

GUITAR

The
Instrument
That **Rocked**
The World

TUNE AMPS
TUNE **AXE**
TUNE DANGEROUS
TUNE WOOD
TUNE HISTORY
TUNE **LOUD**
TUNE **SCIENCE**
CUTAWAY
PUNK
DREADNOUGHT
AMPLIFIERS
POP
POWER
EFFECTS
PICK
FINGERBOARD
6 STRING
SOUND
ARCHTOP
BLUES
STEEL
DISTORTION
SOLO
RHYTHM
NECK
12 STRING
POWER
FRETS
DREADNOUGHT
SHRED
CLASSICAL
FLAT PICK
HARD
STRINGS
SCIENCE
AMP PICKUPS
JAZZ
MUSICIANS
HISTORY
FOLK
COUNTRY
METAL
ROCK & ROLL
SOLIDBODY
MELODIC
ICONIC
INVENTORS
MUSICIANS
GUITAR:
THE INSTRUMENT THAT
ROCKED THE WORLD
REVOLUTIONARY
ELECTRIC
HOLLOWBODY
BLUEGRASS
MAGNETIC
HISTORY
HISTORY
MAGNETIC
BLUEGRASS
HOLLOWBODY
ELECTRIC

STUDY GUIDE FOR THE EXHIBIT



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Introduction to the Study Guide

Science plays a significant role in “GUITAR: The Instrument That Rocked The World.” The science inherent in the guitar (and all music) allows students to explore sound and sound generation from within the instrument itself as well as from the perspective of engineers and musicians.

The following pages are designed to be used as both a Teacher’s Reference to “GUITAR: The Instrument That Rocked The World” and an education and activity book.

Any of the pages herein can be used for classroom presentations and activity, but it is up to the educator to determine the grade appropriate level of each section.

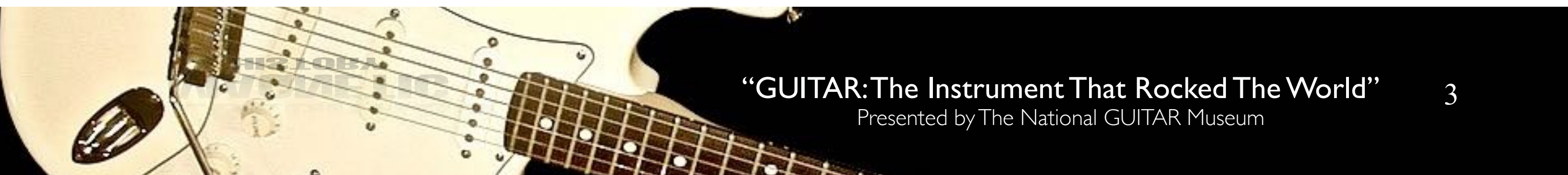
For very young students, teachers may want to disseminate the drawing and activities section only, while using other pages as a guide and prep for the exhibit.

For older students from Grade 5 upwards, all pages – with the exception of the simpler drawing pages – can be distributed as part of an overall learning package. The text has been written so that it can be read and understood at a fifth grade reading level.

NOTE: The STUDENT ACTIVITIES section – beginning on Page 36 – is designed to be printed out separately from the overall guide in order to be used with students in a classroom activities setting.

We have given this section a set of specific STUDENT ACTIVITIES page numbers for ease of use when printed out. We have also included the page number for the overall document in the lower left hand corner of each page. for your reference.

Print from Pages 36-48 on your printer to print just the STUDENT ACTIVITIES section.





GUITAR

The
Instrument
That **Rocked**
The World

Overview

The guitar is the single most enduring icon in American history. There are more guitars made every year than all other instruments combined.

The guitar evolved from European and Asian instruments during the Middle Ages (oud, tanbur, and lute). Here, these instruments are displayed side by side next to the guitar as we know it today, with its signature hourglass shape. Wood and string samples—from maple to catgut—let visitors handle and hear the materials that give each guitar a distinctive sound. An acoustic guitar is spliced open to reveal the intricate woodwork that goes into building a sturdy “box with no nails.”

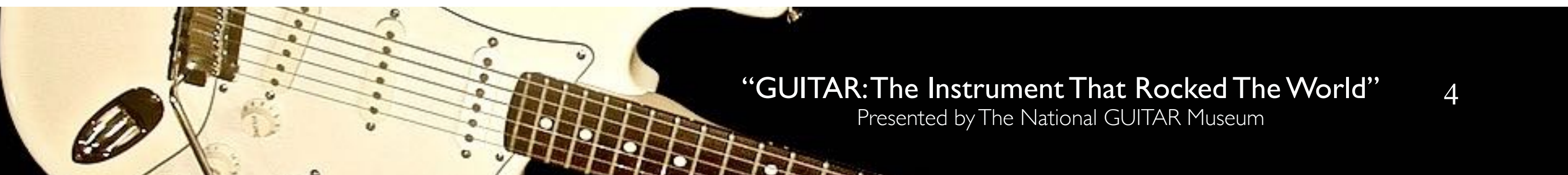
From bowls to flat surfaces to slightly curved lines, guitar makers have experimented with hundreds of different shapes looking for the perfect blend of beauty, physics, and sound. European luthiers who emigrated to the United States changed the guitar’s structure to make it louder and sturdier. Strings may vibrate, but strings by themselves don’t make much noise. The soundboard of an acoustic guitar, not its body, enhances the strings’ vibrations and those vibrations project out to the listener.

The guitar was the first multi-faceted instrument that allowed singers and performers to accompany themselves, and it was easy to travel with. The traveling guitar gave rise in the early 1900s to the blues in the Deep South and country western music in the expanding U.S. west.

Technicians, luthiers, and musicians attempted to make guitars louder for band members who couldn’t hear their guitars above drummers and horn players. They began using electricity in the 1930s to amplify the guitars. Visitors will see how, instead of using a large hollow sound box, the electric guitar uses magnetic coils to capture the vibration of the strings and turn it into amplified sound, making the guitar one of the loudest devices ever created.

Wide-scale production of the electric guitar started in the 1950s and has continued unceasingly to the present. Inventors and designers like Leo Fender, George Beauchamp, Guy Hart, Les Paul, Ted McCarty, and Paul Bigsby came up with new innovations and body shapes that also changed the shape of music.

By the 1960s, the guitar had evolved to become every bit as important to social change as newspaper editorials and politicians’ speeches. Street corner guitarists led anti-war protest movements while angry youths fighting against the status quo took up guitars to fuel their punk instincts. The guitars of this era got wilder by design, employing materials like plastic, carbon fiber, and even metal that led to more radical shapes and sounds than ever before.



HISTORY

CHORDOPHONE

Guitars belong to a group of instruments known as chordophones. These are instruments that make sound using a string—or many strings—stretched between two points. The pulling, plucking, strumming, bowing, or hammering of the string causes a vibration that generates sound waves. The greater the string tension, the higher the pitch of the sound. Chordophones usually have a resonator, or soundbox, that helps amplify and project the sound that is made when the string vibrates.

Examples of chordophones include guitars, banjos, lutes, violins, cellos, harps, and pianos.

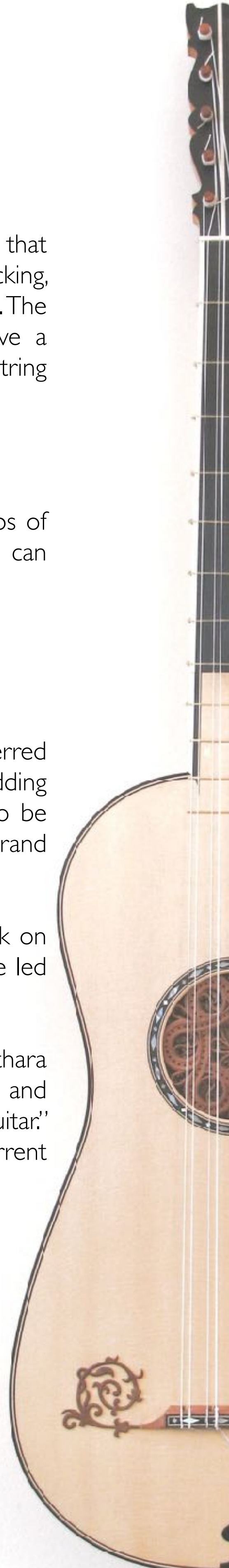
Even though it sounds like a chordophone should be used to play chords—which are groups of notes played together—the name has nothing to do with playing chords. All chordophones can play single notes.

HISTORY

Throughout the Renaissance (from the late 1300s to the early 1600s), the lute was the preferred stringed instrument of European musicians. Many players sought to customize their lutes by adding more strings and lengthening the neck, allowing a wider range and combination of notes to be played. Many of these modifications became so popular that they served as the basis for brand new instruments.

Yet, so much modification resulted in the creation of a huge variety of instruments that took on their own characteristics. Many of them were precursors to the guitar, although no single one led to the guitar as we know it today.

The word “guitar” has a jumbled origin derived from a multitude of sources: kithara (Greek), cithara (Latin), qitar (Arabic), gittern (English), gitarre (German), guitare (French), chitarra (Italian) and guitarra (Spanish) . . . these are all names from antiquity that contributed to the creation of “guitar.” It seemed as if every conceivable spelling of guitar was used prior to the 1800s, when the current spelling was adopted in English.



PARTS

PARTS OF A GUITAR

The guitar is made up of a number of different pieces. On acoustic guitars, these pieces are made primarily of wood, whereas electric guitars have a body of wood but lots of metal and plastic parts as well.

ELECTRIC GUITAR

ACOUSTIC GUITAR



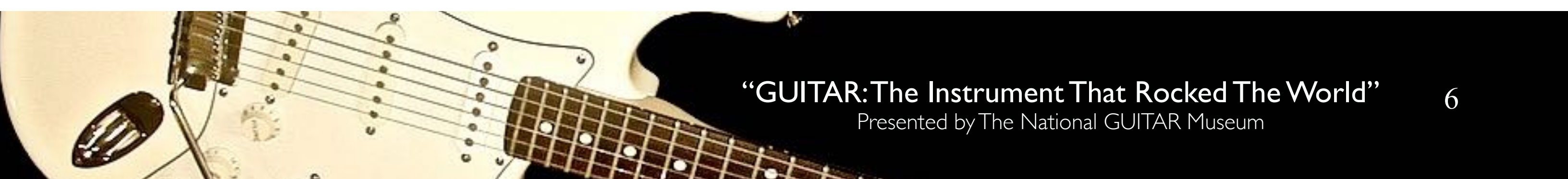
BODY

The biggest part of the guitar is the body. It has a top (or face), a back, and sides. The top of an acoustic guitar is designed to project the sound caused by the vibration of the strings. The front, the back, and the sides are often made of different types of wood.

The body of an electric guitar is usually a block of solid wood. It creates sound using electromagnetic pickups that capture the vibrations of the strings.

STRINGS

The most important part of a guitar is the string. Every guitar has six strings as a standard setup, although some have more, and as many as 12 strings. Strings can be made from metal, plastic, or catgut, depending on the kind of guitar they're attached to and music being played.



PARTS

PARTS OF A GUITAR (continued)

NECK

The neck is the part of the guitar that extends out from the body. Strings are attached to the end of the neck (called the headstock) and run all the way down to the body. The NECK is the part of the guitar where notes are formed by pressing strings against the part of the neck called the fretboard.

FRET

A fret is a narrow piece of wire that is inserted into the fretboard. When a string is pressed against the fret, the vibrating length of the string is shortened. Each fret produces a different note by shortening the string's length a certain amount.

TUNING PEGS

Tuning pegs hold the strings in place at the top of the neck. They can be turned so that each string can be tightened or loosened to achieve a desired pitch. Tuning pegs are also called tuning heads, tuners, machine heads, and pegs. The part of the neck they are attached to is called the headstock.

BRIDGE

The bridge holds the strings to the body of the guitar.

ELECTRIC GUITAR

ACOUSTIC GUITAR



WOOD

WHAT IS A GUITAR MADE OF?

The primary “ingredient” in guitars is wood. Some wood is heavier than others, some stronger, and some more ornate and decorative. All the wood that goes into a guitar is designed to make the guitar sound good, and sometimes make the instrument look beautiful.

