight while it moves between cogs. Rear derailleurs bolt on to a "derailleur hanger," a small metal hanger attached to the bicycle frame located at the rear wheel dropout, where the rear wheel attaches.

What's an engineering fail-safe?

A derailleur hanger is what's known in engineering as a fail-safe. It's designed to break or bend in case of an accident in order to prevent or limit damage to the bike's frame. A very common example of a fail-safe is the electrical system in your home. Every circuit uses a circuit breaker — an electric switch that is designed to switch off or "break" if the electrical load is too high in order to prevent catastrophic electrical overload.

?

Ask students: What does the front derailleur do? What does the rear derailleur do?

Answer: The front derailleur shifts the chain up and down on the front gears. The rear derailleur moves the chain up and down on the rear gears and diagonally across the rear half of the drivetrain.

More Components of the Drivetrain System:

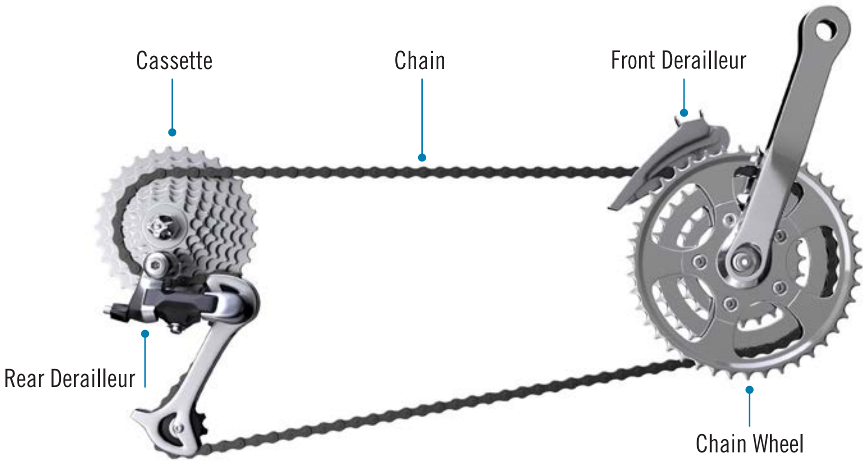
Remind the class that in Lesson 4, they discussed drivetrain components that included the chain, chainrings and cassette. Today's lesson will focus on these other components of the drivetrain:

- **Shifter:** allows riders to apply force to shift between gears (front or rear) using a ratchet system
- **Shifter cable:** transmits the force from the shifter mechanism to the derailleur (front or rear)
- **Cable housing:** allows the shifter cable to be routed around bends and connects the levers to the frame stops
- **Derailleur:** a device that "derails" the chain and moves it between gears
- **Crank arms:** connect the pedals to the chainrings

!

SAFETY TIP

Explain that rear derailleurs are designed to work with a specific size chain, depending on the number and sizes of the gears that are in the bicycle's cassette. Using any type of chain besides the one that's designed for your rear derailleur won't work well and sometimes won't work at all.



Let's Talk Shifting Between Gears:

Explain that drivetrains are amazing inventions, but the actual process of shifting between gears can be a bit of a challenge. It's not uncommon to see people spinning their pedals madly (because their gearing is too easy), or barely able to pump hard enough to move the bike (because they're in a gear that's much too difficult). Cycling is easier for those who know the best gear ratio for their circumstances.

How Shifting Works

- **For front gears**: shifting to a smaller chainring makes the ride easier/slower.
- **For rear gears:** shifting to a larger chainring makes the ride easier/slower.
- **For both front and rear:**
    - Shifting from bigger to smaller causes a spring to release cable tension.
    - Shifting from smaller to bigger uses pressure to tighten cable tension.

Explain that **upshifting** means going from easier to harder and **downshifting** means going from harder to easier. The rider is in charge of these actions using a shifter, which forces the front or rear derailleur to push the chain off one gear and onto the next one over.

- Talk about how different shifter designs are operated.
- Discuss the mechanics of how they function.
- Explain how shifters use a ratchet and spring mechanism to index the amount of cable being pulled or released.

Explain that the best way to know what different gearing feels like is to take your bike to a safe place away from traffic, like an empty parking lot, and shift through all the gears in the front and rear while riding. Cyclists spend most of their time shifting the rear gears to find their cadence sweet spot.

Let's Talk Cadence

Cadence, or pedaling rate, is the number of revolutions of the crank per minute (rpm). This is the rate at which a cyclist is turning the pedals. Cadence is directly proportional to wheel speed, but is a distinct measurement and changes with gearing — which determines the ratio of crank rpm to wheel rpm.

Every cyclist has an ideal cadence (pedaling speed) and an ideal amount of resistance from the pedals (torque). At your ideal cadence, you're putting out the greatest amount of power that you are able to sustain efficiently. The gears needed to support this cadence will depend on the slope of the road, the wind conditions and your own condition at any given time.

Shifters:

Shift levers use a ratchet system that moves the cable from gear to gear.

Cables and Housing:

Show examples of shifter cable and housing and explain how they work with the shifter to make the drivetrain system function in its entirety.

Shifter cables and housing may seem like small parts on a bicycle, but they can make a very big difference in how your ride goes. That's because shifter cables are responsible for carrying out a rider's intentions to move the derailleur exactly the right amount to achieve a perfectly aligned gear shift.

Explore the Science of Gear Ratios:

Explain that when a rider shifts gears properly, riding efficiency improves. What's happening is that each gear change alters the distance the bike will travel with each pedal stroke. That's the whole idea behind multiple gears on a bicycle. So exactly how does shifting gears change the distance that the same bike will move forward with each stroke of the same pedals? It's all about gear ratios.

Explain that gear ratios determine how many times the rear wheel will rotate for each full turn of the crank arms/pedals. The gear ratio is based on the difference between the number of teeth (those pointy bits that hook through the gaps in a bike chain) on the front chainring being used and the number on the selected rear cog.

A bicycle with both a front and rear derailleur will have:

- 2 or 3 different size chainrings on the chainset controlled by the front derailleur
- 5 - 12 different sized cogs on the cassette controlled by the rear derailleur

And every different combination of chainring and cog will have a different gear ratio.

- Simple examples

  1 to 1 ratio (1:1) – For a chainring with 30 teeth and a cog with 30 teeth, the formula would be 30 ÷ 30 = 1, or a ratio of 1:1. That means one full revolution of the pedals would result in one full revolution of the back wheel.

  3 to 1 ratio (3:1) – For a chainring with 36 teeth and a cog with 12 teeth, the formula would be 36 ÷ 12 = 3, or a ratio of 3:1. So one full revolution of the pedals would result in three full revolutions of the back wheel.

  2 to 3 ratio (2:3) – For a chainring with 20 teeth and a cog with 30 teeth, the formula would be 20 ÷ 30 = 2/3, or a ratio of 2/3:1. That means one full revolution of the pedals would result in two-thirds of a revolution of the back wheel.

DID YOU KNOW?

Riding Tip

When approaching an incline, it's best to downshift as soon as your speed starts to drop. If the climb is long or steep, make sure to downshift your front derailleur sooner rather than later. The front derailleur gives you a much bigger step down, and it doesn't shift as well as the rear derailleur under load such as when climbing.

Hands-on:

Determining Gear Ratio

- ✔ Break into groups and make sure each group has a bicycle with both front chainrings and rear cogs.
- ✔ Give each group paper and pencil.
  - Have students take turns being the counter or the recorder.
- ✔ Find the highest/hardest gear ratio on the bike.
- ✔ The hardest gear combination on a bike will be:
  - The largest chainring on the front.
  - The smallest cog on the back cassette.

To determine the ratio of this combination:

- Count the number of teeth on the largest chainring (front teeth, or FT).
- Count the number of teeth on the smallest cog (rear teeth, or RT).
- Now, divide the number of teeth on the front by the number on the rear, or **FT ÷ RT = X**.

- ✔ Express your ratio as X:1.

Ask students what kind of terrain they'd want to be riding when using the hardest gear?

Answer: This is the correct gear to use on flat ground. It takes a lot of effort to get going, but the bike will move quickly.

- ✔ Find the easiest/lowest gear ratio on the bike.

The easiest gear combination on a bike will be:

- The smallest chainring on the front.
- The largest cog on the back cassette.

To determine the ratio of this combination:

- Count the number of teeth on the smallest chainring (front teeth, or FT).
- Count the number of teeth on the largest cog (rear teeth, or RT).
- Now, divide the number of front teeth by the number of rear teeth, or **FT ÷ RT = X**.

- ✔ Express your ratio as X:1.

Ask each student to read out their easiest gear ratio and describe terrain where they might use it.

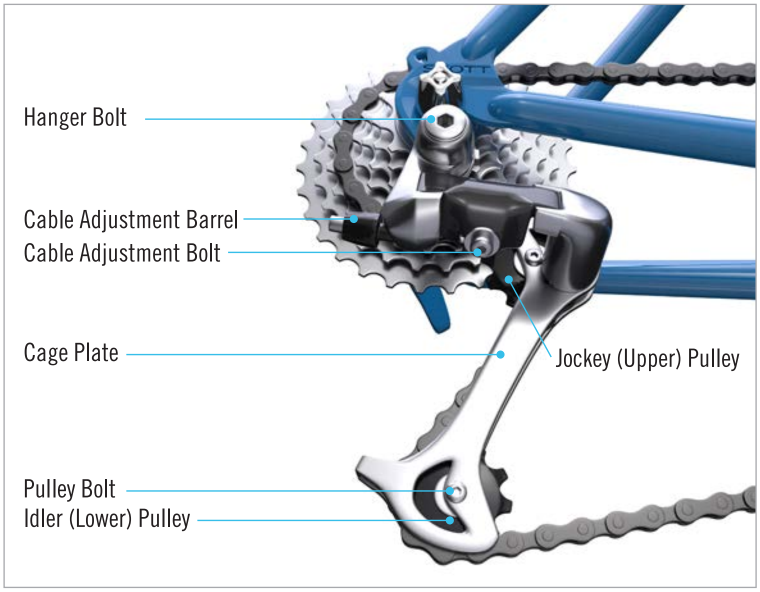
Answer: Each student calculates the number of rear wheel revolutions for every revolution of the pedals.

Derailleur Adjustment and Maintenance:

Incorrect adjustment of derailleurs may not sound nearly as dangerous as improperly adjusted brakes, but there are still important safety considerations. Bad maintenance can lead to having a derailleur push into the spokes, the chain can come off the front chainring or gears start to slip. Any of these may result in a biking accident.

Luckily, modern derailleurs are easy to fine-tune. Adjustment is needed whenever a rider clicks the shifter and the chain doesn't engage the next gear smoothly. The most likely cause for this is incorrect cable tension. Incorrectly adjusted cable tension can result in the derailleur not moving the correct distance when the shifter is clicked.

Explain how to adjust drivetrains and then practice adjusting the rear derailleur. Students should note that these are precise adjustments. Minor errors result in chain noise and improper shifting.



Move to bike stands and bring out bikes in stands with varying levels of functional drivetrains.

Demo: Approximately 30 Minutes

Demonstrate how to check shifting to ensure derailleurs are working properly using demo bikes. Explain cross chaining and why to avoid it.

