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**The Lemelson Center for the Study of Invention and Innovation**



**EDUCATOR'S GUIDE**



The Jerome and Dorothy Lemelson Center for the Study of Invention and Innovation was founded in 1995 at the Smithsonian Institution's National Museum of American History through a generous gift from the Lemelson Foundation. The Center's mission is to document, interpret, and disseminate information about invention and innovation, to encourage inventive creativity in young people, and to foster an appreciation for the central role that invention and innovation play in the history of the United States.

With the mission of the Lemelson Center in mind, it is our hope that teachers will use the video "Reinventing the Wheel" to encourage students to think about the role of invention in their lives and to stimulate students' own inventive creativity.

We have included many resources in this booklet to help you in developing thematic units or to assist your students with their own research. A great place to start the investigation is by visiting the Lemelson Center's website ([www.si.edu/lemelson](http://www.si.edu/lemelson)).

## Goals

1. Students will learn how and why the bicycle developed, from the 1800s to the present.
2. Students will discover the many inventions that make up the bicycle as we know it today and will explore how the various parts work together.
3. Students will learn how the bicycle led to other innovations and changes in society, including its role in the Good Roads Movement and the women's movement in the late 19th and early 20th centuries.
4. Students will learn how contemporary inventors are continuing to reinvent the bicycle.

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# ■ What is an invention?



An invention can be a simple gadget or a complex machine, a new material or a new way of doing things. Some inventions respond to specific needs, others begin by accident, and some evolve through a gradual process of change.

The bicycle, for example, represents many separate inventions that have been constantly modified and improved. Components that have been around for a long time—such as the wheel—come together with contemporary innovations to form the bicycle as we know it today.

The bicycle, in fact, is ideal for tinkering. The parts are visible, and the machine can be taken apart without getting the tinkerer into too much trouble. Tinkering is a good way to learn how bicycles work, and hands-on knowledge is critical to success, whether you're trying to build a better bike or make a completely new machine to take you places.



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# Reinventing the Wheel:

## The Continuing Evolution of the Bicycle

For over a century people have been riding bicycles. An efficient means of human transportation, the bicycle enables people to use the power of their own bodies to move fast and achieve a feeling of freedom. The bicycle is also one of the most celebrated technological inventions in history. Countless innovative thinkers have been inspired to modify and improve upon this unique, human-powered machine. The bicycle has had a profound influence on American and world culture, affecting transportation, the environment, leisure activity, and sports. But who invented the bicycle, and how did it come to look the way it does today?

The urge to combine human power and wheels first took practical shape in 1818. Baron Karl von Drais of Germany patented a two-wheeled, steerable, human-propelled machine, the hobbyhorse or draisine. The rider straddled the machine and moved it forward by pushing his feet against the ground. Handlebars attached to the front wheel could be turned to steer the machine. A draisine fad began among people who could afford to try the device—though riding was hard on the shoes. A top speed of nine miles an hour on a flat road was not enough for the machine to be widely adopted. The novelty faded, and after a couple of years the draisine practically disappeared. For more than 40 years, little change occurred in two-wheeled, human-propelled transportation.

After 1863, the addition of cranks and pedals to the front wheel resulted in the velocipede, the next major advance in two-wheeled, human-powered transportation and the beginning of a boom leading to the modern bicycle. The cranks and pedals allowed riders to propel the machine more easily and with more power, achieving greater speeds than the draisine had permitted. People were astonished to find that they could balance while keeping their feet on the pedals. Manufacturers sponsored schools where men and women learned to ride and then, perhaps, became customers for the velocipede factories. Competing claims from French and Scottish inventors make it difficult to determine who created it first, but what is certain is that by the late 1860s, the velocipede had achieved great popularity.

Velocipedes, however, were both heavy and expensive, and in just a few years, several improvements followed. Ball bearings increased efficiency. Braking mechanisms were introduced. Advances in 19th-century industrial steel production made it economically feasible to use lightweight hollow steel tubes that were strong enough to replace heavy iron rims. The wheel itself was the focus of several changes. A tension-spoke wheel

replaced the wagon-style wheel: instead of heavy spokes to bear the vehicle's weight from the axle to the point of the rim directly beneath, a hub hung in the middle of the steel rim, attached by slender spokes made of steel wire. Solid, rubber tires were introduced, resulting in improved traction. Still, the wheels provided little cushioning from road shocks, and the velocipede was nicknamed the "bone shaker." Despite the bruises it delivered, the velocipede enjoyed considerable popularity; racing competitions for serious riders drew crowds.