Woods that reflect a lot of vibrations usually make bright sound, while woods that absorb vibration tend to be darker and duller. A guitar is made up of different woods to create different tones.

1. Spruce is one of the best woods for projecting sound. It is often used for the top of the guitar, called the soundboard, where most of the string vibrations are projected into the air. Spruce is soft and lightweight, but very stiff. This stiffness makes spruce bounce the sound rather than absorb it. It creates a very bright sound.

- Spruce trees are evergreens that grow in cold climates. Because of its strength and light weight, spruce was used by the Wright Brothers to make their first airplane. It is also used to make paper. The oldest tree in the world is a spruce in Sweden that is estimated to be 9,550 years old.

2. Rosewood is a unique wood that has both good projection and good absorption qualities. It is used on the sides of the guitar to project low- and medium-pitched tones. Rosewood is naturally very oily, which causes it to absorb certain tones.

- Because rosewood is great for creating rich guitar sounds, it has been used for more than a century to produce guitars. However, Brazilian rosewood, which comes from the Amazon rain forest, has been overharvested and has almost completely disappeared. It is now an endangered wood, so no new Brazilian rosewood can be harvested. Luthiers are using relatives of this tree, like Indian rosewood, to make new guitars.



WOOD

WHAT IS A GUITAR MADE OF? (continued)

3. Mahogany is harder than spruce, but lighter than some other woods. It doesn't vibrate like spruce, so it is generally used on the sides or backs of guitars, where it produces a sound that is warmer and not so bright. It is regularly used in block form for bodies of many electric guitars.

- Mahogany trees grow in tropical regions, primarily in Central America and South America. Mahogany is a very popular wood for furniture.

4. Maple is a very hard wood that is frequently used for guitar necks. Its hardness keeps the neck from vibrating, and also helps it stay rigid against the pull of strings. Maple is sometimes used for electric guitar bodies, especially because it can have unusual grain patterns that are very decorative.

- There are over 100 species of maple tree, and they typically grow in areas above the equator like North America, Europe, and parts of Asia. Maple trees are used for everything from producing syrup to making baseball bats.

5. Plywood is a cheap wood created from pasting layers of thin wood sheets together. These sheets are usually from spruce, pine, or fir trees. Plywood is typically used for construction, although some products, including inexpensive acoustic guitars, are frequently made from plywood. Plywood has no significant tonal properties.



Examples of different wood grains found on a guitar



CONSTRUCTION

A BOX WITH NO NAILS

The body of an acoustic guitar is built like a box. It has a top, bottom, and sides. The entire body is usually made of wood that is almost as thin as cardboard. The wood is thin so that energy from the vibrating strings can bounce off of it. It also keeps the guitar light and easy to carry around.

When strings are pulled across the top of a guitar, they exert almost 200 pounds of tension on the guitar. That's almost like having a large man standing on the wood. In order to keep the wood from breaking, the inside of the guitar is built like a skeleton. Thin pieces of wood are attached all around the inside. These pieces of wood, called braces, are placed in spots where there is the most stress on the guitar. They help keep the wood sturdy.

Braces are very important in building the guitar (and many other stringed instruments). The braces cannot be too stiff or the guitar body won't vibrate enough to project sound and will have a dull tone. If the braces are too weak, the body will eventually warp and possibly break.

What makes the construction of an acoustic guitar really interesting is that there are no nails or screws used in the body. Everything is held together only with glue. That's because nails and screws can't completely seal the body—there are empty spaces between where each nail and screw is inserted. Empty spaces would cause the guitar body to rattle. The glue is reinforced by snakelike wood strips called kerfing, which are easy to bend and twist because they have notches cut into them. Once glued, they become just as strong as solid wood.

The curved parts of the guitar—the sides—are created by bending thin strips of wood. Even though the sides are thin, it is hard to bend them in an “S” shape without snapping the wood. For this reason, the wood is soaked in water and heated using a bending iron. This steam heating makes the fibers in the wood surprisingly flexible; this is because water molecules bind with wood molecules and make them “slippery.” Even a thick piece of wood can be bent if it is steamed enough. Boats, barrels, and furniture used to be built using this technique. The wood is bent into shape and held in place using molds and clamps. Once it dries out and cools, the wood keeps the “S” shape and is glued into place.



STRINGS

MAKING NOISE WITH STRING

Strings are the part of the guitar that make sound. The vibrations of strings are projected into the air by the top—the soundboard—of the guitar.

Different kinds of strings create different sounds. Thicker strings make lower tones, while thin strings make higher pitched tones.

There are three categories of guitar strings, each having to do with the material the string is made of: catgut, steel/metal, nylon.

CATGUT

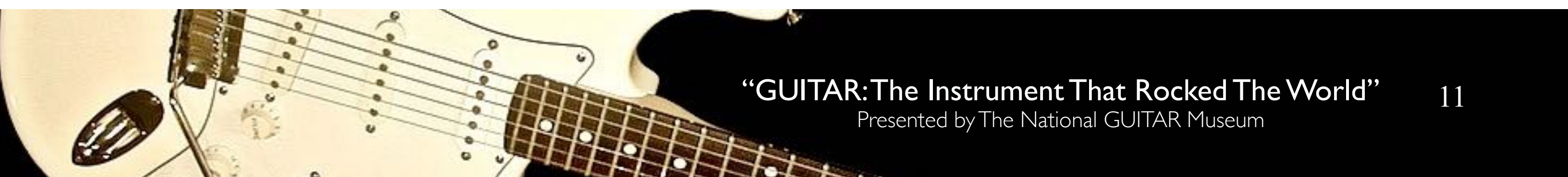
For most of recorded history, right up until the mid-1900s, musical instrument strings were made primarily from a material called “catgut.” It had nothing to do with cats, but it did have a lot to do with guts. The strings were actually dried sheep intestines (although they occasionally came from other farm animals). The intestines went through various cleanings and treatments to create smooth yet strong strings for everything from lutes and violins to cellos and guitars. They were also used as medical sutures to stitch up wounds and as strings for tennis racquets.

No one knows how the word “catgut” came into being. It may have been a derivation of “cattlegut,” meaning the intestines of farm or ranch animals. Or it may have originally been called kitgut, meaning the gut strings attached to a kithara. In any event, there aren’t any cat parts in catgut.

STEEL

Metal strings made out of steel and bronze were first used on guitars around 1890. The popularity and loudness of the mandolin and banjo, which both used steel strings, encouraged many players to replace their gut strings with steel. The problem was that steel strings exerted more tension on the guitar’s body than gut, and oftentimes ripped the instrument in half. It wasn’t until better bracing, created by the Martin family, that steel strings would be used regularly on guitars. Ultimately, steel strings were cheaper and lasted longer than their gut counterparts.

Steel strings became used even more frequently during the two World Wars, when other materials were scarce (copper pennies were even made of steel for period of time). Steel strings were also louder (their strength vibrated the guitar’s top more than nylon or gut), made more pitch changes when bent slightly, and also responded well to the use of a metal or glass slide.



STRINGS

MAKING NOISE WITH STRING (continued)

Heavy steel strings are made up of two parts. A core wire is wrapped from top to bottom with another wire, adding thickness and strength to the string. This configuration also helps create a warmer tone for these strings than that produced by a lone wire. Usually the bottom three strings of a guitar, and occasionally the fourth, are wound strings. Electric bass strings are always wound.

NYLON

For guitarists who played classical or flamenco guitar, steel was not an option to replace catgut. It was too loud and brash to allow for the subtleties of those musical styles. Yet gut tended to wear out quickly and was expensive. With the creation of nylon and other plastics in the 1930s and 1940s, natural and hard-to-find materials were replaced in every area of daily life. Tortoise shell combs were made of nylon, parachutes and carpets were made of nylon, and ultimately the catgut used for guitars strings and tennis rackets was replaced by nylon.

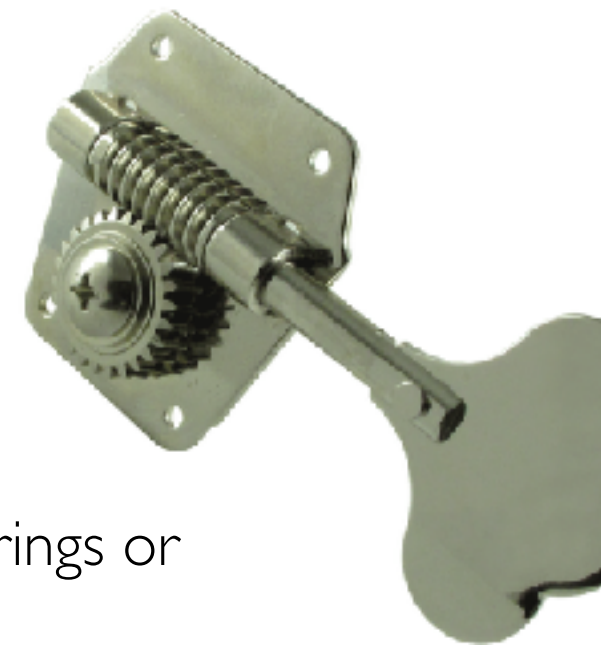
In 1946, Andres Segovia—the man credited with popularizing the classical guitar all over the world—worked with a luthier named Albert Augustine to create a nylon string with all the tonal properties of gut, but that would be stronger, easier to tune, and last longer (a fear of many performing classical guitarists was the possibility of a gut string breaking during a recital). Augustine used cables of thick nylon thread from the DuPont company to craft strings that would be suitable for Segovia. With Segovia's blessing, nylon became the standard for guitar strings on classical and flamenco guitars, as well as for smaller, introductory guitars for kids. Like steel strings, the heaviest nylon strings are wound for better sound and strength.

Some manufacturers still make gut strings in limited quantities, but these strings are almost 10 times more expensive than their nylon counterparts.





GEARS



GEARS

For most of history, strings were tuned to the right pitch by tying knots at the base of the strings or by affixing the strings to turnable friction pegs. These pegs were inserted into holes in the instrument's headstock at the top of the neck. They were turned to the right pitch, and then pushed hard into the holes so that friction would keep the string from loosening. Violins, cellos, and many other instruments that use gut or nylon strings are still tuned using friction pegs.

When steel strings became standard on acoustic guitars, friction pegs weren't strong enough to hold them in place. It was too hard for the guitarist to turn the peg with the metal string attached to it, and even harder to force the peg into the hole to keep the peg and string from slipping.

The answer was to use gears, or more precisely, machine heads. These machine heads were a type of tuning peg that contained metal gears that could hold the strings in place without slipping. Machine heads could also be used to fine-tune the strings using a combination of gears that allowed even people with big hands or fingers to make very, very tiny adjustments. That's because for every 14 turns of the machine head's knob, the actual peg only makes one full turn. This takes a long time to wind the strings, but it makes tuning strings very precise.

- Gears are simple rotating mechanical devices that can change the speed, direction, or power of whatever is turning them. But they have some very unique characteristics, as you will see in the sets of gears on this display.
- Gears that are next to each other always turn in the opposite directions.
- In order for two gears to turn in the same direction, they have to be separated by a gear in between them.
- For groups of gears to turn in the same direction, they all have to be either odd or even. For example, 1, 3, 5, 7, etc. all move in the same direction, as do 2, 4, 6, 8, etc.