- Check adjustment by pedaling and using the shift lever to shift each derailleur.
  - Do they shift smoothly?
  - Does the chain fall off?

Demonstrate how cable tension affects the shifting of gears on the bike.

Show students the tools needed to adjust rear derailleurs.

- Box wrenches and Allen wrenches
- Phillips head screwdrivers and sometimes small Allen wrenches like 2mm Allen's
- Needle nose pliers

Look at the rear derailleur from the back of the bike.

- Is it bent or loose?
- Is the hanger straight, and do the pulleys line up parallel with the cassette cogs?
- Can you push it against the spokes or frame?

Go over basic adjustments for rear derailleur:

- Check the condition of cables and housing for rust, breakage or wear.
- Use the barrel adjuster to tighten the cable.
- Check to see if the limit stop and B tension screws are too loose? Too tight?
- Test the limits to make sure the derailleur won't drop the chain.
- Check to see if shift levers are worn.

Hands-on:

Divide students up into small groups and have groups work independently on bikes to adjust shifting/derailleurs.

- ✔ Have students adjust a rear derailleur limits so they are wrong and then have them fix them.
- ✔ Have students correct a maladjusted cable tension on a rear derailleur.
  - Consider a friendly competition to see which team finishes making corrections first.

Evaluation Actions and Questions:

1. What's an engineering fail-safe?
2. How do front derailleurs work?
3. What is Newton's second law of motion?
4. What is the easiest gear combination on the bike?

Final Check-in:

Ask students to share something they learned today and what they are most interested in learning more about. Then do a final check-in to make sure everyone is in good spirits. You might want to do "fist to five," where a closed fist is 0 (signifying a bad day) and five fingers means it was an awesome day. Thank the students for their participation and introduce the next week's class subject.

LESSON 6

Riding the Bike, Bike Safety and Sustainability

LESSON GOAL

Know how to conduct a pre-ride safety check and what's required for a cyclist safety check.

LESSON OBJECTIVES

Over the course of this class, students will:

- ✔ Learn about the efficiency of bike riding
- ✔ Understand the different forces acting upon cyclists
- ✔ Learn about the environmental sustainability associated with bike riding
- ✔ Know the muscles used for riding a bike
- ✔ Understand the importance of nutrition and hydration for cycling endurance

MATERIALS NEEDED

- ✔ Bikes with various safety issues that need attention
- ✔ Earned bikes, helmets and locks
- ✔ Certificates of completion

LESSON PLAN

Provide an Overview of the Lesson:

Let students know that this is the final lesson. Today they'll learn how chemical energy is converted into kinetic energy when riding a bike, the different muscles used to power the bike, and the importance of nutrition and hydration. Explain that they will also learn how riding a bike is good for the environment by reducing their carbon footprint on the planet.

Also, today learn how to do all-important bike and rider safety checks. At the end of the class, bikes, helmets, locks and certificates of completion will be distributed. This can be amended as the policy of the individual chapter dictates.

Group Check-in and Connect:

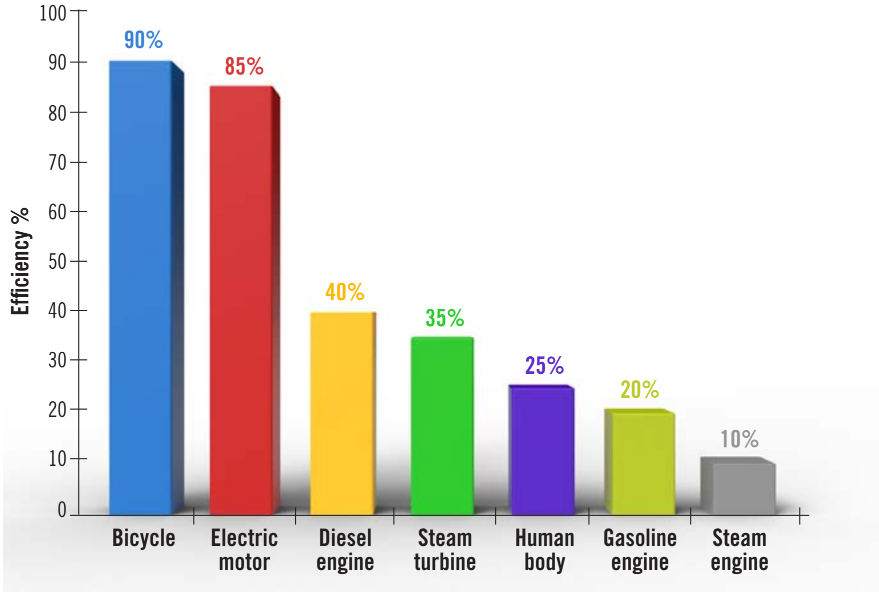
Go around the room and ask students how they feel about getting their bikes today. Ask them to say what they've enjoyed the most about the lessons.

It's Time to Ride:

Congratulate your students for getting to this point in the course — the last lesson. Let them know they should be proud of all they've achieved.

Bicycle Transportation:

Explain to your students that the bicycle is a tremendously efficient means of transportation. In fact, cycling is more efficient than any other method of travel, including walking. With a bike, you can get places quickly without using fossil fuels or creating carbon emissions.



This chart compares the efficiencies of everyday machines. The bike is the most efficient machine humans have developed to date.

Ask students: Why is a bicycle able to convert 90% of the energy supplied at the pedals into power and motion?

Answer: A bicycle has very small amounts of friction and energy loss in the drivetrain, partially because the chain only makes contact with half or less of the chainring teeth and the rear cassette cogs.

Human-Powered Efficiency:

Explain that the engine of the bicycle is the human body, which is fueled by food. Food supplies chemical energy that powers the different muscle groups. They in turn supply power to turn the pedals which generate kinetic energy, otherwise known as the energy of movement.

Ask students: Do you remember the law of physics we discussed in Lesson 3 called the conservation of energy? What is it?

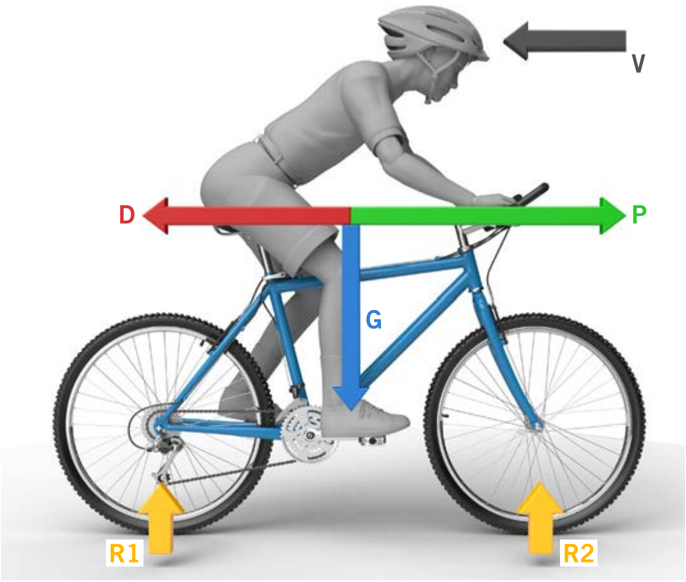
Answer: Energy can neither be created nor destroyed. It means you can't create energy out of thin air or make it vanish without a trace. All you can do is convert it from one form of energy to another.

Ask students: So where does all the energy you expend in cycling go?

Answer: It depends on what you're doing. Let's push further into the lesson.

Forces that Act on the Bike and the Cyclist:

The primary forces a cyclist must overcome are air resistance, or aerodynamic drag, and gravity:



V: The wind direction

P: The propulsion force

D: The aerodynamic drag force

G: Gravity

R1, R2: The ground reaction, i.e., the normal force

Explain that if you're going fast, you're working against the force of air resistance **(D)**.

- Even on a flat road, aerodynamic drag accounts for 70-90% of the resistance while pedaling.
- Air resistance increases exponentially with speed.

Explain that if you're going uphill, your energy is working against the force of gravity **(G)**, which outweighs the effect of air resistance.

- As with all masses, gravity pulls the rider and all the bike components toward the earth.

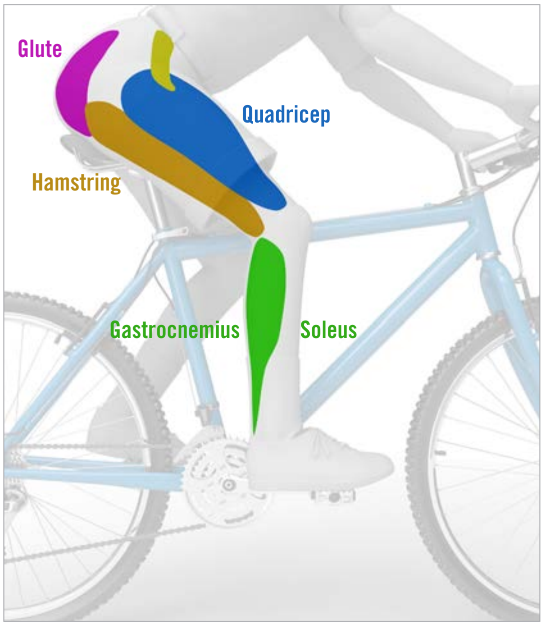
Remember from a previous lesson:

What is Aerodynamic Drag?

You probably recall from Lesson 2 that aerodynamics is the study of how air flows over objects and the forces that the air and objects exert on each other. Drag is the force of wind or air resistance pushing in the opposite direction to the motion of the object, in this case, the cyclist and the bike.

How Do Cycling Muscles Work?

Explain that a cyclist's legs supply the power for cycling. The main muscles at work are the quadriceps and hamstrings in the upper leg, and the gastrocnemius and soleus in the calf. The thigh bone acts as a lever and the muscles contract in a sequence that creates the pedaling action. The quadriceps and hamstrings do most of the work when you ride a bicycle.



The Importance of Glycogen

Explain that when we eat carbohydrates, our body changes it into a form of sugar called 'glucose' that can be used for energy. The glucose, in turn, is changed to glycogen, a form of sugar that can be easily stored by our muscles and liver. It is the predominant storage form of glucose and carbohydrates in animals and humans.

While glycogen is crucial for energy production at all levels of effort, we have a very limited capacity to store it. If your glycogen stores are fully stocked, you have between 350-500 grams in your body, about 80% in your muscles and 20% in your liver.

You burn about 1 gram of glycogen a minute just riding along and about 2 grams at endurance pace, so it's important to keep your tank topped up. Aim for a minimum of 30 to 60 grams of healthy carbohydrates an hour on long rides. Many long-distance cyclists will use high-carbohydrate drinks, bars or even gels for instant energy.

Don't Forget to Hydrate:

Explain that up to 60% of the human adult body is water and that even losing as little as 2 percent of the body's fluid through sweat can adversely affect cycling performance. As a general rule, an average adult weighing 155-160 pounds should drink 12-16 ounces of fluid per hour of cycling in moderate to cooler temperatures. For more intense rides in warmer weather, you may need to consume two to four 16-ounce bottles per hour. If you tend to sweat profusely, you may need to monitor your salt intake as well.

Ask students: What percentage of your lungs are made of water?