The velocipede's shortcomings in speed and comfort brought about the era of the high-wheel in the 1870s. To achieve faster speeds, builders enlarged the front wheel so that each turn of the crank carried the bicycle farther forward. The trailing wheel was small, to minimize the weight. The large front wheel took bumpy roads better, but potholes or sudden stops dangerously pitched the rider forward from the high seat. High-wheels, in fact, were difficult to mount and unsafe for women in long skirts. Designers and manufacturers continued to improve high-wheel design throughout the 1870s and into the early 1880s.

Finally, a shape emerged in the mid-1880s that resembled the bicycle we know today. The safety bike featured two wheels of equal size and was low enough that riders at rest could put their feet on the ground. The pedals and cranks were no longer on the front wheel; instead, they rotated a sprocket which drove a chain that transferred power to a smaller sprocket on the rear wheel. The difference in size between the sprockets caused one turn of the crank to turn the small rear wheel more than once, allowing the rider to achieve speeds similar to those possible on the high-wheel bicycle—an advance that rendered the high wheel unnecessary. The addition of a pneumatic tire—a hollow rubber tire filled with pressurized air—made riding on bumpy roads easier.



# TIMELINE

- 1818** Draisine invented by Baron von Drais in Germany 
- 1839**  Swinging pedals appear in Scotland
- 1863** Rotating pedals added to two-wheeled machine in the French shop of Pierre Michaux, creating the velocipede 
- 1869** Velocipedes manufactured in U.S.; Solid rubber tires replace iron wheels
- 1871** High-wheel manufactured in Britain 
- 1876** Albert Pope sees bicycles at the Philadelphia Centennial 
- 1880**  League of American Wheelmen founded; lobbying for better roads begins
- 1884** Starly introduces the Rover safety bike 
- 1888** Pneumatic rubber tires invented by John Dunlop
- 1894** Bloomers introduced 
- 1898** Bicycle manufacturing at its height
- 1900-1905** Bicycle popularity declines
- 1900-1950** Bicycle racing continues
- late 1960s** New bicycle boom begins 
- 1981** First mass-produced mountain bikes appear 
- 1996** Mountain biking introduced as an Olympic sport 

Soon after its invention, the bicycle became a means of recreation as well as practical transportation; it also provided a measure of personal freedom. It was faster than walking and cheaper than keeping a horse or buying train tickets. Riders could go when they wanted to go, not merely when the train schedule allowed. And the bicycle would take them wherever there was a road.

The bicycle inspired several related inventions, including water bikes, bike boats, ten-man bikes, side-by-side seaters, and more. Some inventions were popular for a time, while others never found a market. These innovations demonstrate the many ways inventors continued to experiment with bicycle technology.

City people adopted the bicycle as a way to get to work. City police departments put officers on bikes. The U.S. Army even experimented with using bikes instead of horses for a cavalry unit. The development of the automobile, and its increasing affordability, ultimately eclipsed the bicycle boom of the late 1800s, but the bicycle industry adapted by creating the motorcycle and by focusing on bicycles for children. Adults used bikes at resorts and on special occasions. Bicycle racing continued, but with little publicity. Some inventors tried to improve the bike, but nothing really new caught on with the public. Stylistic innovations dominated for half a century, such as producing bikes that looked more like motorcycles.

In the late 1960s and 70s, a new bicycle boom began in the United States. Teenagers and adults began riding ten-speed, racing-style bicycles for recreation and physical fitness. The connection between motorcycles and bicycles became more than just stylistic. Backyard inventors modified children's sturdy bikes to imitate motocross off-road motorcycles, creating the BMX, or bicycle motocross. The bicycle industry tried to get on board, but BMX remained a specialty. Another grass-roots innovation, the mountain bike, would come to dominate the industry. For this generation of riders, freedom means being able to find your own way even when there is no road. Experimenting with European parts, BMX parts, and tandem bicycle parts, inventors created bikes with multiple super-low gears and long crank arms that would allow riders to maintain control and achieve speed over uneven terrain. These improvements launched an explosion in the bike industry.

Most changes since the invention of the safety bicycle have been incremental changes that make the bike better for a particular use: racing bikes, bikes for all terrain, bikes for disabled individuals. As a new century begins, adults are once again using bicycles for transportation as well as for fitness and fun. We've come a long way from the demands of the 1890s. We have paved roads and comfortable clothes. Today's revived interest in cycling is calling for new kinds of adaptive thinking to provide bike lanes on streets, bike parking at work, and bike trails on abandoned railroad rights-of-way. The innovations continue, meeting different needs, exploiting the weight and strength advantages of new materials, and thinking creatively.

# The Bicycle and Its Impact on Society

The story of the bicycle is not only about engineering and technological invention. It is also a story of social and economic innovation.