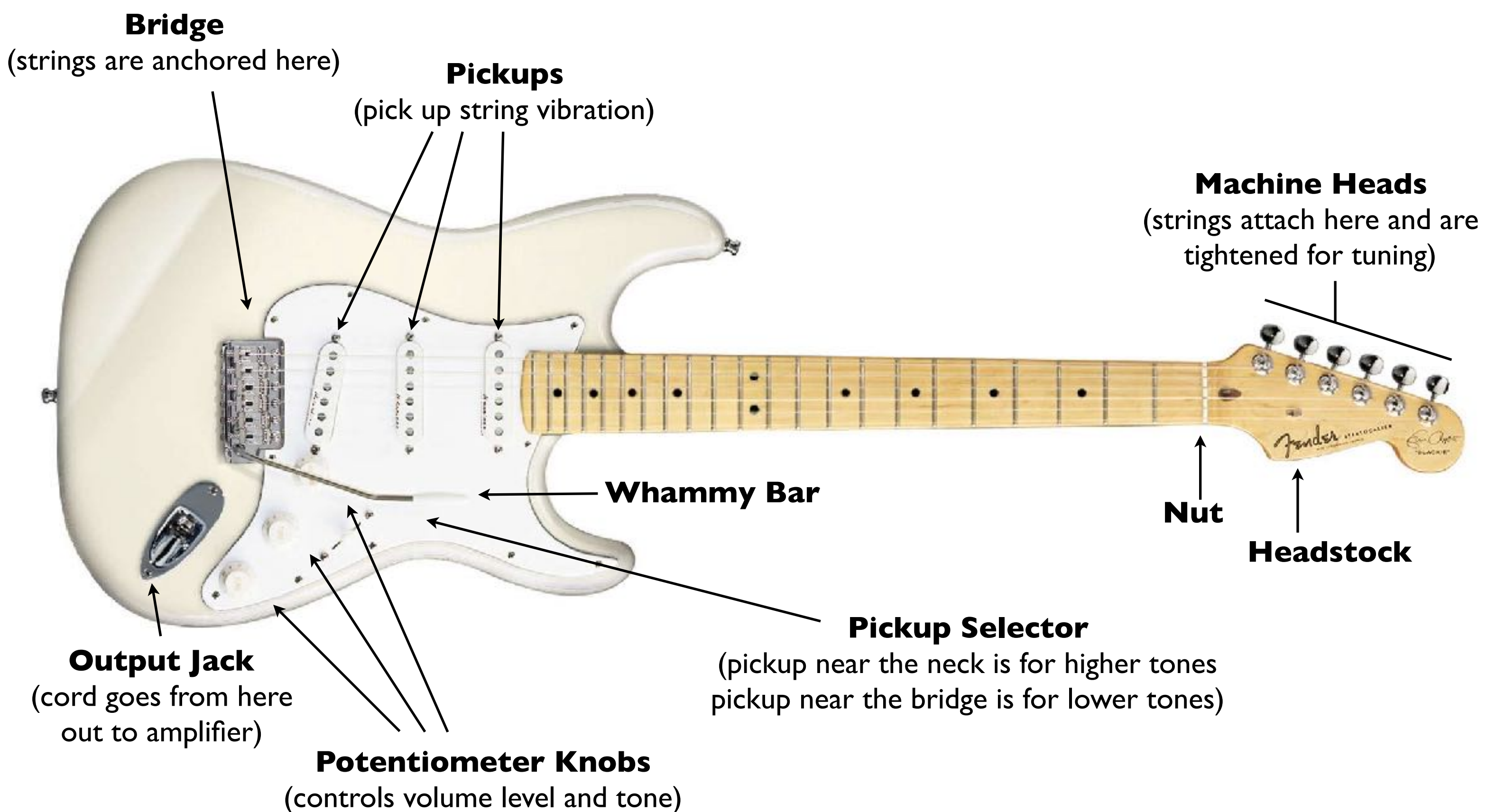
PARTS

THE ELECTRIC GUITAR

An electric guitar is a simple device that relies on electromagnetism to produce sound. In this see-through guitar, you can see how each of the three magnetic pickups is wrapped in copper wire.

When the magnetic field of the pickup is disrupted by the vibration of a metal string, it creates a current in the copper wire. This current, or signal, is then transmitted through another wire to devices called potentiometers. These potentiometers, which are controlled by knobs, adjust the frequencies in the signal that control volume and tone—just like a dimmer switch adjusts the level of light from a bulb. The signal then leaves the guitar through the output jack, which is where a cord is plugged in that leads to an amplifier.

The rest of the guitar is made up of metal screws, metal bridge pieces, plastic knobs, metal tuners, plastic pickguard, metal springs to control the tension of the bridge when a whammy bar is used, and metal wire for the frets.



PARTS

PICKUPS

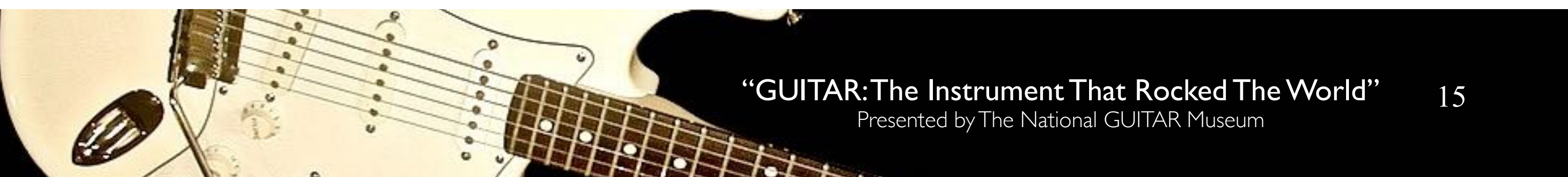
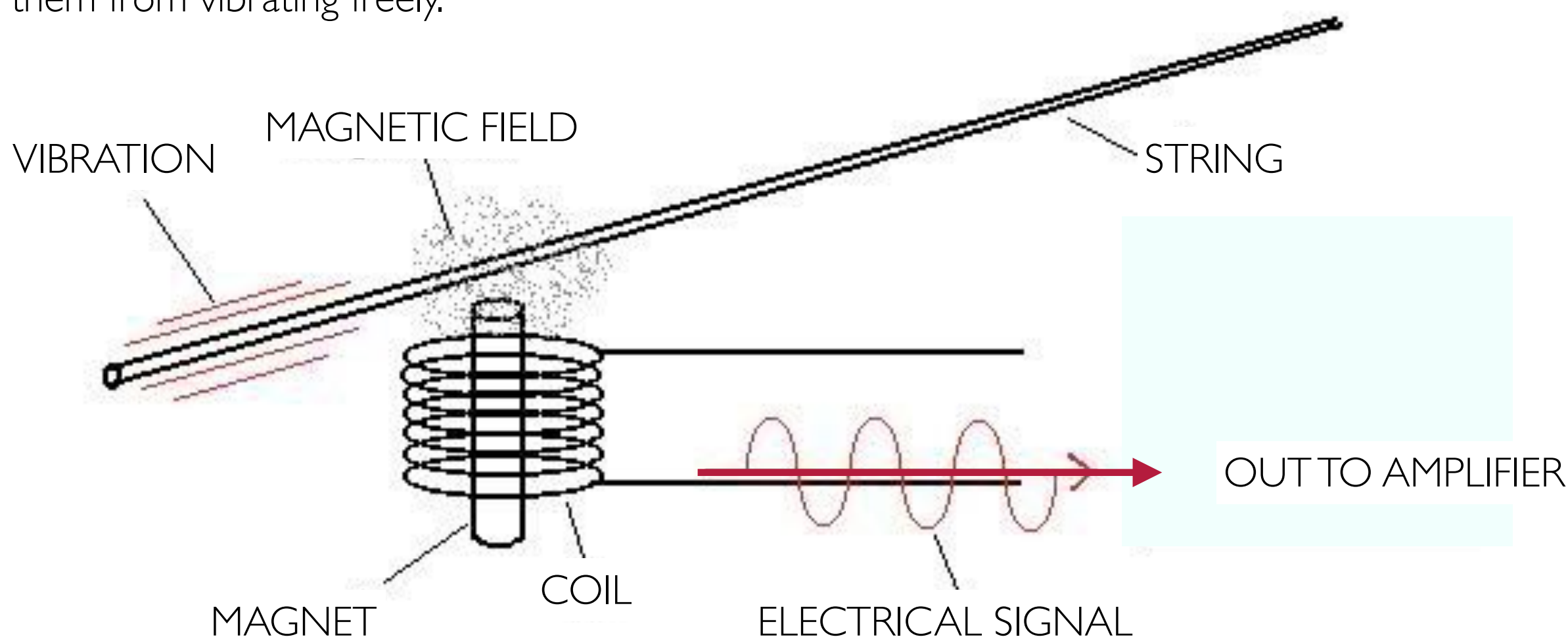
Pickups are small magnetic devices. At the heart of the pickup is a magnet. Wrapped around this magnet is very thin copper wire. Together, the magnet and the wire form a magnetic field that can send electrical signals. But one thin strand of wire doesn't make for a strong signal, so there are usually 5,000 or more loops of wire (called turns) wrapped around a pickup. With that many turns, the pickup is strong enough to send a signal.

So where does that signal come from? Well, an electromagnet only produces signals when its magnetic field is disrupted by something in motion. In the case of pickups, the metal guitar string vibrates over the pickup, causing a disturbance in the magnetic field surrounding the magnet and copper wire. The magnetic field creates an electrical signal that matches the vibrations caused by the string vibrations. Basically, it translates the mechanical signal into an electrical signal, which is then sent via a wire out to the other electronic parts of the guitar, including its volume and tone controls.

As soon as the string stops vibrating, the electromagnetic pickup goes back to rest and doesn't send any more signals until the string is plucked again.

Interestingly, the magnets on some pickups will be affected by electrical sources such as fluorescent lights, cell phones, and large machines. This causes the pickups to buzz or hum when the guitarist is near these power sources. In order to minimize this hum, some pickups use two magnets placed next to each to cancel out some of the vibrations that occur when this interference occurs. These pickups are called "humbuckers" because they are designed to stop or "buck" the hum and reduce unwanted noise.

Most pickups have magnetic poles that are designed to pick up the vibrations from a single string. These can't be too strong or they can actually start pulling magnetically on the strings and prevent them from vibrating freely.



PARTS

AMPLIFIERS

Without an amplifier, an electric guitar is hardly louder than a whisper. Amplifiers turn the electrical signals picked up by the pickups and strengthen them so they can be heard.

A tube amplifier is a type of amplifier that uses vacuum tubes to increase the power and/or amplitude of the signal from an electric guitar. When an electrical current passes through these tubes, the current actually gets stronger, or amplified.

This signal is received by the amplifier through the guitar cord. A transformer inside the amp uses regular electricity to move the signal through several components, including the tubes (which increase the signal) and a capacitor (which helps control it). The strong signal is then sent through a cable out of the amp to speakers.

The speakers vibrate because of the signal from the amp. This vibration creates sound waves in the air. The stronger the signal, the more air that the speakers push outward. The speakers are in an enclosed cabinet so that the sound waves move forward, and also create a deep bass sound.

The speaker cabinet in the exhibit contains four 12" speakers that move a lot of air and can be incredibly loud. When a guitarist is playing this particular amplifier and speaker configuration, it can be loud enough for everyone in a stadium to hear it.



THE INVENTORS

PASSION + SKILL = INNOVATION

Most of the people who contributed to the design of stringed instruments over the centuries are unknown. However, a number of individuals in modern times made significant changes to the guitar and helped it evolve into the instrument we know today. These people ranged from carpenters and electronics repairmen on to musicians and aeronautical engineers. Each brought their own unique skill to the design of the guitar.

• **Antonio de Torres Jurado (1817 – 1892)**

In the mid-1800s, Spanish luthier Antonio de Torres Jurado determined, correctly, that the part of the guitar most responsible for producing volume and tone was its top, or soundboard. Torres found that spruce was the perfect wood to create a top that could produce the kind of volume and tone that guitarists wanted. But the spruce needed to be very thin. Torres, a brilliant craftsman, determined the necessary thickness of each piece of wood by running it between his thumb and forefinger. In order to keep the spruce from snapping under the tension of the strings, Torres developed a system of braces that he placed underneath the top, hidden inside the guitar. These braces kept the soundboard rigid enough to keep from breaking, but allowed it enough flexibility to produce the required sound. By the 1900s, Torres' design had become the standard blueprint for building the classical guitar – and remains that way even today.



• **C.F. Martin (1796 – 1873)**

Christian Frederick Martin was a German cabinet maker and guitar maker. Known as C.F., he emigrated to New York in 1833 and set up a luthier shop in Manhattan. After several years in the city, he moved his family to the rural town of Nazareth, Pennsylvania. C.F. experimented with numerous adaptations of the guitar, and developed an “X” bracing that could support steel strings, which gave his guitars a wider range of tones than those delivered by Torres' guitars. Martin began mass production of his guitars in 1859, and he died in 1873. Today, C.F. Martin & Company is still run by the Martin family and is one of the longest-running family-owned businesses in U.S. history.