Answer: 83%

DID YOU KNOW?

Water Composition In the Body

Brain and Heart **73%**

Lungs **83%**

Skin **64%**

Muscles and Kidneys...... **79%**

Bones **31%**

Good for Your Body and Good for the Earth. How Bicycle Riders Can Be Sustainability Heroes:

Explain that a majority of scientists agree that keeping global temperatures from rising above a certain level is one very important thing that must be done to protect our ability to meet future needs.

Explain that the use of fossil fuels contributes to rising greenhouse gas emissions and higher CO_2 levels in the atmosphere, both of which cause an increased greenhouse effect. This leads to overall average temperature increases around the globe. When greenhouse gasses decrease in the Earth's atmosphere, average global temperatures go down. There needs to be CO_2 in the atmosphere for the planet to survive, but we are currently contributing too much. And one of the very best ways for any individual to contribute to keeping global temperatures down is by lowering your "**carbon footprint**."

What's Your Carbon Footprint?

Your carbon footprint is the total amount of greenhouse gases — mostly carbon dioxide (CO_2) but also methane, nitrous oxide and fluorinated gases — that gets released into the atmosphere by your activities. (A carbon footprint can be calculated for any individual, group, event, organization or region.) It's often measured in tons of greenhouse gases, but it can be measured in smaller quantities, including grams.

Bicycling Energy

Explain that riding a bicycle is one of the best ways a person can reduce their carbon footprint! That's because the energy to power a bicycle comes from its rider, not from burning fossil fuels.

We've already established that food intake and the energy it produces allow a cyclist to propel a bike. But if someone wanted to get technical, the total carbon footprint associated with riding a bike would have to include all of the direct and indirect greenhouse gas emissions associated with the "life cycle" of whatever food they ate before a ride. And that would require doing a life cycle assessment of those foods.

A group called CO2 Living has made some simple and fun calculations to give people an idea of how it would work. They measure in grams of CO_2e, which stands for CO_2 equivalent, which is another way of saying all greenhouse gases. Assuming a rider burns 50 calories a mile, their carbon footprint would be:

- 65g of CO_2e when powered by bananas
- 90g CO_2e when powered by cereals with milk
- 200g CO_2e when powered by bacon
- 260g CO_2e when powered by cheeseburgers
- 2800g CO_2e when powered by air-freighted asparagus

To compare, the EPA has calculated that the average passenger vehicle emits at least 411 grams of CO_2 per mile.

DID YOU KNOW?

What's A Life Cycle Assessment?

A life cycle assessment (LCA) is a systematic analysis of the environmental impact of an item (or product) during its entire life cycle, including production, use and disposal. It's surprisingly complicated! For example, with a food "product" you'd need to consider at least these things, and often many more:

- Input materials , e.g., seeds, fertilizers, pesticides
- Packaging materials such a cartons, boxes and plastic
- Modes of production, e.g., water, heating, greenhouse ventilation
- Transportation methods (ships, trucks, airplanes) to get it to market

DID YOU KNOW?

A quick review of those outputs shows that cycling is a very carbon-friendly way to get around the world — unless you're consuming something like air-freighted asparagus that takes enor-mous amounts of energy to grow and transport!

Put Safety First:

Explain that before heading out on a bike, there are a few things you should do to make sure your bicycle is safe to ride. Steps 1-3 should be performed before EVERY ride, while steps 4-5 are recommended before every ride if you have the time. Otherwise, they should be checked periodically as a matter of preventive maintenance.

Pre-Ride Bike Safety Check

1. Check your tire pressure and use your air pump to adjust, as needed.

- Also inspect the outer surface of your tires. Look for excessive wear in the tread, cuts or cracks on the tread or sidewall, exposed threads or wires, or bulges. If you see any of these, replace the tire.

2. Check wheel quick releases and make sure they're tight.

- If you have bolt-on wheels instead of quick releases, make sure the axle nuts are tight.

3. Check your brakes.

- Stand on one side of the bike, grab both brakes and pull the bike forward. If your brakes are working correctly, the rear end of your bike should lift.
- Then, push the bike backward. If your brakes are working correctly, the front end of your bike should lift.

4. Check your wheels.

- With the bike resting on the ground, hold the handlebars with one hand and grab the top of the front wheel with the other hand. Try to rock the wheel side-to-side; there should NOT be any "play" or movement in this direction.
- Lift the front end of the bike and spin the front wheel. As the wheel spins, it should feel and sound smooth. If it makes a crunchy or grinding noise, or if the wheel wobbles from side to side as it spins, have it serviced by a qualified bicycle mechanic.
- Repeat the above process for the rear wheel.

5. Check your chain.

- Closely inspect the chain. If there's a little surface rust, then you can probably get away with cleaning and re-lubricating it. If it's completely covered solid with rust, then it needs to be replaced.
- Spin the cranks backwards and observe if the chain moves freely over the cogs without any kinking, skipping or binding. It should turn relatively quietly without squealing or grinding. If it does any of these, it needs to be cleaned and lubricated.
- If the chain is covered with hunks of grease or grime, either partially or completely, then clean and lubricate it.

SAFETY TIP

Every year, an average 220,000 children age (5 to 17 years old) are treated in U.S. hospital emergency rooms for bicycle-related injuries.

According to five scientific studies, helmets provide a 66 to 88% reduction in the risk of head, brain and severe brain injury for all cyclists.

Some states require that you wear a helmet. Others do not.

ALWAYS wear a bike helmet.

Pre-Ride Bike Rider Safety Check

Provide students with questions they should ask themselves:

- Is my helmet on correctly?
- Are my shoes tied?
- Are my pants rolled up if they need to be?
- Are my hands where they should be on the brakes?
- Am I wearing reflective gear if I'll be riding beyond dusk or in cloudy conditions?
- Are my light, bell, and reflector in place and functioning?
- Do I have my lock with me?
- Do I know the rules of the road for my location?

Hands-on:

Provide students with bikes with various issues that need attention and have them perform a safety check.

Evaluation Actions and Questions:

1. Bike riding is how many more times efficient than walking?
2. Name a few of the best foods to eat to keep your carbon footprint low when riding.
3. What is the rule of thumb for water you need to take on a ride?
4. Which leg muscles do most of the work when riding?
5. Name the four parts of the bike rider safety check.

Final Check-in:

Ask students to share something they learned today and what they are most interested in learning more about. Thank the students for their participation and get everyone together for a group photo. Then give each rider their bike, helmet, lock and certificate of completion.

Hands-on:

Let the students take a circle ride in the indoor space if there's room or right outside in a safe area, weather permitting. Take a group photo of the class and individual photos of each student with their earned bike, helmet and lock.

YOUTH@WORK PROGRAM

As your students prepare to complete this beginning course, provide them with information about the Youth@Work program, which is potentially available to them after they complete more advanced Earn-a-Bike programs.

The Youth@Work Program:

Providing Job Training for Young Leaders

The Trips for Kids Youth@Work program was created to address the critical issues of unemployment, financial exclusion, and academic underachievement of youth from underserved communities. It consists of on-the-job training, mentorships, internships, and resume/interview skill building that can lead to placement in a local bike shop and contribute to creating healthier, happier, and more successful adults.

The program provides youth with work-readiness-skills training and hands-on-skills practice. The program specifically targets high-school-aged youth who have no prior work experience and teaches them the basics of employment. We hire participants as paid interns, giving them an opportunity to learn while they earn. Through a combination of direct instruction, daily hands-on practice, and regular performance feedback, we enhance the soft skills, life skills, work ethic and leadership skills of participants and help them build a strong foundation for their future success.

Ways participants engage with the Youth@Work program include:

- **Learning to Work**
  After students complete their Earn-a-Bike program, they are eligible to return to the classroom whenever they need a repair or part, or if they just want to come and hang out. Graduates must work to earn parts and supplies, reinforcing the concept of earning what they get.

- **Mentoring Others**
  Youth who excel at bicycle mechanics, and/or are consistent, dedicated, trustworthy and motivated can be promoted into an entry-level leadership role by becoming a mentor to new participants and younger students. Mentors are given responsibilities such as helping younger kids to complete their Earn-a-Bike lesson modules.

- **Internships**
  Mentors who excel are then considered for paid or unpaid internships, depending on the resources of the local chapter. Youth of high school age can learn to teach, manage programs and even learn to become bicycle mechanics. Interns develop their skills and gain valuable experience that can be directly applied to future employment opportunities.

- **Employment**
  Ultimately, high-school-aged interns who excel can become eligible for part-time employment with Trips for Kids, helping adult staff to manage workshop operations and teach the Earn-a-Bike curriculum as well as our Trail Ride and Mobile Programs. Where applicable, they might find employment in one of our ReCyclery bike thrift shops.

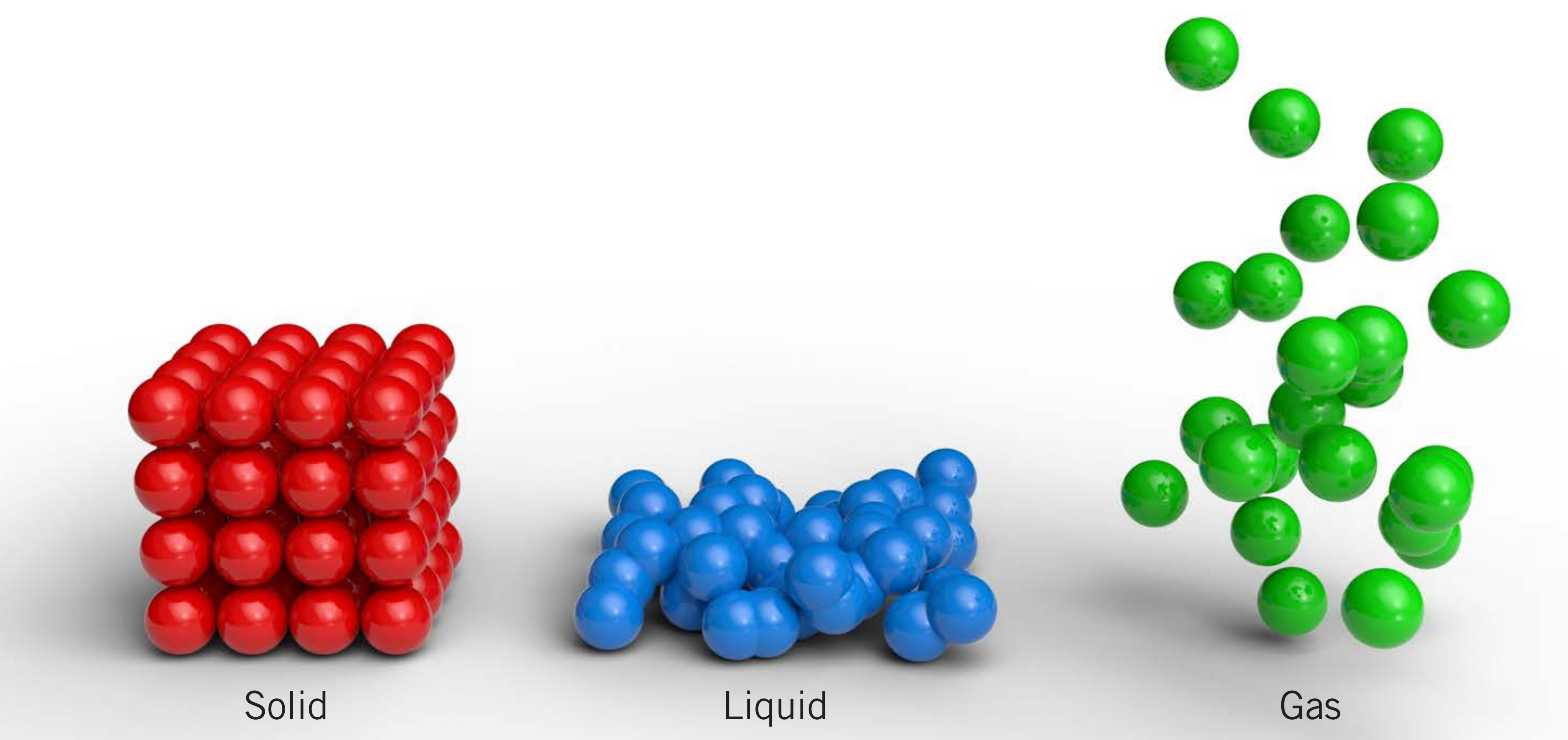
Older youth who have excelled in Trips for Kids programs such as Earn-a-Bike Workshops, apprenticeships and mentoring may be hired as paid staff. They may also be referred to local for-profit bike shops and other businesses or vocational schools for professional employment and career opportunities along with the guidance and support from Trips for Kids staff and community partners.