## Albert Pope and the American Bicycle Story



Early bicycles were expensive, and the first American cyclists were wealthy. Colonel Albert Pope, a manufacturer of shoemaking machines in Massachusetts, would change all that.

In 1876, a display of English high-wheel bicycles at the Centennial Exposition in Philadelphia, Pa., caught Pope's eye. The United States was observing the 100th anniversary of its independence, and the exposition

represented an opportunity for the country to celebrate its economic and creative vigor. Exhibits included an enormous Corliss steam engine and Alexander Graham Bell's new invention, the telephone.

Pope had seen bicycles in Boston, but at the exposition he began to think of making money by manufacturing and selling them. Before Pope, bicycles were produced by hand in small shops and thus were expensive. Pope and others applied American methods of mass production to bicycle building, and prices came down.

As a successful American businessman, Pope appreciated the power of advertising and public relations. To get people excited about the bicycle, he sponsored cycling clubs, bicycle races, and a publication called *The Wheelman* to promote the sport.

The early bicycle era coincided with a growing appreciation for the connection between exercise and health, and so Pope urged doctors to write articles praising the health benefits of bike riding. Pope turned laziness into a selling point. He said, "I am naturally a lazy man, as far as athletic exercise goes, and I think if I can enjoy the bicycle, almost anybody else can."

Although Pope didn't invent the bicycle, his story shows us the importance of entrepreneurial energy in bringing inventions to the public. Others soon followed his example.

An advertisement for Columbia Chainless Bicycles. The top part is a white box with black text. The bottom part is a black and white photograph of a woman in a long dress and hat riding a bicycle on a path, with another person on a bicycle in the background.

**Columbia**  
Bevel-Gear  
Chainless Bicycles  
\$125  
Make Hill Climbing  
Easy.

**Columbia**  
Chain Wheels, \$75  
Hartfords, . 50  
Vedettes, \$40 & 35  
**POPE MFG. CO.,**  
Hartford, Conn.

# Women and the Bicycle

Women were not encouraged to participate in vigorous physical exercise until late in the 19th century. They "bathed" but did not swim; they performed gymnastics, but only those exercises "suitable" for female health. Standards of decency at the time required that women's legs be completely covered. Corsets produced the famous hourglass figure by squeezing the waist and lower rib cage. Tight-fitting sleeves restricted arm movement.

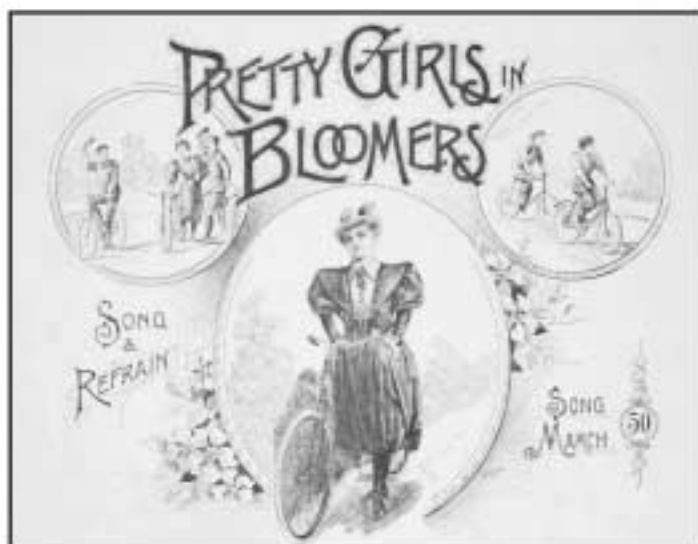
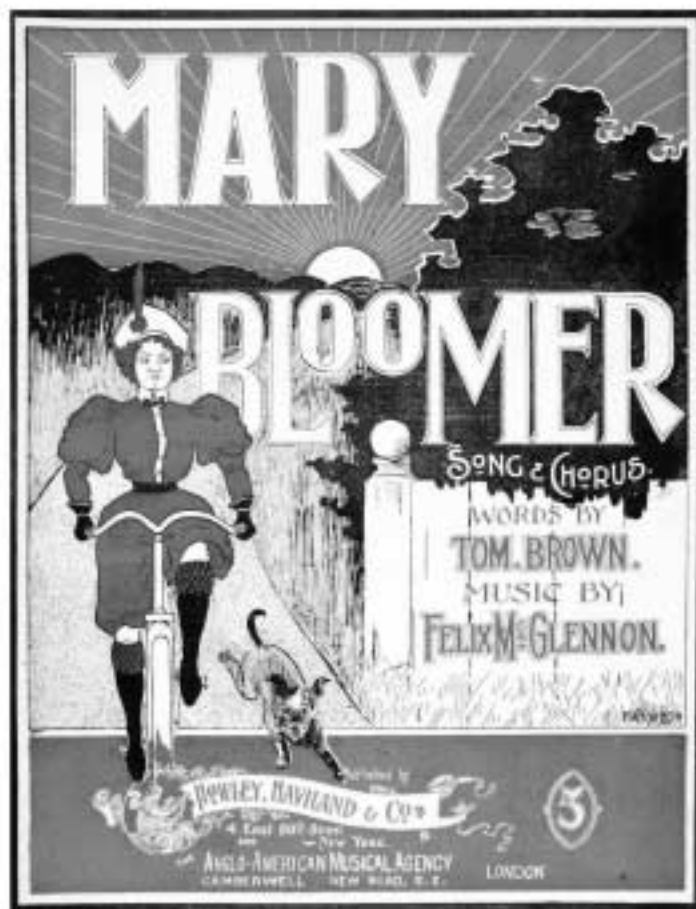
As women began to use the bicycle, corsets changed to permit freer breathing. Women tried bloomers and combinations of trousers and skirts that let them move their legs more freely while staying covered. The creation of bloomers—trousers gathered at the ankle and covered by a skirt—was an important breakthrough that contributed to dramatic changes in women's lives and their attire.