• **Orville H. Gibson (1856 – 1918)**

Orville Gibson lived in Kalamazoo, Michigan where he performed a variety of jobs while developing his skills as a luthier. From his home shop, he began making mandolins, and then guitars that he sold to local musicians. For reasons unknown, Orville started modifying the shape of the front and back of his instruments. After several years of experimentation, Orville determined that mandolins and guitars would sound better if their tops were slightly curved, or arched, like the top of a violin. In 1896, he filed a patent for his archtop creation and used the design in a wide number of unique and elaborate guitar-like instruments, including harp guitars. The archtop was eventually to become a defining characteristic of guitars in the mid-20th century, and is still used today on many high-end instruments. The company Orville founded is still one of the most famous makers of guitars in the world.



THE INVENTORS

PASSION + SKILL = INNOVATION (continued)

• **George Beauchamp (1899 – 1941)**

A Texas guitarist who got tired of being drowned out by his band, George Beauchamp (pronounced bee-chum) created the first device that worked by "picking up" vibrations directly from metal strings. Working with Adolph Rickenbacher in 1931, he fitted the "pickup" on a Hawaiian guitar, creating what was arguably the first solidbody electric guitar. Beauchamp filed a patent in 1932 and then again in 1934 for his pickup. His partner started producing the "frying pan," a name that described the shape of the guitar. Guitarists ever since have never had to worry about being loud enough.

• **Paul Bigsby (1899 – 1968)**

Bigsby was a motorcycle mechanic during the 1940s in Southern California. He became friends with country star Merle Travis when the two met at a motorcycle racetrack. Travis discovered that Bigsby was a notorious tinkerer, and asked Bigsby—in 1946—if he could build an electric guitar, complete with pickups that wouldn't feed back (feedback occurs when a microphone picks up its own sound from a nearby speaker, causing a high-pitched and very annoying squealing sound). Using a design from Travis, Bigsby created what may have been the first solidbody electric guitar, made out of solid wood, and not hollow like an acoustic guitar. But Bigsby had other business interests and decided not to focus on building guitars. For this reason, even though he was a pioneer of the modern electric guitar, his name is not as well-known as other innovators.

• **Clarence Leonidas Fender (1909 – 1991)**

Leo Fender had a natural ability to fix electronic equipment of all types, and opened a store in California in the 1940s to perform repairs and sell parts for radios and televisions. Country & Western music was flourishing in Southern California, and local bands brought electrical equipment like amplifiers and acoustic guitars with pickups to Leo for repair. Leo spent a lot of time listening to the musicians' gripes about their equipment: how it was unreliable, how it didn't work right, and how they'd make it if they had their way. Leo started making his own electric guitars. It was simply built, portable, easy to play and easy to repair. It also had a solid body, so it wouldn't feedback like acoustic guitars that had pickups or used microphones. After seeing it, other guitarists asked Leo for a solidbody guitar for themselves; demand became so great that he started a company dedicated to building the guitars. Today, it is the largest producer of guitars in the world. Leo is considered one of the most important developers of electronics technology in the history of music – not just guitars. Perhaps the one thing that is most interesting about this electronics and engineering genius is that he never learned how to play the guitar, and never even learned how to tune one.



THE INVENTORS

PASSION + SKILL = INNOVATION (continued)

• **Les Paul (1915 – 2009)**

Lester Polfuss was one of the most important inventors in all of modern music. Lester is better known to the world as Les Paul. He was a successful jazz guitarist, had his own TV show, and changed the way music was recorded. Les was responsible for the invention of tape machines that could record different parts of a band (the singer, the guitarist, the drummer) one at a time, instead of all at once. Being a guitarist, he also had his own ideas about how to electrify guitars. He took one of his hollowbody archtop guitars, sliced it in half, and then put a solid beam of 4 x 4 wood in the center where he could mount pickups and electronics and still keep the natural sound of the guitar. This hybrid creation was dubbed "The Log," and in 1941 he tried to convince Gibson to build a version of it. The company said no, but when Leo Fender's solidbody guitars started selling well a few years later, Gibson came back to Les and asked him to lend his name and some of his ideas to a new line of guitars. Their collaboration resulted in a solidbody guitar called simply the Les Paul, which was introduced in 1952.



• **Charles Kaman (1919 – 2011)**

Charles Kaman gave birth to the world of "acoustic electrics." Kaman was an aeronautical engineer who formed Kaman Aircraft in 1945 to build helicopters based on his own designs. He eventually founded Ovation Instruments in 1965 and charged his engineers with reinventing the guitar using the most advanced technology available. The company's researchers determined that a bowl-shaped back constructed of glass fibers and bonding resin would produce an acoustic guitar that would sound good and could also be easily amplified. Ovation built a pickup with controls right into the body of the guitar, giving guitarists more control over their live acoustic sound than they had ever previously had and almost completely eliminating feedback. This changed the way that acoustic guitarists performed in concerts.



ARTIFACTS

1. The Origin Of The Species

Tanbur (Persia)
Luo Nyatiti (Africa)
Oud (Mesopotamia)
Lute (Europe)

2. The Close Relatives

Pipa (China)
Balalaika (Russia)
Sitar (India)
Ukulele (Portugal and Hawai'i)
Mandolin (Spain)
Banjo (America)
Charango (South America)

3. The Transitions

Viheula (16th Century Spain)
Baroque Guitar (17th Century European)
Romantic Guitar (19th Century Germany)
Torres-Style Spanish guitar (19th Century Spain)
Spanish Guitar (20th Century)

4. The American Perspective

Martin Parlor
Gibson L-1
Gibson Harp Guitar

5. Bigger Sound

Martin D-28
Gibson J-200
Gretsch Resonator/Dobro
Guild 12-String

6. Electricity Changes Everything

Rickenbacker Lapsteel
Gibson L4 CES
Fender Precision Bass
Fender Telecaster
Gibson Les Paul

7. Pop Culture & Mass Production

Silvertone Amp In Case
Sears Emenee Wingding
Gretsch White Falcon
SG
Gibson ES-335 "Lucille"

8. Unique Designs

Hofner 500/1 Bass
Coral Sitar
Ovation Breadwinner
MusiConics Guitorgan
Vox Phantom/Teardrop
Teisco Spectrum 4

9. Material Issue

Dan Armstrong Acrylic
Ovation Roundback Acoustic
Aluminum Guitar
Modern Classical

10. Over The Top

Ibanez Giger Iceman
Steinberger Headless
Hondo H-1
PRS Dragon
Ibanez Jem

11. Outrageous

BC Rich 10-String
Bond Electraglide
XOX Handle
Roland G707 Synth Guitar
Visionary Instruments TeleVision

12. Modern Times

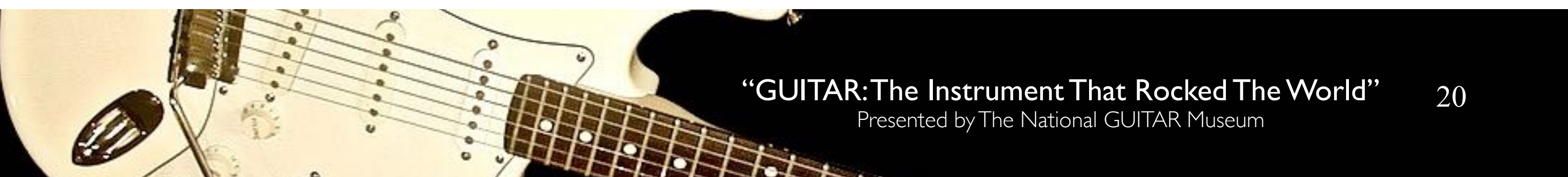
ODD 3D Printer Guitar
Ztar
Air Guitar
Guitar Hero/Rock Band Controller
Cochran Boostercaster

13. The World's Largest Playable Guitar

Certified by Guinness World Records. 43.5' long, 16' wide.

The following artists, manufacturers, luthiers, and collectors have provided instruments, information, and/or support to the collection:

Steve Vai • Joe Bonamassa • Liona Boyd • Vic Flick • Johnny Winter • Adrian Belew • C.F. Martin and Company • Fender Musical Instruments • Pete Prown • David Hill • Phantom Guitarworks • EKO • National Resophonic • The Electrical Guitar Company • Dan Larson • Rich Maloof • PRS Guitars • Danser Guitar Works • Visionary Instruments • Starr Labs • XOX • Cochran Guitars • Manuel Rodriguez Guitars • Hercules Stands



TUNE AMPS
 TUNE **AXE**
 TUNE DANGEROUS
 TUNE **WOOD**
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THE GUITAR IN ART



THE GUITAR IN ART

The guitar and its stringed ancestors have been a frequent subject of painters for hundreds of years. Some of history's most important classical and modern painters have featured the guitar in their paintings.

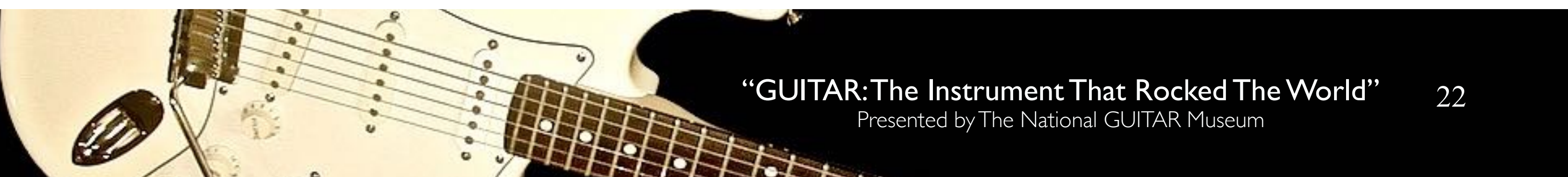


The Lute Player (c. 1596)

Michelangelo Merisi da Caravaggio

The famed Italian painter Caravaggio created three versions of this painting, showing a young boy playing a 14-stringed lute.

(Question: Can you identify this instrument inside the exhibition?)



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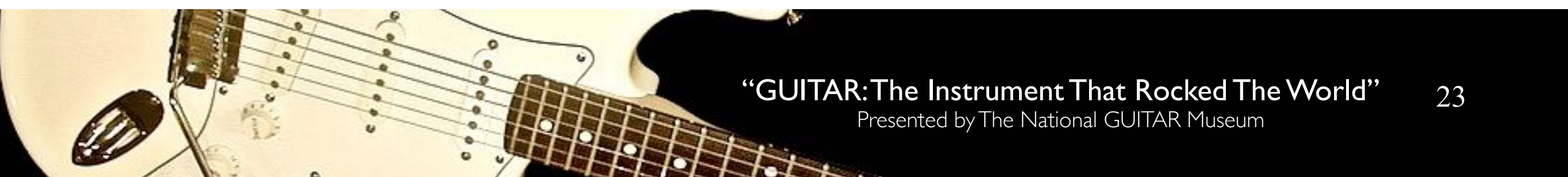


The Guitar Player (c. 1672)

Johannes Vermeer

The subject in Vermeer's work is playing a very ornate Baroque guitar. The picture is well known for its detail and the unique way in which the painter used light and shade.

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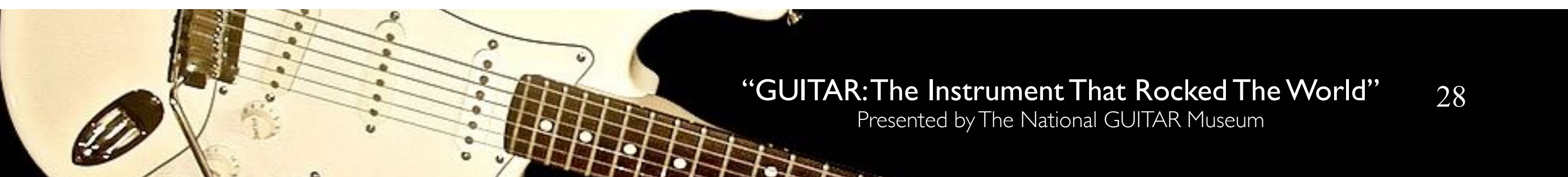


The Music Lesson (1870)

Edouard Manet

Manet was known for painting realistic scenes of the world around him. This painting is a self-portrait of Manet playing the guitar next to his wife.

(Question: Can you identify this instrument inside the exhibition?)