APPENDIX

This appendix contains full-page images that can be used as visual aids during their respective lessons. Instructors are also encouraged to print these as handouts.

Note that two images — Lesson 2/Bike Frame and Lesson 3/Brake Systems — are provided in two formats. One is for instruction and the other is to be distributed and filled in as part of the Evaluation phase of the lesson.

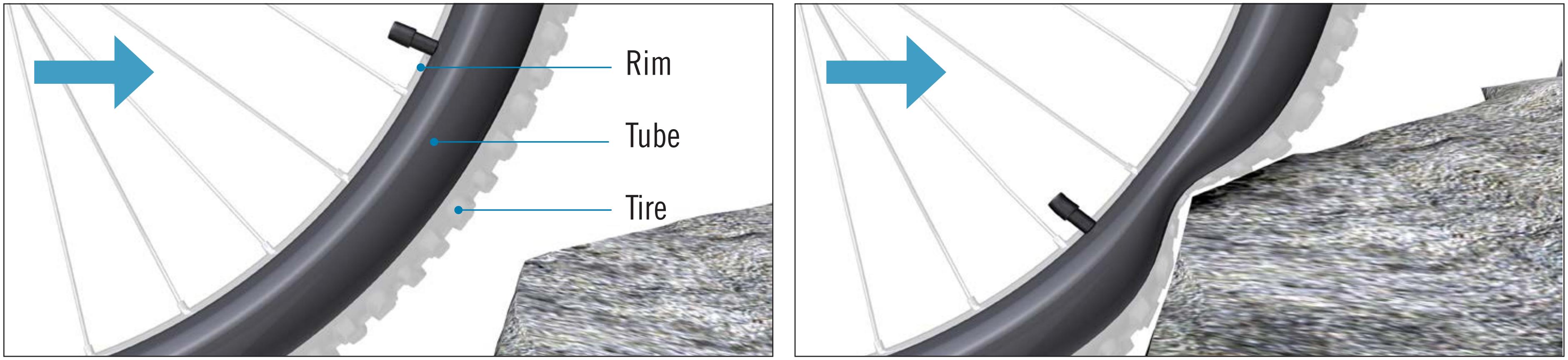
SUPPLEMENT TO PAGE 8 OF THE GUIDE:
Lesson 1: Relative Density of Particles



Relative Density of Particles

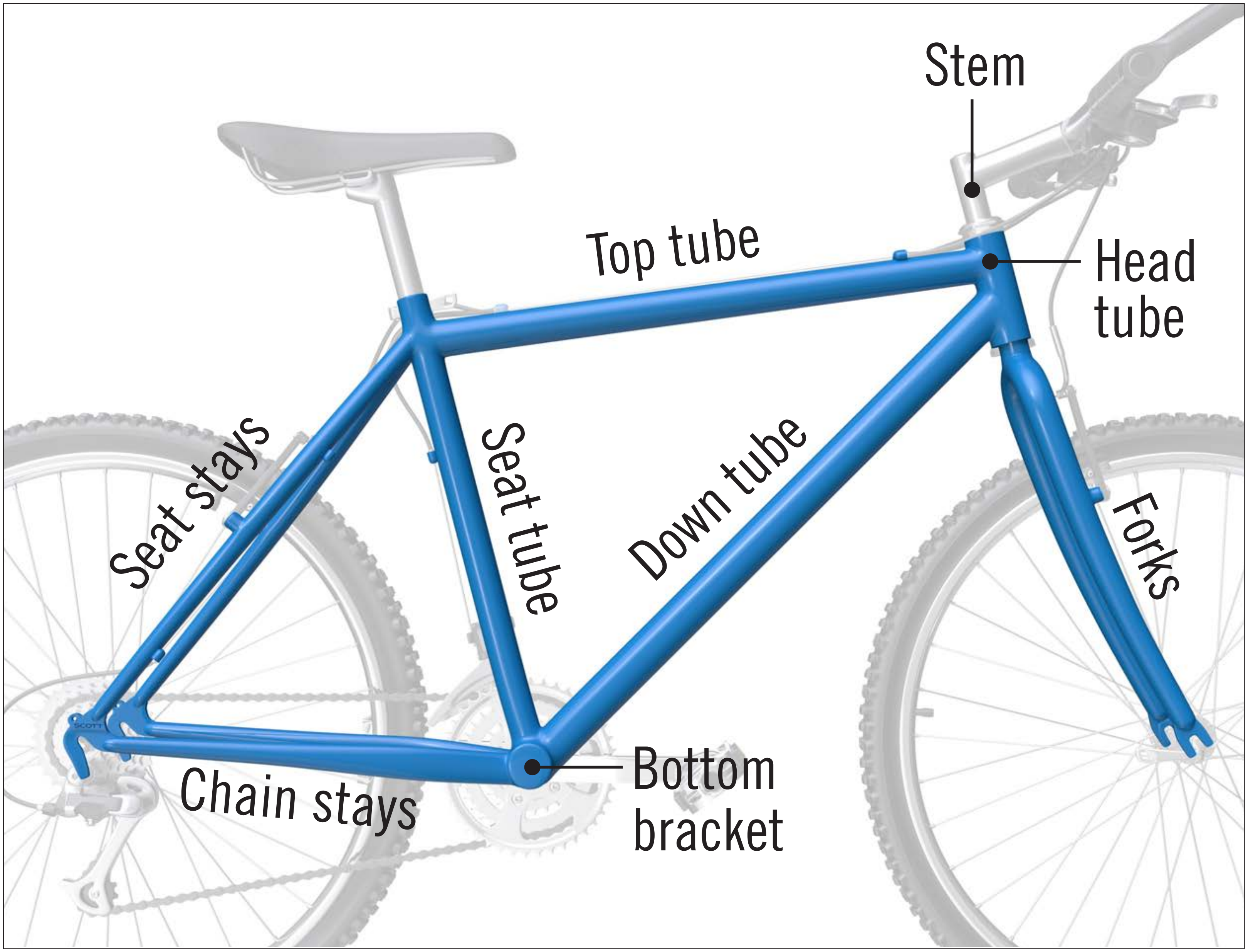
SUPPLEMENT TO PAGE 11 OF THE GUIDE:

Lesson 1: How Pinch Flats Happen



SUPPLEMENT TO PAGE 13 OF THE GUIDE:

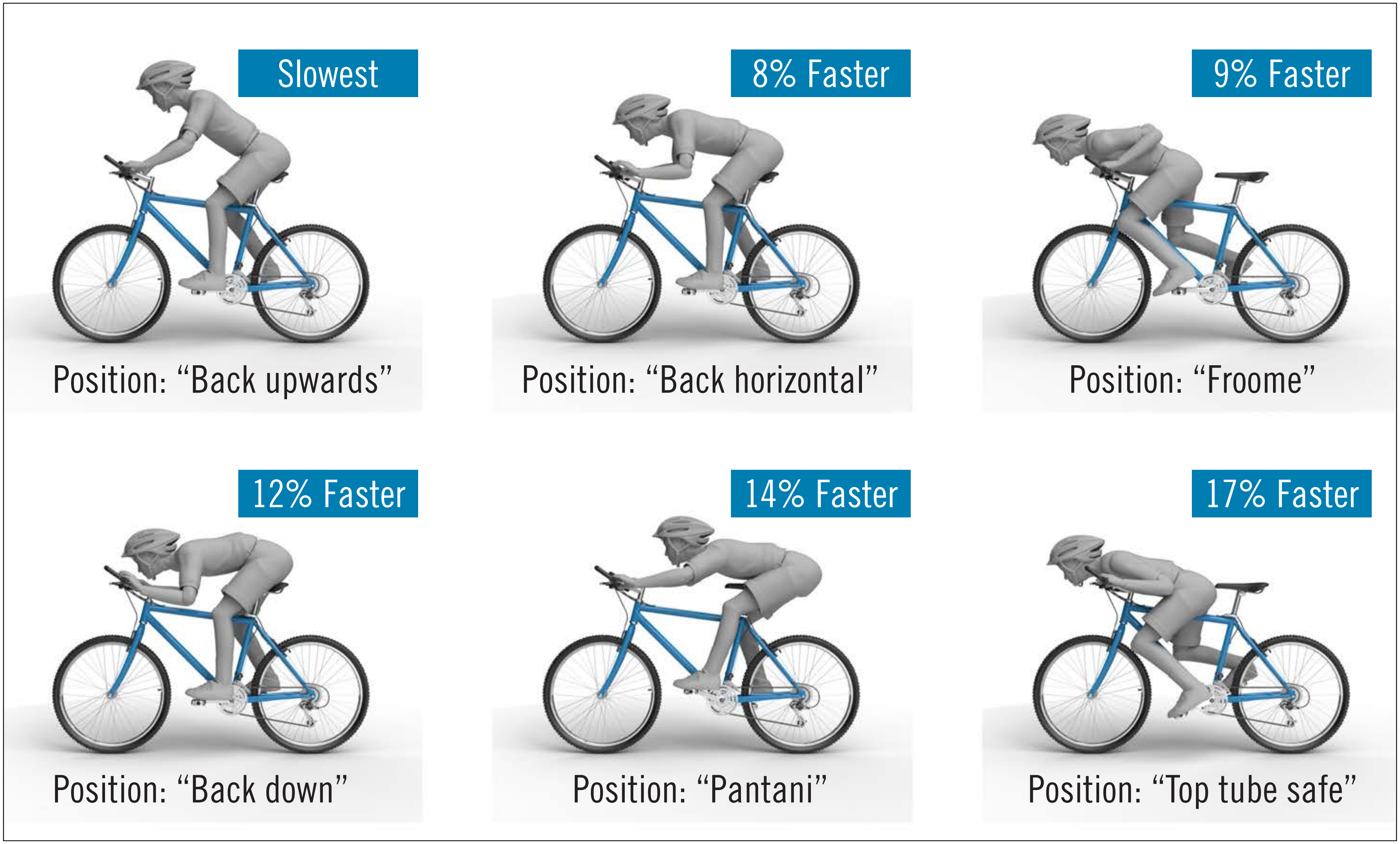
Lesson 2: Let's Explore the Frame



SUPPLEMENT TO PAGE 14 OF THE GUIDE:

Lesson 2: How Riding Positions Affect Aerodynamic Efficiency

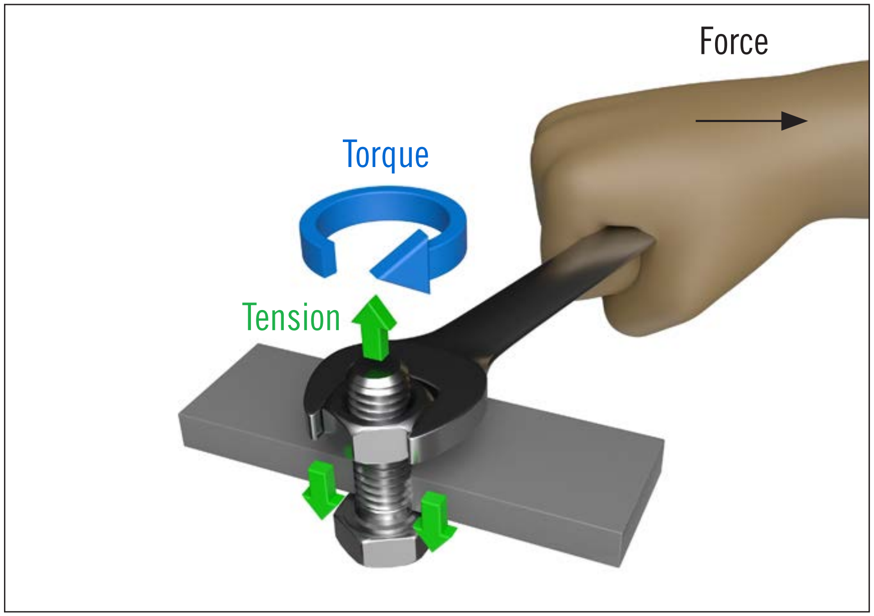
Different riding positions change a rider's body profile and center of gravity to maximize aerodynamic efficiency and stability, which affects handling and speed.



SUPPLEMENT TO PAGE 16 OF THE GUIDE:

Lesson 2: How Torque Works

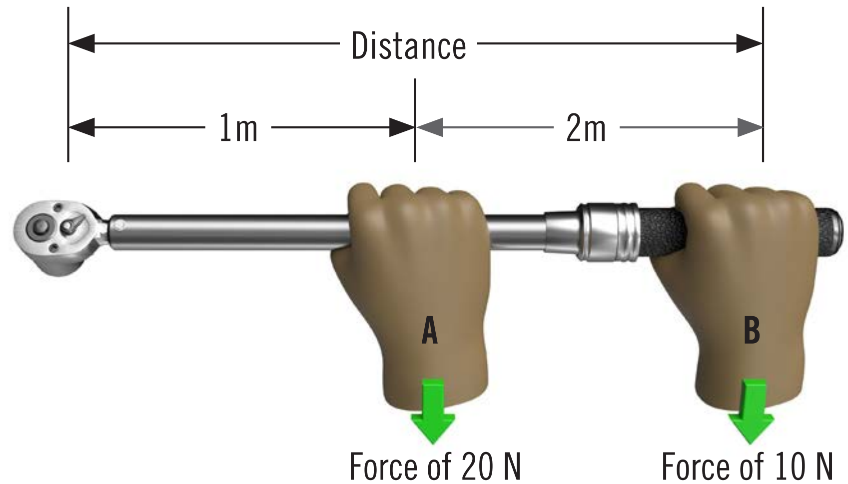
Torque is the amount of force you can push on a lever arm, multiplied by the distance from the pivot point where you're applying that force.



SUPPLEMENT TO PAGE 16 OF THE GUIDE:

Lesson 2: Explaining Newton-meters

A Newton is a measure of force and a meter is a measure of distance.



Example

10 Newtons x 1 Meter = 10 Nm (Newton-meters)

Let: T = Torque

F = Force

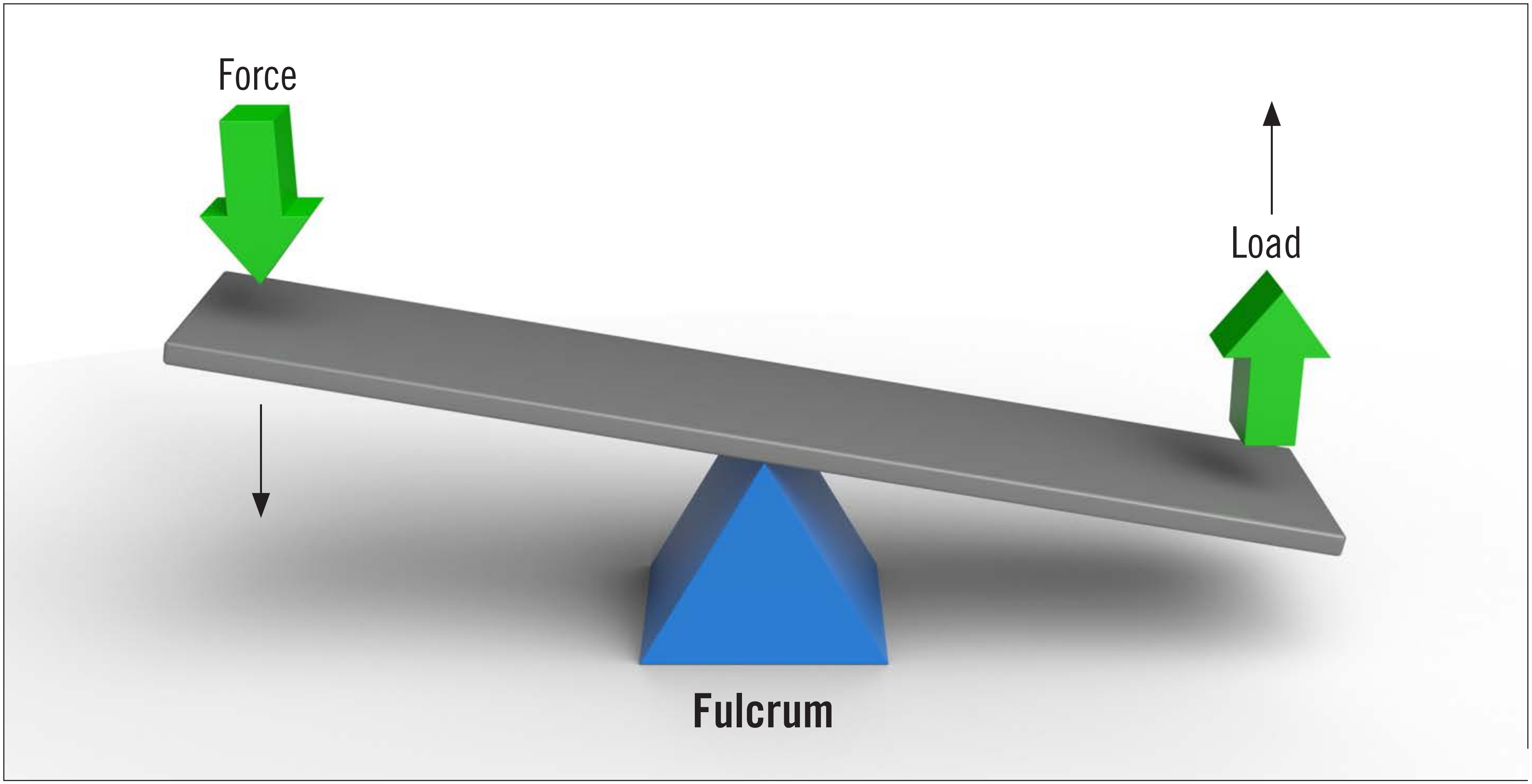
L = Length of lever or wrench

Then: **T = F X L**

SUPPLEMENT TO PAGE 18 OF THE GUIDE:

Lesson 2: A Lever Works Using Mechanical Advantage

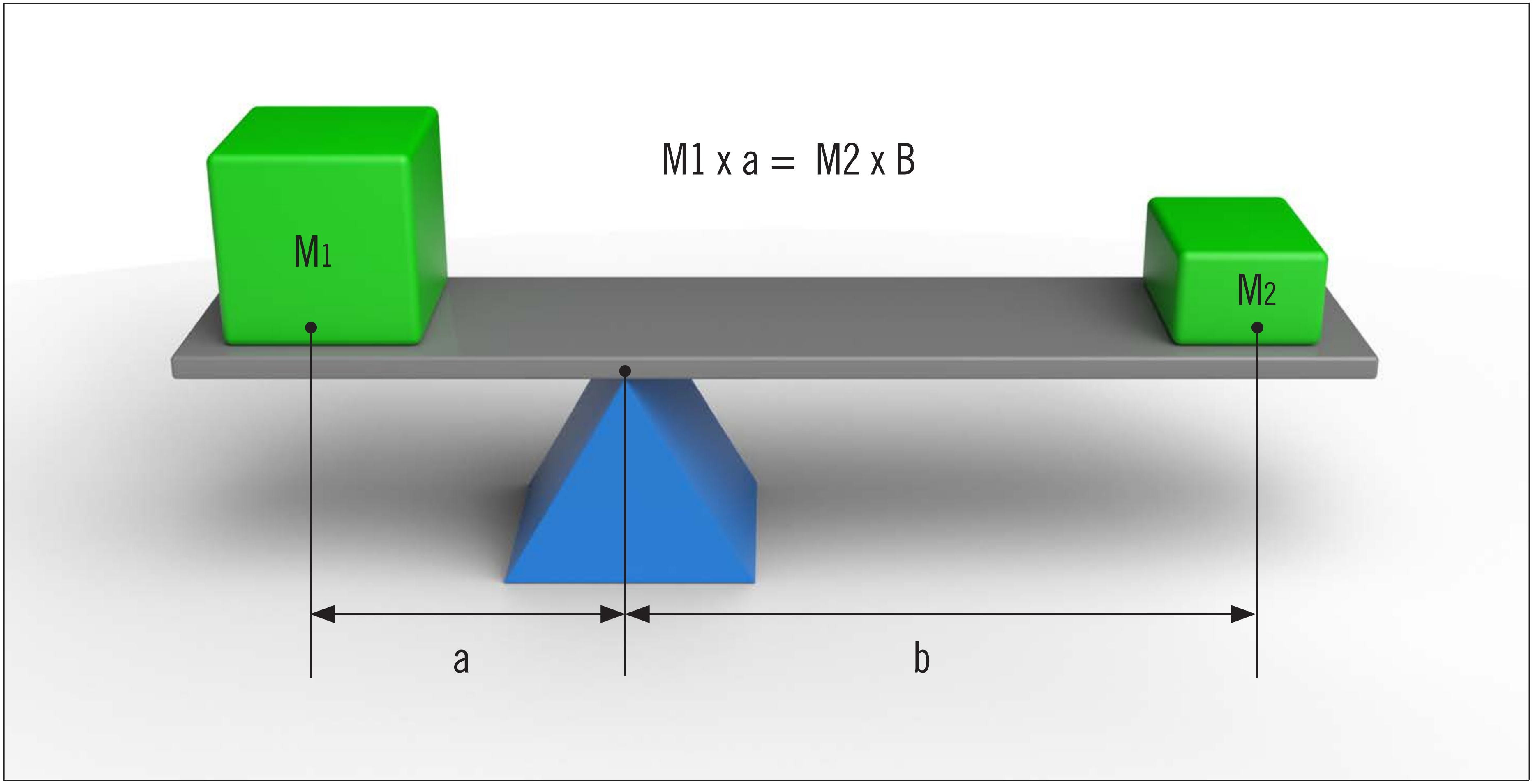
This seesaw works by using mechanical advantage. It redirects a force from one end and transfers it to the other end as load force or load output.