The invention of the safety bicycle coincided with a movement toward greater equality and social liberation for women. The safety bike was more stable and easier to learn to ride than the high-wheel bicycle, and its balloon tires made it more



comfortable. In 1896, suffragist leader Susan B. Anthony said, "Let me tell you what I think of bicycling. I think it has done more to emancipate women than anything else has in the world. I stand and rejoice every time I see a woman ride by on a wheel. It gives woman a feeling of freedom and self-reliance." Another reform leader, Frances Willard, shared Anthony's enthusiasm. Willard learned to ride at age 53 and recommended it for its power in building self-confidence. She wrote, "She who succeeds in gaining the mastery of the bicycle will gain the mastery of life."

As young men and women rode bikes, their freedom to meet each other away from home began to erode the custom of having a chaperone—usually an older relative—present at such meetings.



# An Innovative Path: The Good Roads Movement

Equally important to evolving bicycle technology were good roads, the most fundamental of resources for bicyclists. Roads in the 19th century were very different from today's paved superhighways. A transportation authority in 1854 described roads in the U.S. as "inferior to those of any other civilized country." In fact, very little was known in the United States about scientific methods of road construction and maintenance. Trade was primarily local and was conducted on rivers or, during the winter, overland on ice and snow.

Industry-supported cycling groups started a Good Roads Movement, hoping that better roads would encourage more people to take up bicycling. In 1880, representatives from 31 local bicycle clubs met in Newport, R.I.,

and founded the League of American Wheelmen to "encourage and facilitate touring." Eventually, the league united some 100,000 cyclists to advocate for surfaced roads. Joined by academics, engineers, and motor vehicle manufacturers, the league became a leader in the Good Roads Movement.

In the 20th century, motorists continued and expanded the efforts begun by the cyclists. This eventually led to the national highway system, new methods of construction, and the increased role of the federal government in funding road projects. Although the automobile has long since taken over the highway system, the League of American Bicyclists and other nonprofit groups continue to strive for better facilities for cyclists.



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# Contemporary Inventors and Innovators

Contemporary inventors who have made contributions to the bicycle come from many different backgrounds, but they share a joy in working with the technology. They bring to their work a sense of the fun of riding, and they take a personal interest in making machines that work better or let the cyclist ride in a new or better way. Here are recent inventions featured at the Lernelson Center's Innovators' Expo.

## Inventor Dan Hanebrink

For Dan Hanebrink, it is the challenge of extreme sports that provokes creative thinking. This downhill snow-racing bicycle can go as fast as 130 miles per hour. The unusual adjustable seat gives the rider added power, and a parachute helps to stop the bike at high speeds.



## Inventor Rod Miner

Rod Miner applies bicycle technology to make practical machines that do a variety of jobs, such as this bike that features fairings to adjust wind flow and provide protection and "tricycle" construction for stability on ice or snow.



This bicycle has a long wheelbase and relatively large tires suitable for gravel and unpaved roads. The 147 gears enable it to climb steep slopes.



# Inventor Spotlight: Mike Augspurger

**"If you want to make an improvement or an innovation or an invention, the place to look is in yourself."**

Mike Augspurger, inventor of the One-Off all-terrain handcycle

Mike Augspurger is speaking from his own experience as an expert cyclist, a skilled machinist, and a designer and builder of bicycles. Founder of One-Off Titanium, Inc., Augspurger is a specialist in custom and unusual titanium-frame bicycles, including the first all-terrain handcycle designed for wheelchair athletes.