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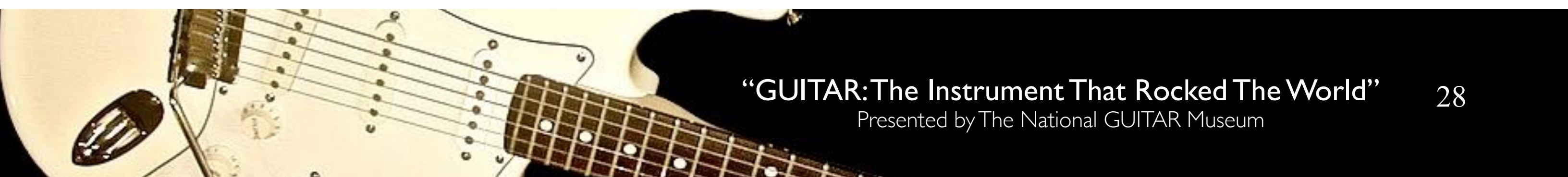


The Guitar Player (1894)

Paul Gauguin

The French post-Impressionist is known for his paintings of tropical themes, but he deviated here for a picture of a man playing a Romantic guitar.

(Question: Can you identify this instrument inside the exhibition?)



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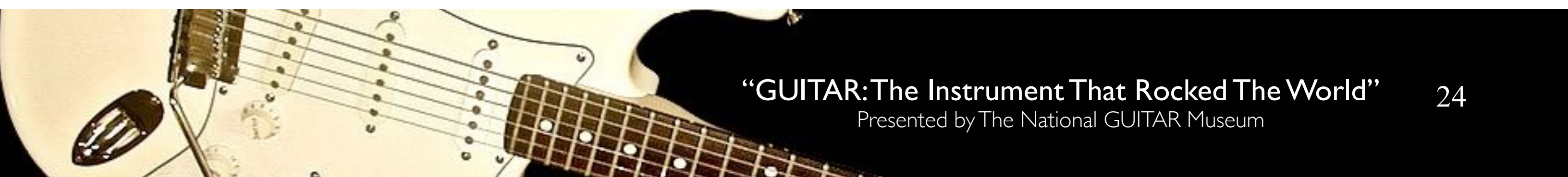


The Sleeping Gypsy (1897)

Henri Rousseau

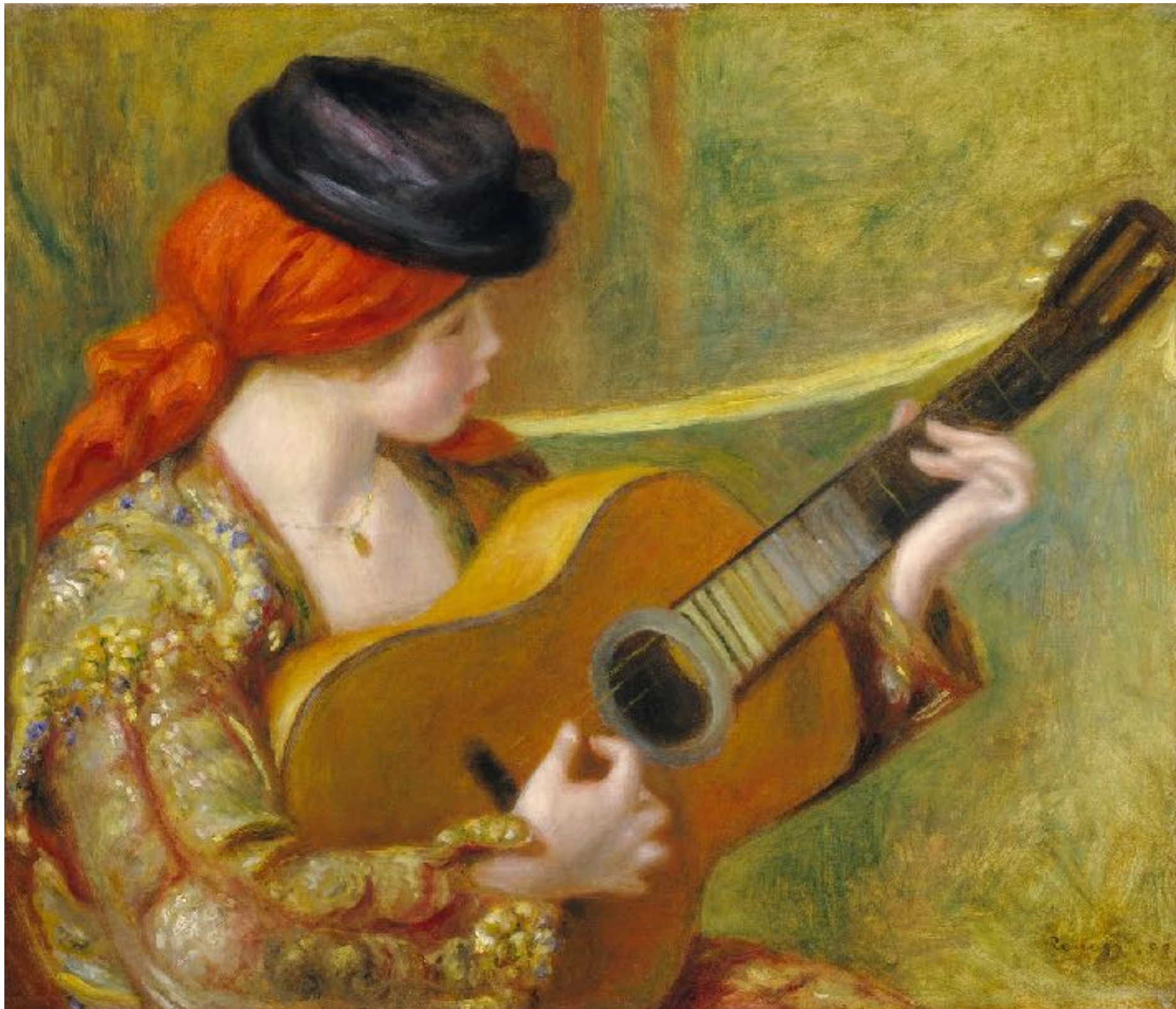
This painting of a gypsy asleep in the desert under a full moon is one of Rousseau's most famous. The gypsy has fallen asleep with her instrument tucked in next to her.

(Question: Can you identify this instrument inside the exhibition?)



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Young Spanish Woman With A Guitar
(1898)

Pierre-Auguste Renoir

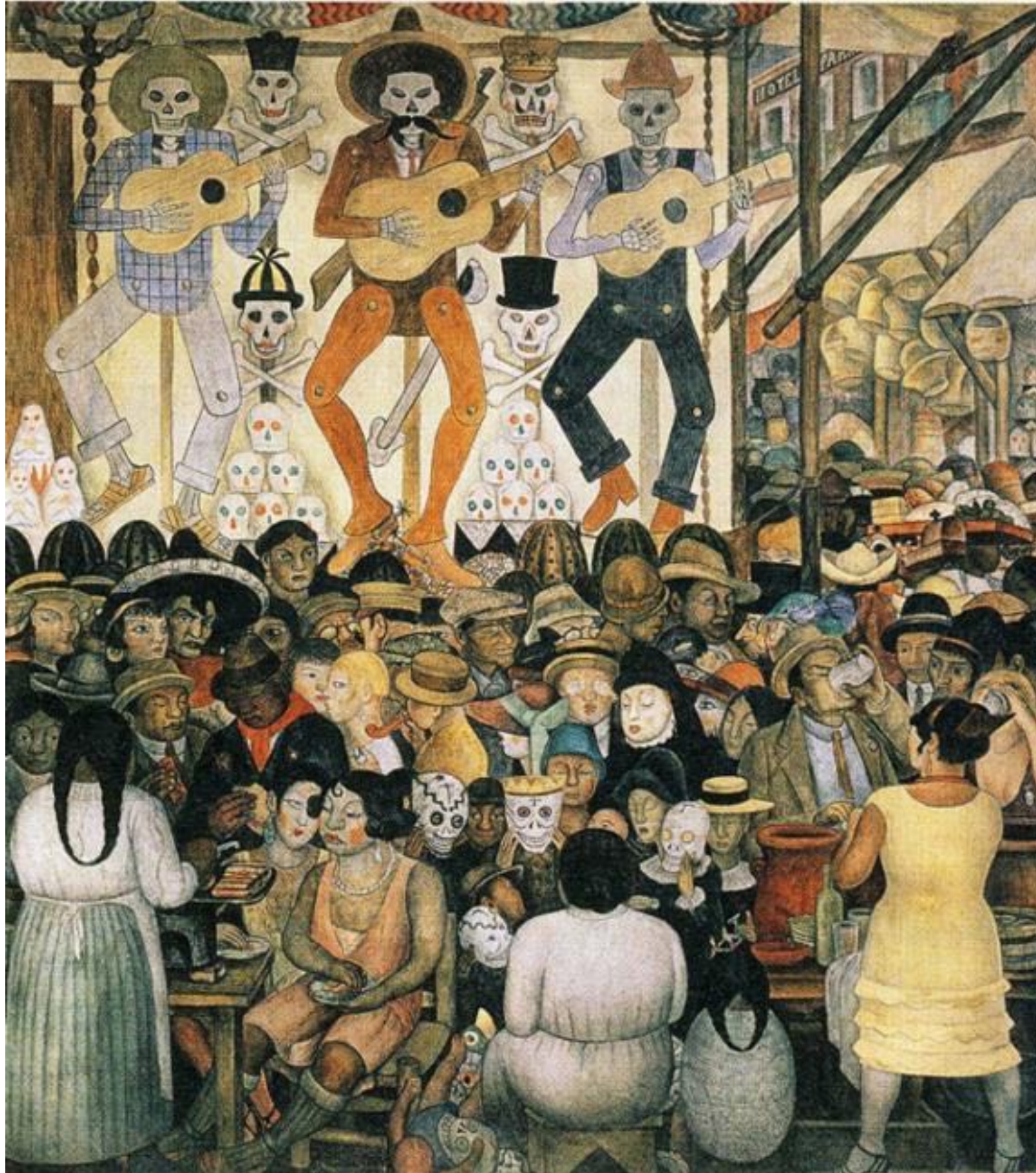
The French Impressionist, known for his scenes of Paris painted this portrait of a woman playing an early Spanish acoustic guitar.

(Question: Can you identify this instrument inside the exhibition?)



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Dia de los Muertos / Day Of The Dead
(1924)

Diego Rivera

Known for painting murals in big cities all over the world, Rivera was a Mexican painter who drew on his own culture for his work. The icons of the November 1st festival are seen playing guitars on a banner.

(Question: Can you identify this instrument inside the exhibition?)



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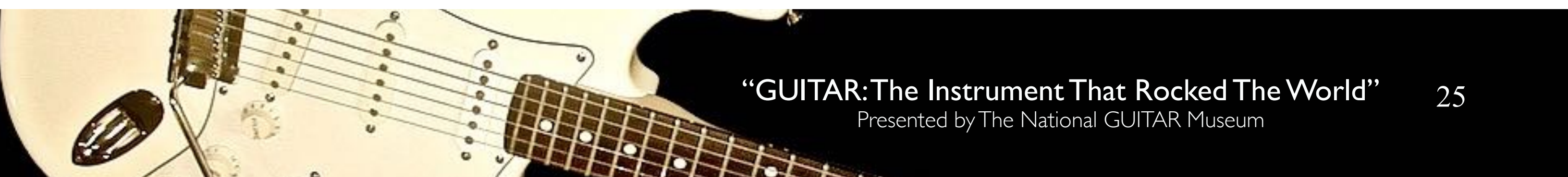


The Sources Of Country Music (1975)

Thomas Hart Benton

Benton's painting depicted life in America during the mid-1900s. This painting was designed for the Country Music Hall Of Fame and was his last work.

(Question: Can you identify this instrument inside the exhibition?)