SUPPLEMENT TO PAGE 19 OF THE GUIDE:

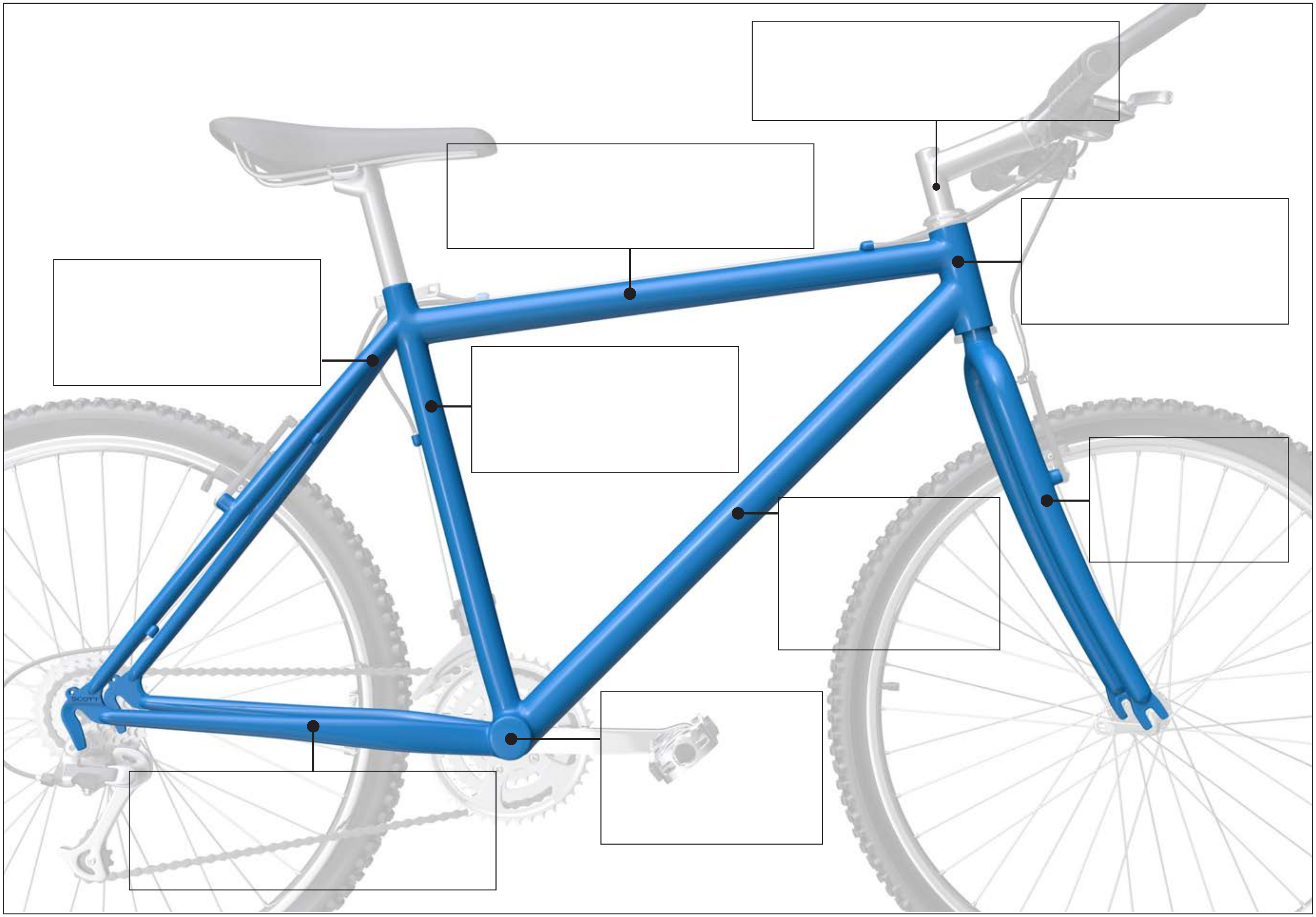
Lesson 2: Measuring Mechanical Advantage

This illustration demonstrates that the longer the leverage (or section of ruler), the less mass needed to move a greater mass.



SUPPLEMENT TO PAGE 20 OF THE GUIDE:

Lesson 2 Evaluation: Fill in the Names of the Parts of the Bike Frame



SUPPLEMENT TO PAGE 21-22 OF THE GUIDE:

Lesson 3: Different Brake Systems

Coaster Brakes

Caliper Brakes

U-Brakes

Cantilever Brakes

Linear-pull V-Brakes

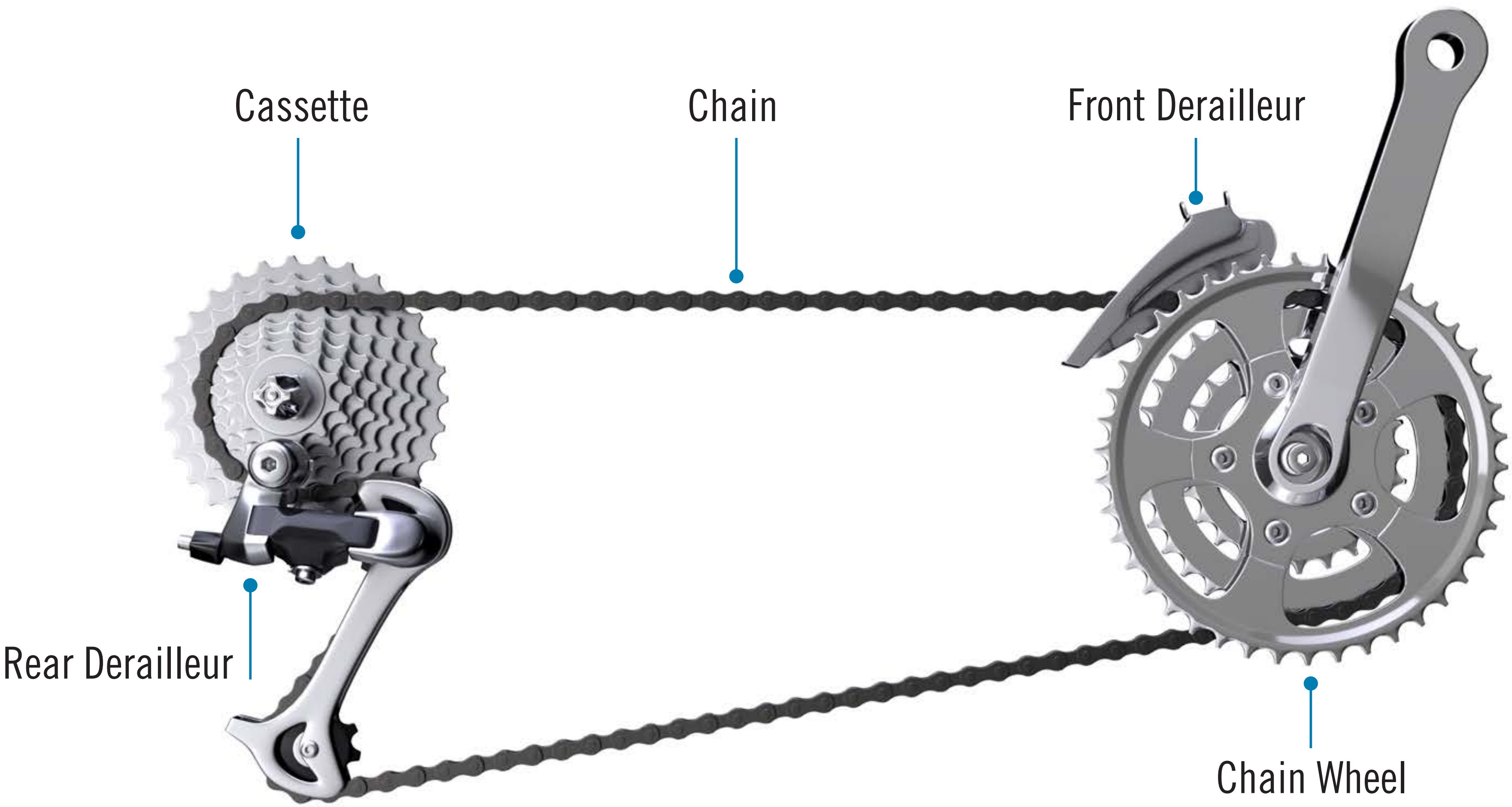
Disc Brakes

SUPPLEMENT TO PAGE 27 OF THE GUIDE:

Lesson 3 Evaluation: Name Each of the Bicycle Brake Systems

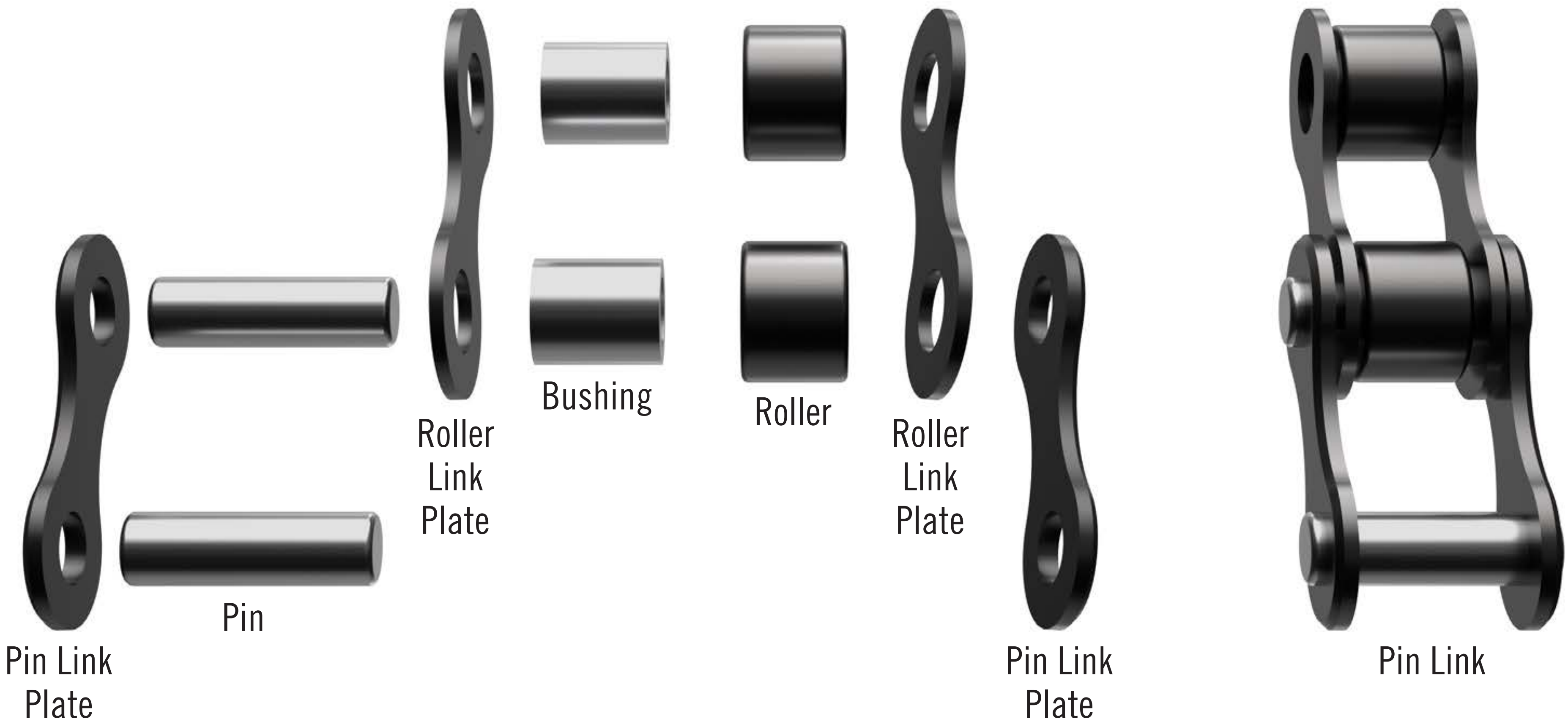
SUPPLEMENT TO PAGE 28 OF THE GUIDE:

Lesson 4: The Drivetrain of the Bike



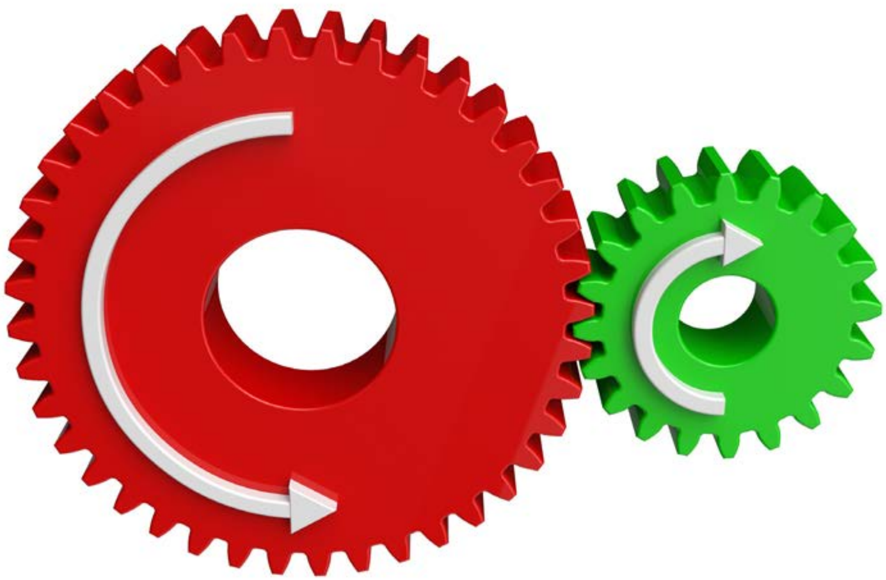
SUPPLEMENT TO PAGE 30 OF THE GUIDE:

Lesson 4: The Components of a Roller Chain

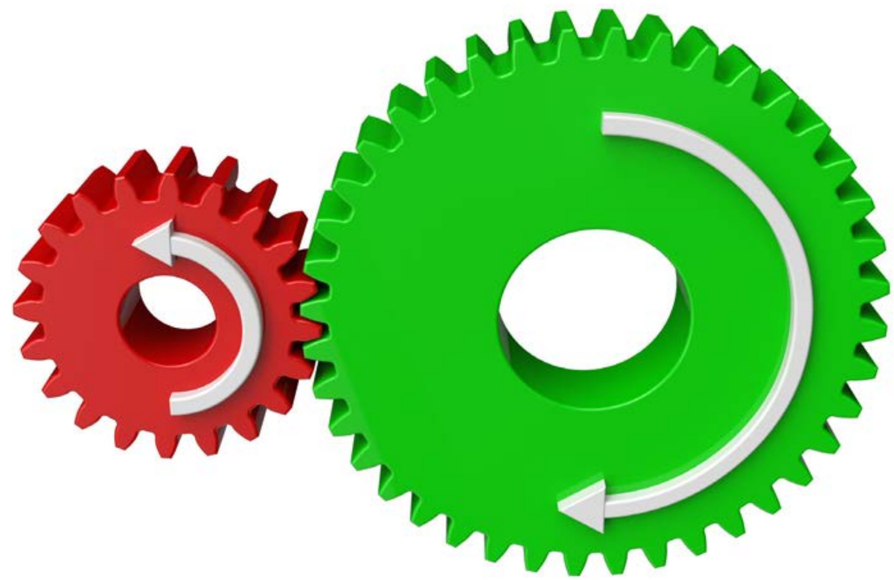


SUPPLEMENT TO PAGE 31 OF THE GUIDE:

Lesson 4: How Gears Work



Increase speed: If you connect two gears together and the first one has more teeth than the second one, the second one has to turn round much faster to keep up. So, this means the second wheel turns faster than the first one but with less force. Turning the red wheel with 24 teeth would make the green wheel with 12 teeth go twice as fast but with half as much force.



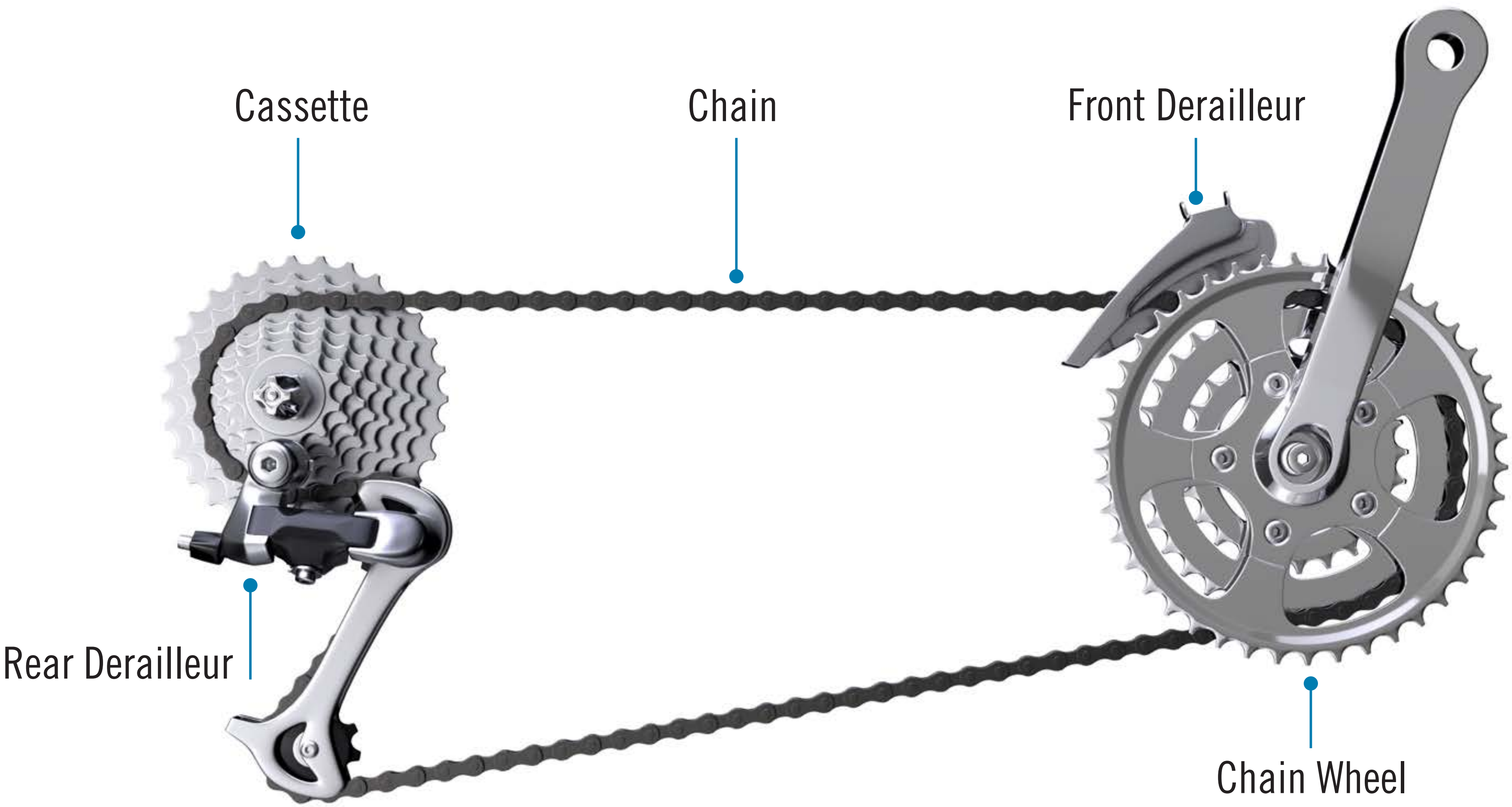
Increase force: If the second wheel in a pair of gears has more teeth than the first one, it turns slower than the first one but with more force. Turn the red wheel and the green wheel goes slower but has more force.