Augspurger was born in 1956 in Fort Wayne, Ind. He received an early introduction to tinkering with and riding machines through his parents' interest in go-carts. In fact, one of Augspurger's earliest memories is of wearing an oversized motorcycle helmet, sitting between his parent's knees, and holding the go-cart's steering shaft on a loud, windy ride around the track. Without any formal instruction, Augspurger picked up a variety of hands-on skills from his father and other sources, including skill in woodworking, electronics, and machining.

Introduced to mountain biking in 1978 while attending Hampshire College, Augspurger bought one of the early mountain bike models. He immediately began to make improvements and even built his own frames. Through a job at a bike factory in the Boston area, Augspurger gained valuable experience in bike design and construction. Biking, however, was not simply a job: Augspurger became a skilled mountain biker, winning third place in the 1985 national bicycle trials in Reno, Nev.

In 1987, Augspurger joined with his wife and two partners to found Merlin Metalworks, the first modern producer of titanium bicycle frames. Originally used in the aerospace industry, titanium is a strong, lightweight, corrosion-resistant metal that is more flexible and resilient than steel. It is commonly found in beach sand, but the extraction process is expensive, about ten times the cost of steel. Thought to involve difficult welding conditions, titanium's use in other kinds of



production was limited until Gary Helfrich, a partner at Merlin, found a way. Merlin Metalworks quickly gained a reputation for its titanium bicycle frames and racing wheelchairs.

Augspurger struck out on his own two years later to start One-Off Titanium, Inc. Working independently gave him the freedom to specialize in custom and unusual titanium bike designs, such as a fully suspended mountain bike frame in steel and titanium. Augspurger connected to the wheelchair industry through his experience at Merlin. Dissatisfied with existing models, he had long desired to create a sports wheelchair that—similar to mountain bikes—would offer wheelchair athletes the best performance over rough terrain. After ten years of ideas, rough sketches, and prototype testing, the One-Off handcycle became a reality. Augspurger has been working on the all-terrain arm-powered vehicle idea ever since.



# Vocabulary List

**ball bearing:** a machine part in which one component turns upon loose hardened-steel balls that roll easily, reducing friction

**bloomers:** billowy women's pants that gathered at the knee or lower leg

**bone shaker:** *see velocipede*

**brakes:** a device for slowing or stopping motion, using friction

**chain:** a series of usually metal links or rings connected to or fitted into each other and used for transmission of mechanical power

**crank:** an arm that connects the pedal to the axle

**draisine:** an early form of two-wheel bicycle that was pushed along with the feet

**fairing:** a structure that reduces air resistance by allowing air to flow more easily around bike and rider

**gears:** a wheel having teeth or sprockets that engage with the chain to transmit power from the pedals to the wheel

**high-wheel:** an early bicycle with a large, "high" front wheel and a small back wheel; the crank was attached to the axle of the front wheel.

**hub:** the central part of a wheel

**pedal:** a lever pressed by the foot

**safety bicycle:** a bicycle with wheels of similar size and a chain drive

**velocipede:** (French for "fast feet") an early bicycle with two wheels, propelled using a crank attached to the front wheel; also known as a "bone shaker".



**spoke:** a small radiating bar inserted in the hub of a wheel to support the rim

**sprocket:** a tooth or projection shaped so as to engage a chain

# Suggested Activities

1. Like the bicycle, many other inventions are made of several different parts. Have students identify an invention of their choice. Investigate and draw the many small inventions inside the big invention.

2. Explore the various components of a bicycle and how they work together. What systems are at work? What happens if a system is missing? Do you observe any simple machines? How do they work together? Have students develop a simple chart to describe the relationships that allow a bicycle to work.

3. Compare early bicycles with contemporary designs. How are they similar? Different? What early parts still exist? Investigate why bicycles have different designs. Using biking magazines, students can classify various designs according to purpose. What features do bicycles in each group have in common? How do the features equip the bicycle for its purpose?

4. The story of Albert Pope demonstrates the importance of marketing in bringing inventions to the public. Discuss the strategies Pope used. What other things might students try? Have students brainstorm strategies for making their own invention popular, and put together an ad campaign.

5. Read the story "Women and the Bicycle." Did bloomers lead to modern women's sports? Have students write a paragraph describing why or why not.

6. Read the "Innovative Path" story. Is there a bike trail where you live? What is the story behind it? What were some design challenges? If there is no bike trail, where would you put one? How would you go about creating it?