THE GUITAR IN ART

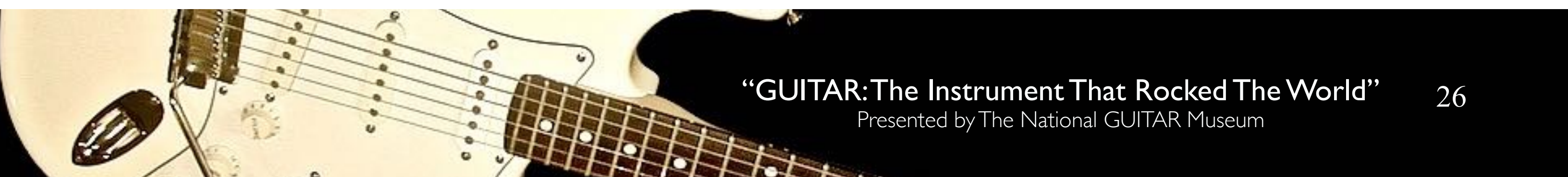
Pablo Picasso (1881–1973) created many abstract painting and sculptures featuring the guitar. This was due to the importance of the guitar in the music of his native Spain.

You can see how varied Picasso's approaches to the guitar were in the following images, which include paintings, collages, and paper sculpture.



The Old Guitarist, 1904
Painting

(Question: Can you identify this instrument inside the exhibition?)

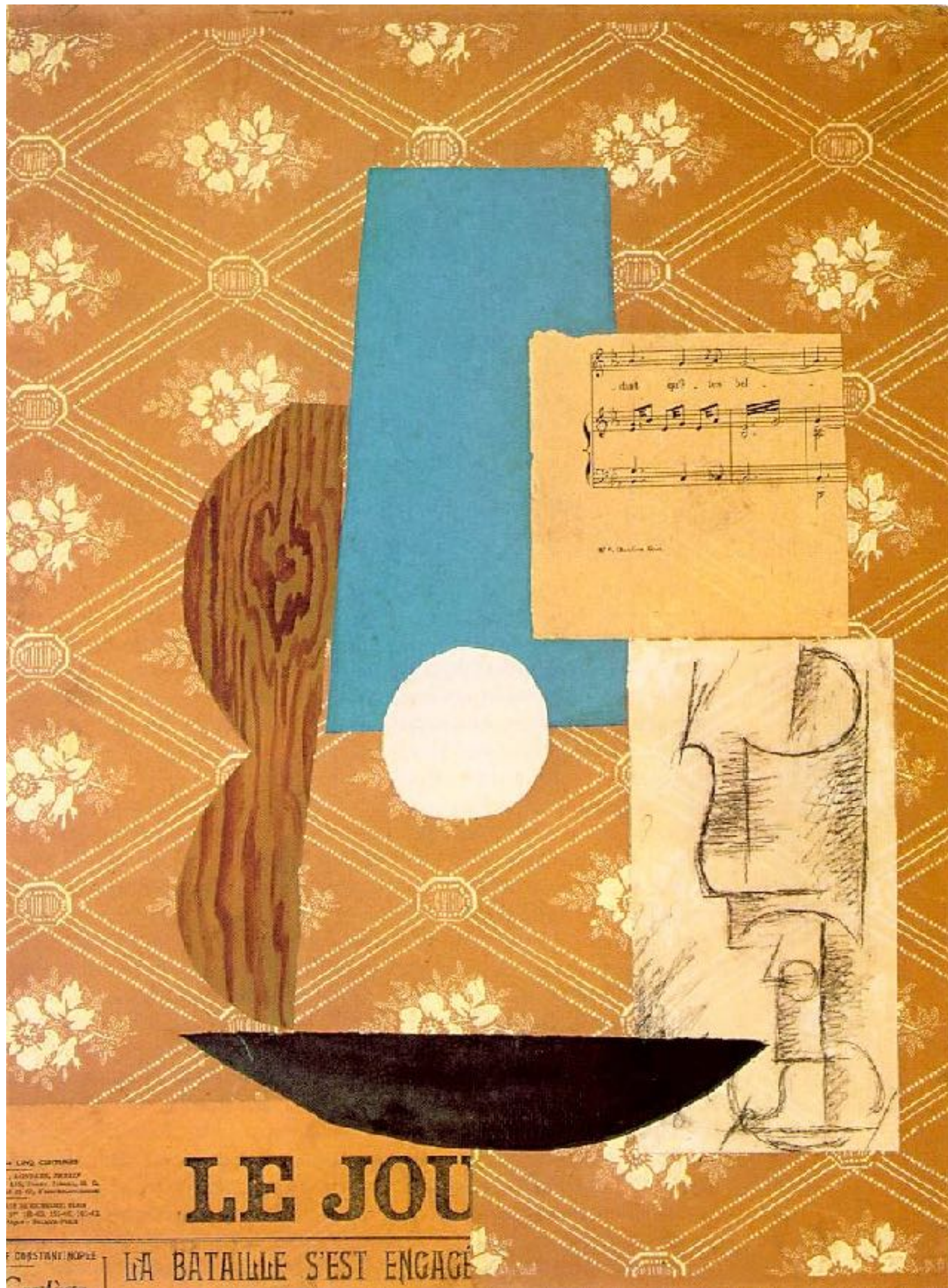


ART

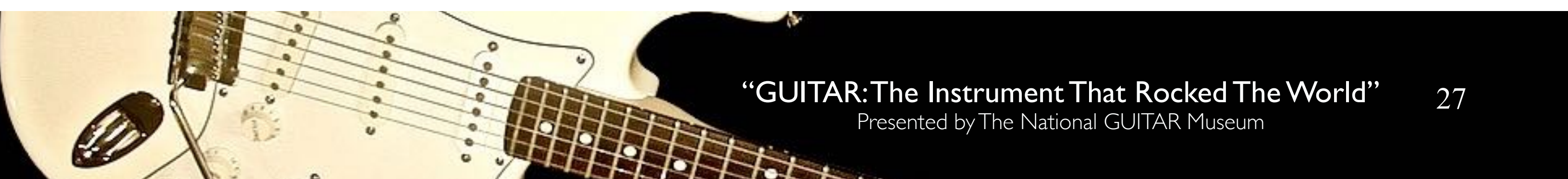
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Guitar, Sheet Music, Wine Glass (1912)
Collage

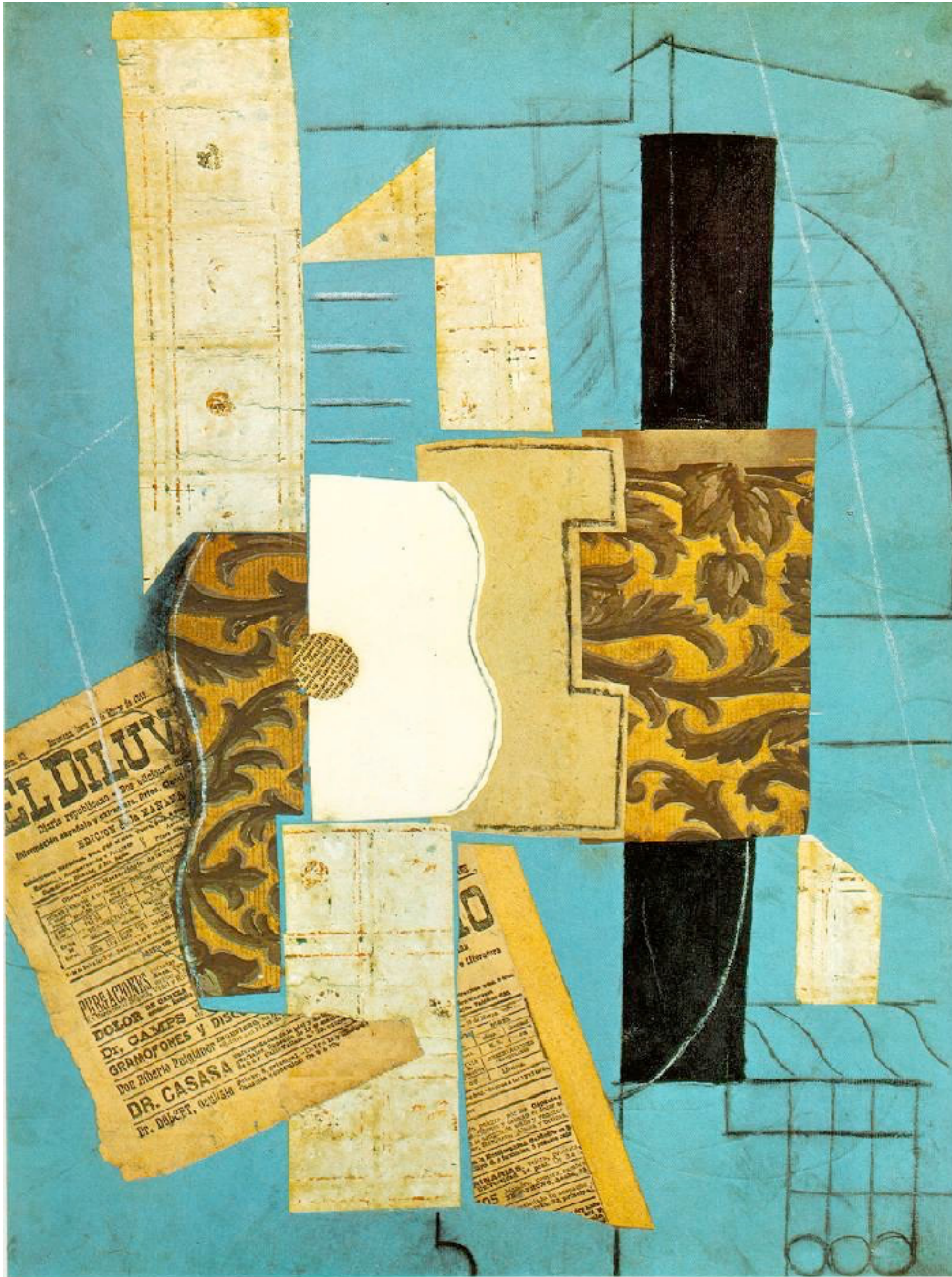


ART

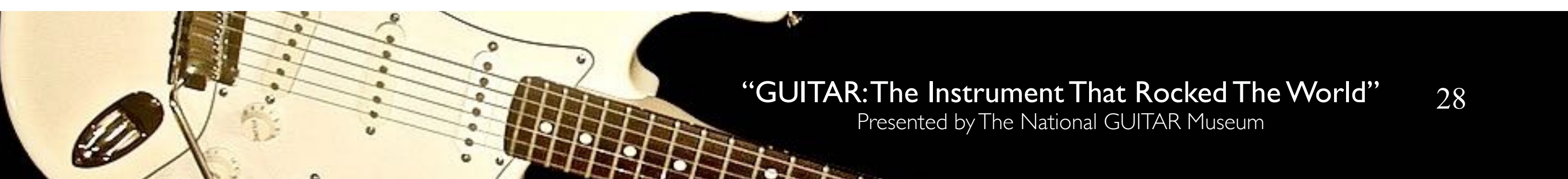
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Guitar, 1913
Collage



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Guitar, 1912
Sheet metal and wire



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INTERACTIVE DESCRIPTIONS



SOUND

WATCHING THE WAVES

The GUITAR STROBE is another INTERACTIVE you'll get to play with.

1) Spin the barrel.

Notice that the black and white lines on the barrel blur into gray.

2) Strum the strings.

Notice that the strings vibrate in waves. You can see the waves because the black strings stand out only against the white stripes on the barrel. Your eyes combine the individual images of the wave into a pattern that shows you the vibration, but in a slowed-down version.

3) Watch for different patterns.

Pulling the string harder does not change the number of waves per pull, but it does make them bigger. When the waves get bigger, the sound is louder.

The strings are tighter on the right side than they are on the left. Pluck each one individually and notice how these tighter strings vibrate more quickly than the ones on the right. There are more waves in each pluck. When the waves are more frequent, the pitch of the sound gets higher.

HOW IT WORKS

The barrel works like a strobe light, which is a light that flashes on and off very quickly. A strobe light makes things appear to move in slow motion because your eyes only see brief flashes of an object separated by periods of darkness. The flashing is so fast that it tricks your brain into putting all the flashes together to form a single continuous image, like a flip book or a movie. The same thing happens with the white lines; you can only see the black string against the white lines, which are like the flashes from a strobe.



SOUND

MEASURING SOUND

Sound is invisible, but it has physical properties. It moves in waves through the air, which creates air pressure. You hear things because your ears respond to this pressure.

Decibels are the units for measuring sound pressure, just like inches are units for measuring length. There is a decibel scale: the louder the sound, the higher the number of decibels. Zero decibels is the softest sound that can be heard, and 194 decibels is the loudest sound that can be created. Decibels are named after Alexander Graham Bell, the inventor of the telephone.