SUPPLEMENT TO PAGE 35 OF THE GUIDE:

Lesson 5: Front Derailleur

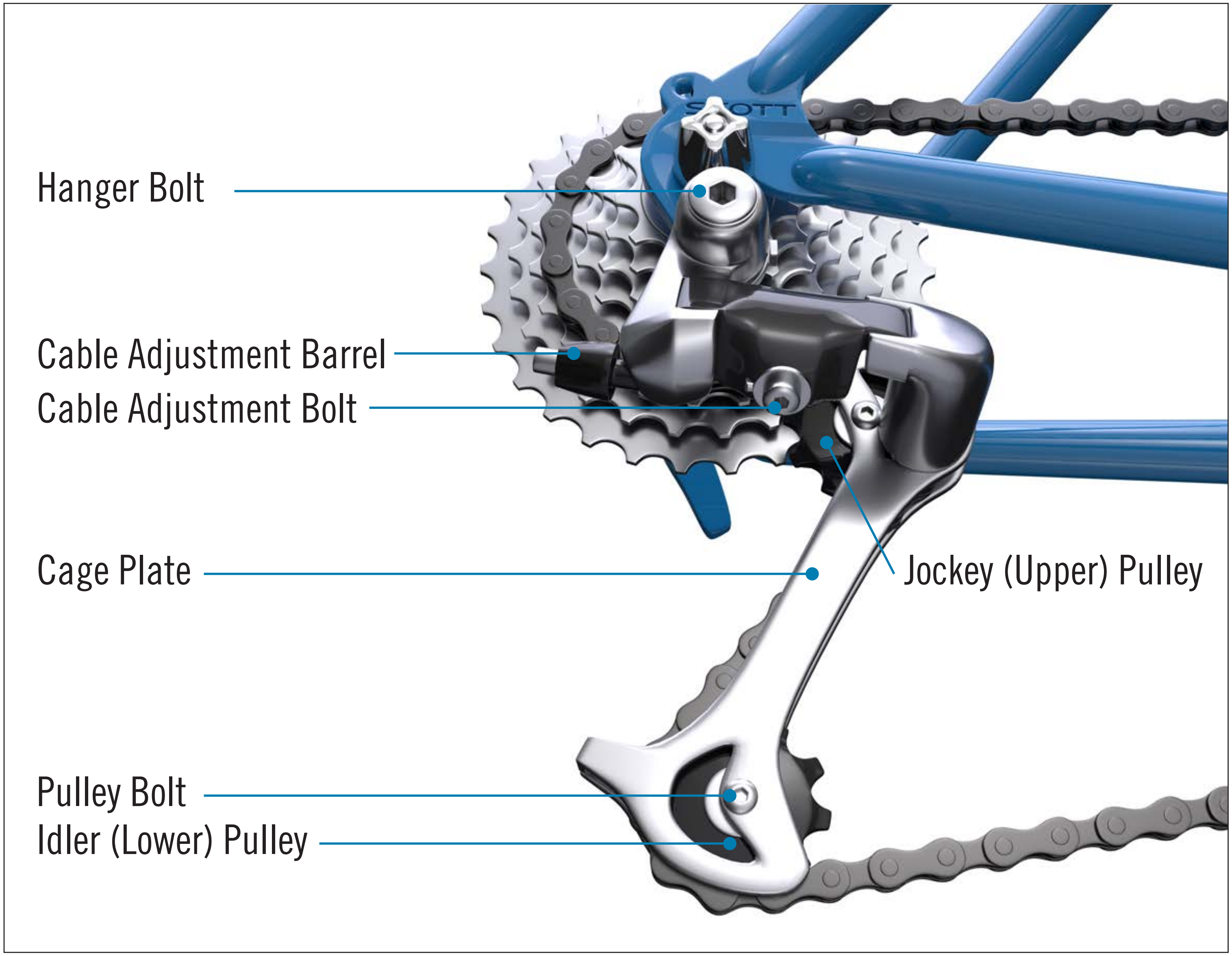
SUPPLEMENT TO PAGE 37 OF THE GUIDE:

Lesson 5: Components of the Drivetrain System



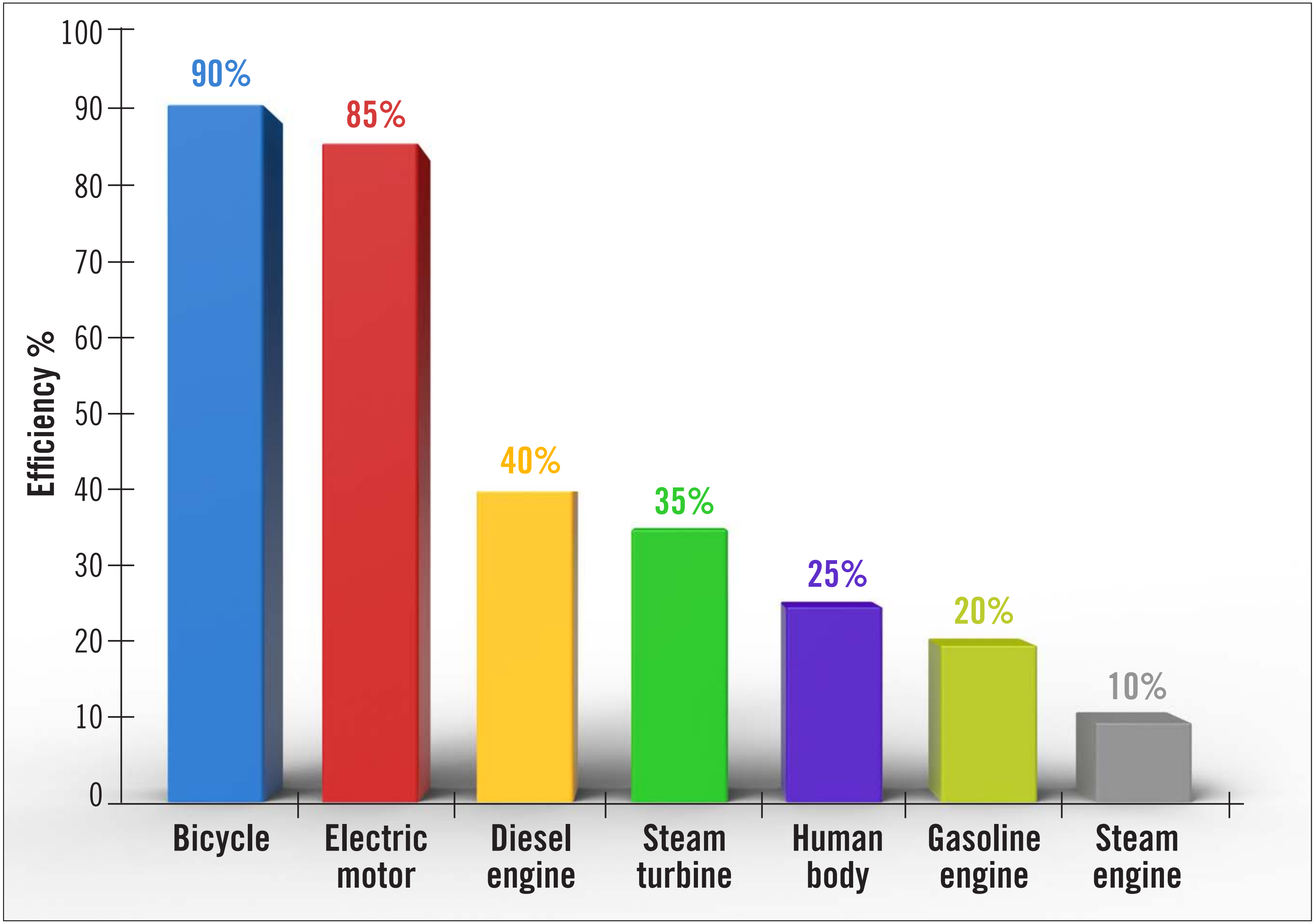
SUPPLEMENT TO PAGE 40 OF THE GUIDE:

Lesson 5: Rear Derailleur



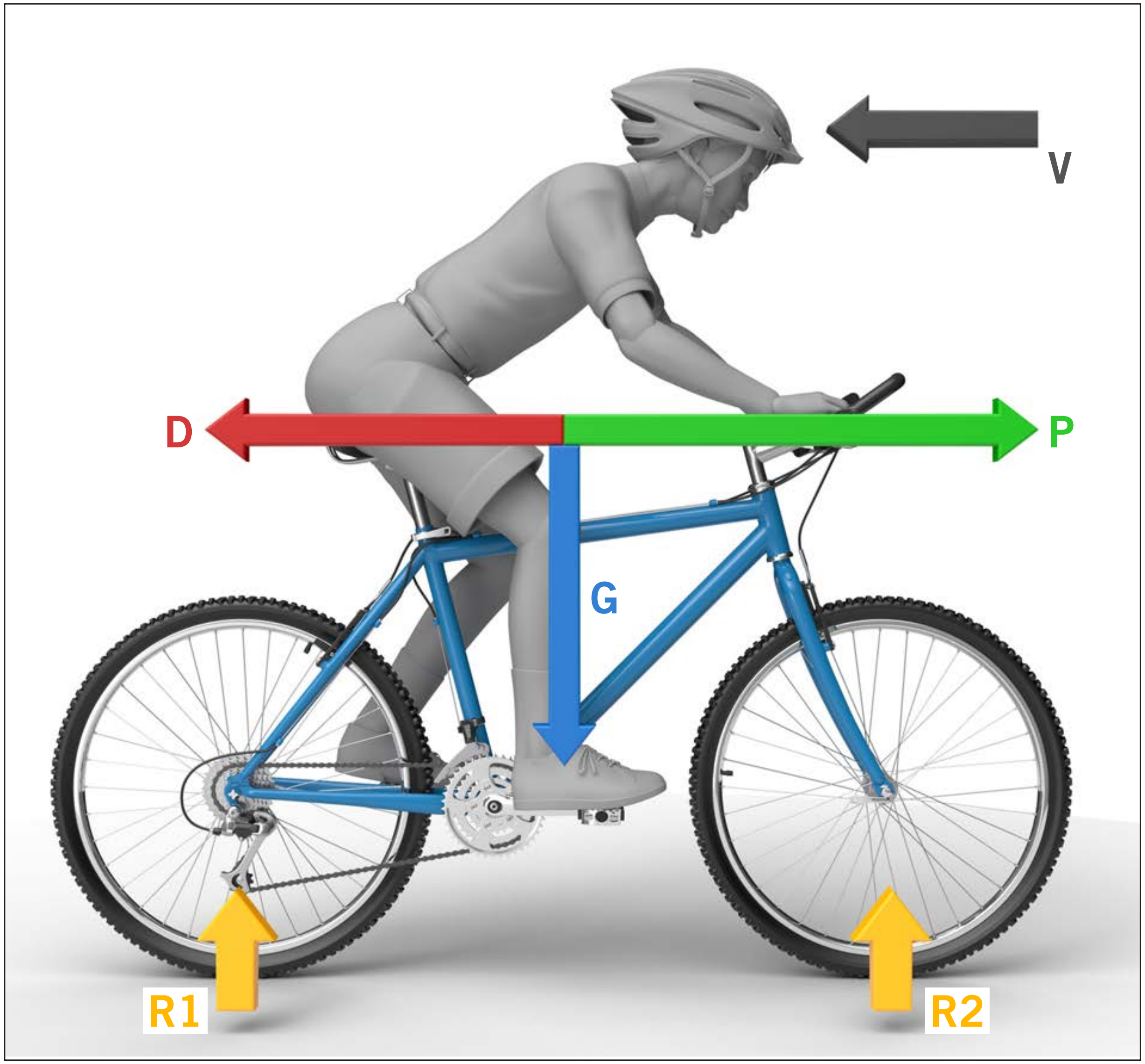
SUPPLEMENT TO PAGE 42 OF THE GUIDE:

Lesson 6: Comparison of Human Body Efficiency with Everyday Machines



SUPPLEMENT TO PAGE 43 OF THE GUIDE:

Lesson 6: Forces That Act on the Bike and The Cyclist



V: The wind direction

P: The propulsion force

D: The aerodynamic drag force

G: Gravity

R1, R2: The ground reaction, i.e., the normal force

SUPPLEMENT TO PAGE 44 OF THE GUIDE:

Lesson 6: Cycling Muscles