Decibels are determined by a very complicated mathematical formula, and not by addition. For instance, 10 decibels is not twice as loud as zero decibels – it is 10 times as loud. In the same way, 20 decibels is 10 times louder than 10 decibels. 30 decibels is 10 times louder than 20 decibels, and so on. Using this kind of math, a guitar amp cranked up all the way to 120 decibels is one million times louder than a normal conversation of 60 decibels ($10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000$).

Decibels change depending on how close something is. The headphones of an mp3 player can produce 100 dB because they're in your ear, which is like standing 20 feet away from a roaring motorcycle. If the motorcycle was in your ear, it would create more decibels than it does from far away.

Above 194 decibels, the waves generated from an energy source are no longer considered sound. Because the air is moving so fast and violently, these waves are huge blasts of energy known as shock waves. Volcanic eruptions, the most powerful energy blasts on earth, cause these types of waves.

The 1815 eruption of Mount Tambora, located in Indonesia, was heard over 1,600 miles away, or about the distance from New York City to Denver, Colorado. This is believed to have been the loudest sound ever heard by humans.

NOTES:

One-third of the total sonic power (loudness) of a 75-piece orchestra comes from the bass drum.

Guinness Book of Records no longer has a loudest band in the world because it was concerned with promoting a competition that could result in severe hearing loss.



SOUND

DECIBELS & THE STRENGTH OF SOUND

Decibel Levels

194+ Energy source creates shock waves instead of sound waves.

194 Loudest sound possible (volcanic eruption)

• At 190 decibels, your eardrums can rupture. Other internal organs can also become damaged after being exposed to this level of sound.

• At 180 decibels, the delicate tissue in your ear can become permanently impaired after a few seconds.

160 High powered racing dragsters

150 Trumpet blast, snare drums

140 Jet engine on takeoff

• At 140 decibels, short-term exposure of even a few minutes can cause permanent damage.

125-130 Loudest human scream, loud rock concert

125 Cymbal crash, jackhammer

120-125 Point at which ear pain begins, Threshold of pain

120 Guitar with amplifier at full volume, band practice, police siren, jet engine on runway

110 Power tools, chain saw, pounding on a bass drum

100 Motorcycle, snowmobile

• 95 decibels is the level at which continuous exposure of more than 15 minutes can cause hearing loss.

95 Subway train

90 Heavy trucks, buses in traffic, lawnmower

80 Loudly strummed acoustic guitar

70 Vacuum cleaner, radio

• At over 60 decibels sounds are categorized as loud, and in many cases, irritating.

60 Normal face-to-face conversation

50 General office noise, rainfall

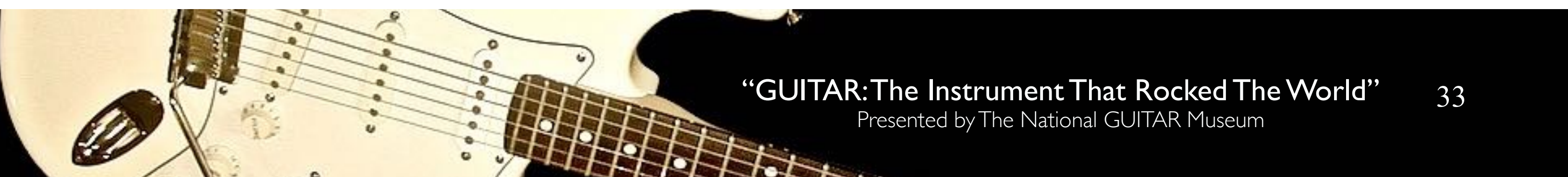
40 Refrigerator humming, a flowing stream, bird calls

30 Loud whispering

20 Mosquitoes, leaves rustling

10 Soft breathing

0 Softest sound that can be heard; below this nothing can be heard by humans



MEMORY

MUSIC & MEMORY

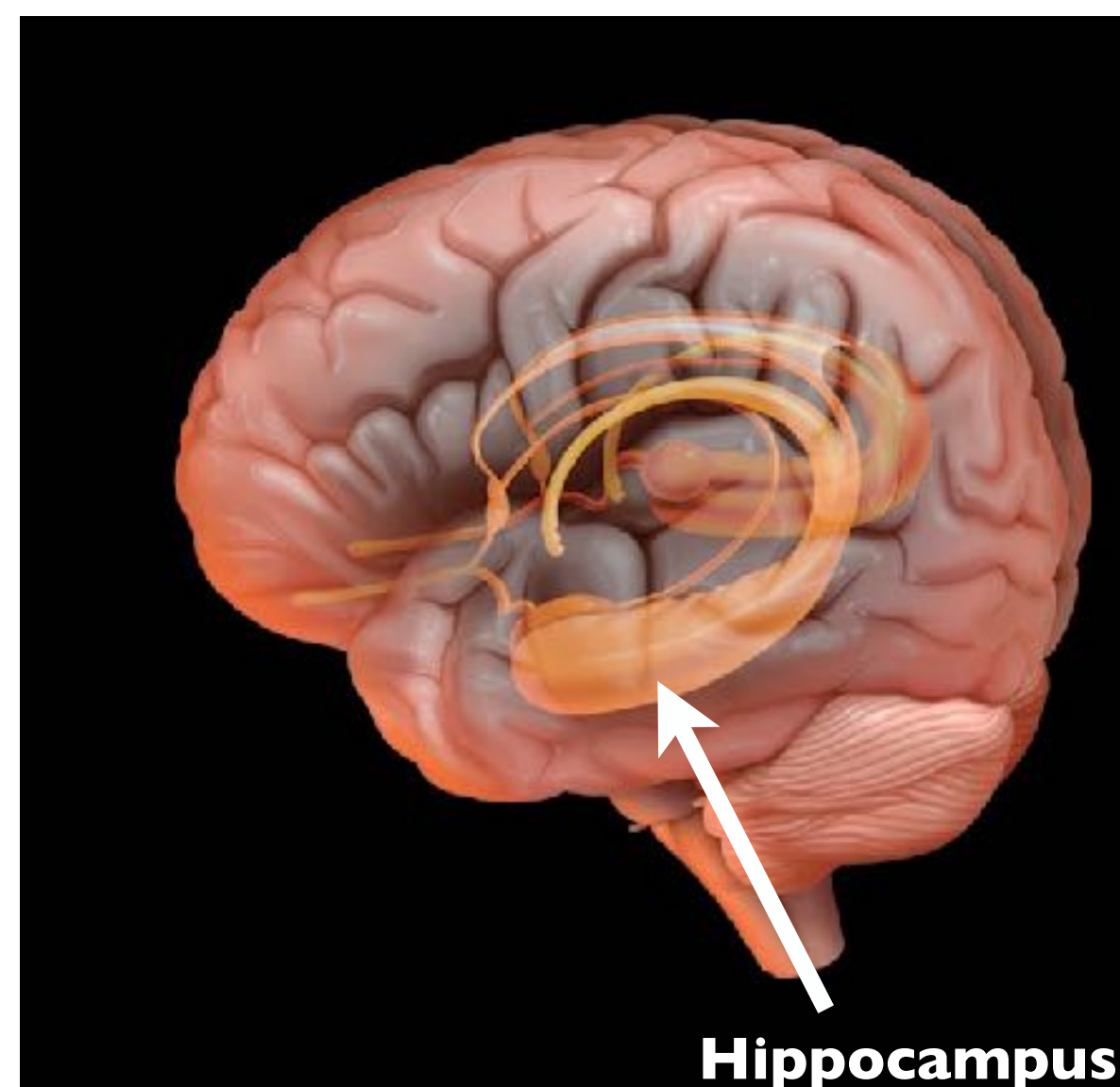
Short-term memory is the part of your thinking brain that holds on to information only as long as you need it. Trying to remember an address, or a phone number, or where you left your headphones are the kinds of information you only need to remember for a brief period of time . . . then you can forget about them. This information is processed by a section of your brain called the hippocampus, which determines which things you'll remember and those you'll soon forget.

Researchers have found that seven items (such as numbers, facts, letters) are about the maximum that most people can keep in their memory and hold on to. If there is much more than that, people usually can't hold all the information in their heads. Even better are groupings of two or three which people seem very able to hold onto for long periods of time, for instance The Three Little Pigs, The Three Bears, and The Three Blind Mice.

The exception to this is music. We can remember musical phrases that are much longer than seven notes. In fact, it's likely that you learned the alphabet as a toddler by singing the 26 notes of "the alphabet song." And, when you try to remember the alphabet today, you probably still hear that song playing in your head. The human brain is uniquely wired to remember musical patterns better than series of numbers and letters.

Much of popular music is built on riffs, which are groupings of notes that are repeated throughout a song. Riffs can range from two notes on up to dozens. Our mental ability to embrace musical patterns allows us to remember long riffs even when we wouldn't be able to remember that many numbers. Some guitarists learn—and memorize—hundreds upon hundreds of riffs in their lifetimes.

You will experience this with the Remember The Riff interactive, which tests your memory by asking you to listen to, and watch, a riff pattern . . . and then repeat it on your own.



STRINGS

MAKING TONES . . . WITH A STRING

The DIDDLEY BOW is one of the INTERACTIVES you'll encounter.

The diddley bow is a simple instrument with one string. It was originally used to teach children the basics of the guitar. It could be made out of basic materials found around the home or farm, notably wire and wood. The wire was screwed into the wood and then tightened to give it some tension. Instead of a fretboard and fingers, the player would slide a piece of metal pipe or glass tubing across the string to create notes.

The diddley bow here has a pickup built into it so that it is easier to hear.

1) Pluck the single string.

There is a single note that you will hear. This is the string's "open" note, or its natural pitch.

2) Press down gently on the string with the metal tube.

Pluck the string over the pickup with your other hand. It now has a different pitch.

3) Take the metal tube and move it along the length of the string while you pluck.

Notice that the longer the string is, the lower the notes. The shorter the string gets, the higher the notes get. This is just like playing the notes on a guitar, a violin, or a cello. When your hand is directly in the center, and the strings are equal length on either side, the sounds are exactly the same.

HOW IT WORKS

Stringed instruments use the shortening of strings to create individual notes. Every string starts out with a certain amount of tension that makes a particular note (this is called the "open string" note). By making the string shorter—you can't make it longer—in a series of movements, with the metal tube you can create the different notes that go up the scale. Remember that the shorter you make the string, the higher the notes get. Try moving the metal tube to make simple songs like "Happy Birthday" or "The Alphabet Song" on each string.



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ACTIVITIES FOR STUDENTS



STUDENT ACTIVITIES

Activity #1

Personal Phones

Overview: Students make phones using cups and string. They will learn how sound waves are produced when objects vibrate and in turn vibrate the air around them. This activity also shows how various materials—because of the way they vibrate—transport sound differently.

Materials: Plastic cups, tin or aluminum cans (with one end carefully removed), light wire, string; for phones. Foam pieces, paper towels, cloth/rags, marbles, or rubber pieces: for soundproofing options

Instructions: Students should pair up or divide into two groups. Push string or wire through holes in the bottom of the cups or cans. Tie knots on the ends of the string and wire to keep them from pulling through. Have the students then stand apart, pulling the cups or cans far enough to make the wire or string taut—but not so much that the string and wire threaten to pull out. Have the students conduct conversations, one speaking while the other listens. Try it first with Styrofoam and string, then with cans and wires.

Lesson: Sound energy travels as waves from the mouth to the bottom of the first cup. This makes the bottom of the cup vibrate. The vibrating cup then makes the string vibrate (in a back and forth motion) along its length. This vibration passes the entire length of the string from the first cup to the second cup. The bottom of the second cup vibrates and the air is directed through the cup to the listener's ear. The parts of the ear—including the eardrum—then “translate” the airwaves into sound.

Additional note: Tell students that sound travels quite far and quite clearly underwater because water molecules are more tightly packed than air molecules. Thus, the energy from sound passes easily from molecule to molecule rather than being dispersed in the spaces between air molecules. Too much density, such as in thick metal, can prevent the molecules from moving at all, which stops the sound abruptly.

Activity #2

Instructions (second activity with Personal Phones):

Have students place different materials into the cups or cans at different times. This includes crumpled paper towel, crumpled writing paper, cloth, foam, etc. Have them repeat the first activity. They should hear varying levels of dampening, or possibly complete obstruction, of the sound in their cups and cans. Have students rate which materials allow the most sound to pass through, and those which block the most sound. Guess why paper is not as useful as foam for soundproofing.

Lesson: Since sound is made of airwaves, it can be affected by obstacles. This is especially true of obstacles that absorb the vibrations without passing them on. Soundproofing in noisy areas is accomplished by using materials that absorb the most vibrations. Paper, for instance, is too thin to block the vibrations and they pass through easily. However, when paper is crumpled into a tight ball, it has more density and internal surfaces to block and absorb the vibrations. Very hard materials like marbles will allow the vibrations to bounce off of them and continue on their way.

STUDENT ACTIVITIES

Activity #3

Making Waves

Overview: Sound waves are longitudinal waves which means they move in a direction that is parallel to the sound source. Basically this means they move in one direction outward from the sound source.

Materials: Jump rope at least 8 feet in length, shallow but wide pan (like a pie plate) or tray filled with water.

Instructions: Students can see the shape of waves by flicking a length of rope (a long jump rope will work). Have two students hold a rope, one on each end, and instruct one person to flick his or her hand up and down—once—very quickly. The movement results in a sine wave that travels the length of the rope from end to the other.

Next, in a wide pan or tray, fill water to near the top. Have students tap their fingers into the middle of the water to create ripples. These ripples are waves created by the energy of the fingers hitting the surface of the water at primarily a right angle.

Lesson: Longitudinal waves move in one direction, which is how sound waves move. A different kind of wave is a transverse wave, in which waves move in a perpendicular direction to the energy source. The most obvious of these is a ripple in a pond. While it appears that this would only be a transverse wave, longitudinal waves are also generated down from the point of impact.

STUDENT ACTIVITIES

Activity #4

Focusing The Waves

Overview: Sound waves get broken up easily in the air by interfering waves from other sources. Focusing the waves can strengthen them and propel them farther . . . which makes them louder.

Materials: Paper sheets or thin cardboard.

Instructions: Roll three sheets of paper into a cone to make a simple megaphone. (Three sheets helps strengthen the cone and deflect the waves. Note that a single sheet might not work so well because the paper is so thin that it allows the air waves to pass through instead of deflecting and focusing them.)

Students should stand 10 feet apart from a partner. Have them speak normally to each other with their regular voices, all at the same time. The students will notice crosstalk, or the interruption of their voices by their neighbors' voices. Then have the students use the paper megaphones, still speaking at a normal volume. Students should note the increased volume and clarity of their partners' voices.

Lesson: The speakers that push air from a stereo or guitar amplifier are designed in a roughly conical shape in order to concentrate the sound. For the human voice, we can use something similar, such as a megaphone. The conical shape of a megaphone keeps the air leaving our mouths from scattering to the side and directs it powerfully in a specific direction. The megaphone also keeps these air waves leaving our mouth from immediately getting broken up by interfering air waves, such as those that come from other voices or nearby sounds.

STUDENT ACTIVITIES

Activity #5

Decibels: What They Are

Overview: A decibel is a unit for expressing the relative intensity of sounds, which is caused by how much pressure they exert. Decibels are measured on a scale from zero for the least perceptible sound to about 130 for the sounds that cause pain in the ears. Decibel levels are determined by very complex equations.

Materials: Found objects in the classroom, images from the page after next.

Instructions: Ask students if they know what a decibel is. Provide the definition from above and then cite two or three examples from below.

There are specific sounds found on the touchscreen interactive called "It Might Get Loud." The images from the touchscreens are also attached on the following page. Print out the images and ask students to sort them in order from lowest decibel level to highest decibel level. Have the group vote on what they think the order should be. After several minutes, the teacher/facilitator will review the order using the following scale:

- 194+ Energy source creates shock waves instead of sound waves.
- 194 Loudest sound possible (volcanic eruption)
 - At 190 decibels, your eardrums can rupture. Other internal organs can also become damaged after being exposed to this level of sound.
 - At 180 decibels, the delicate tissue in your ear can become permanently impaired after a few seconds.
- 160 High powered racing dragsters
- 150 Trumpet blast, snare drums
- 140 Jet engine on takeoff
 - At 140 decibels, short-term exposure of even a few minutes can cause permanent damage
- 125-130 Loudest human scream, loud rock concert
- 125 Cymbal crash, jackhammer
- 120-125 Point at which ear pain begins, Threshold of pain
- 120 Guitar with amplifier turned to full volume, band practice, police siren, jet engine on runway
- 110 Power tools, chain saw, pounding on a bass drum
- 100 Motorcycle, snowmobile
 - 95 decibels is the level at which continuous exposure of more than 15 minutes can cause hearing loss
- 95 Subway train
- 90 Heavy trucks, buses in traffic, lawnmower
- 80 Loudly strummed acoustic guitar
- 70 Vacuum cleaner, radio
 - At over 60 decibels sounds are categorized as loud, and in many cases, irritating.
- 60 Normal face-to-face conversation
- 50 General office noise, rainfall
- 40 Refrigerator humming, a flowing stream, bird calls
- 30 Loud whispering
- 20 Mosquitoes, leaves rustling
- 10 Soft breathing
- 0 Softest sound that can be heard; below this nothing can be heard by humans

STUDENT ACTIVITIES

Estimate the decibel level of different sounds in the classroom: whispering, shouting, conversation, dropping a book on the floor, stamping feet on the floor, etc.

Lesson: Sound is invisible, but it has physical properties. It moves in waves through the air, which creates air pressure. You hear things because your ears respond to this pressure.

Additional Notes: Decibels are named after Alexander Graham Bell, the inventor of the telephone.

Decibels change depending on how close something is. The headphones of an mp3 player can produce 100 dB because they're in your ear, which is like standing 20 feet away from a roaring motorcycle. If the motorcycle was right next to your ear, it would create more decibels than it does from far away, possibly over 150 decibels.

Above 194 decibels, the waves generated from an energy source are no longer considered sound. Because the air is moving so fast and violently, these waves are huge blasts of energy known as shock waves. Volcanic eruptions, the most powerful energy blasts on earth, cause these types of waves. The 1815 eruption of Mount Tambora, located in Indonesia, was heard over 1,600 miles away, or about the distance from New York City to Denver, Colorado. This is believed to have been the loudest sound ever heard by humans.

Activity #6

Determining Loudness

Overview: Decibel levels, the measure of how loud something is, change due to how near or far the source of a sound is.

Materials: Hands, paper megaphones.

Instructions: To demonstrate varying degrees of loudness, have a student clap his or her hands close to the side of another student's head. Now have them go across the room and clap their hands again. The sound is not nearly so loud.

Have them whisper to a partner from a few feet away. Then have them whisper through the megaphones constructed earlier. The sound is amplified.

Lesson: As sound waves move through the air, they become weaker. The farther away the sound source is, the farther the sound waves have to travel to reach the ear, and the weaker the pressure of the air on eardrums. Artificial devices like megaphones and amplifiers give sound waves an added boost that keeps them focused so they don't deteriorate so quickly as they move through the air.

STUDENT ACTIVITIES



Mosquito



Acoustic Guitar



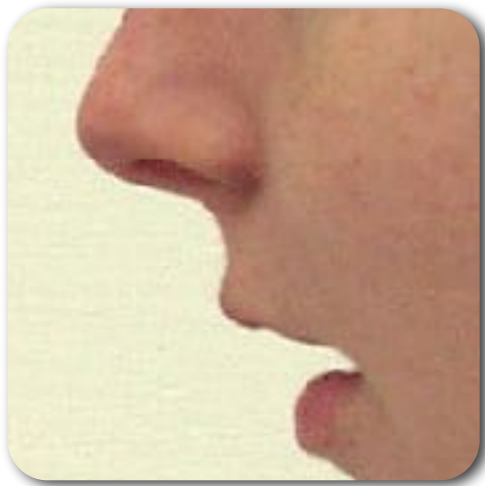
Siren



Whisper



Dragster



Breathing



Subway Train



Jackhammer



Volcano



Electric Guitar



Conversation



Rain



Rock Concert



Vacuum Cleaner



Traffic



Motorcycle



Scream



Birds



Chainsaw



Jet Engines

STUDENT ACTIVITIES

Activity #7

Cutting The Frequency

Overview: Waves vibrate at different frequencies depending on their lengths. Shortening the length increases the number of vibrations and causes higher frequencies.

Materials: Rubber band or string, tape, short length of wood or cardboard (less than 12 inches).

Instructions: Cut a notch in both ends of the wood or cardboard. Fasten the string or rubber band in the notch, making it taut. If you can't make a notch, attach the string with tape or a stapler.

Ensure that the string is tight enough to create a sound when plucked with a finger. Have students pluck the string with their right index finger. Then have them “fret” or hold down the string at different points with their left index finger. Note that the string has a different pitch depending on where the left hand finger is placed. Have the students try different notes on the string to play a simple tune.

Lesson: Strings vibrate at a set frequency until they are fretted. Fretting a string changes the length of a string because a player's finger creates a new “stop” point that keeps the string from vibrating any further than that point. When a string is fretted, the shorter length of the string vibrates at a higher frequency than it usually does, creating a higher pitch.

Guitars have metal frets built into the fretboard that define where certain notes can be sounded, while violins do not have any frets. Violinists memorize the placement of their fingers along the fretboard to get the correct note.

Activity #8

Instructions (second activity with wave frequencies): To show that waves can be mathematically divided using a strict scale (like on a guitar fretboard), use a ruler to find the halfway point of the string. Have the students press their fingers down at the point—and then pluck on either side. It will be the same pitch on both sides, but the pitch will also be the same note as the “unfretted” string, only one octave higher.

Lesson: When a string is fretted at the halfway point, it doubles the frequency of the string. Doubling the frequency increases the pitch by an octave. Each octave on a scale is double the frequency of the previous octave.

STUDENT ACTIVITIES

Activity #9

What Makes Music?

Overview: Sounds in all instrument families are made by vibrations. There are four types of musical instruments:

- Idiophones are instruments that make sound by vibrating the instrument itself. Examples: Wood block, triangle, bells.
- Membranophones cause a vibration on a stretched membrane. Examples: snare drums, bass drums, drums with heads.
- Aerophones cause the air inside the instrument or around the instrument to vibrate and create sound. Examples: horns, trumpets, trombones, flutes, clarinets.
- Chordophones make sound because of the vibration of chords or strings. Examples: guitars, banjos, mandolins, pianos, harps.

Materials: Found and household objects, such as soda bottles, PVC pipe, water jugs, film canisters, coffee cans, balloons, glass bottles, turkey baster and discarded pieces of wood.

Instructions: Create simple instruments using the found objects. Fill the bottles with water or sand to different levels. Demonstrate how each object can produce a sound by blowing on it, tapping it, and slightly modifying it. Have students blow across the top of an empty soda bottle and blow into different lengths of PVC pipe. Fill the soda bottles or glasses with water of varying levels and then tap them to hear the difference. Bang on different solid and semi-solid objects like wood, chairs, cushions, pipes, books, and boxes to hear the difference in the tone and volume they produce.

Lesson: Musical instruments have a long history and most of them evolved from found objects like hollow branches and logs, gourds, bones, vines, water reeds, and the shells of dead animals. The random objects used for this activity are similar in their simplicity to the items that were used as some of the earliest musical instruments.

All musical instruments make unique sounds because of the way they vibrate when energy is applied to them. Drums are struck with solid objects, guitar strings are plucked, flutes are breathed into, etc. Beyond that, each object or instrument has a “resonant frequency” that is specific to that instrument. This resonant frequency is created because of the structure and design of the instrument, and the resulting sound waves are distinct from other instruments. It’s the shape and size of a saxophone that makes it sound different than a bugle, for instance, or why a ukulele sounds different than a cello.

STUDENT ACTIVITIES

Activity #10

Tuning An Instrument

Overview: Every instrument is constructed so that it can produce specific notes. This involves elements that make the instrument vibrate at different frequencies, such as holes in a flute and strings on a guitar.

Materials: 8 identical glasses or empty soda bottles, water, filling or measuring cup, spoon. A toy xylophone if available.

Instructions: Fill each glass with a different amount of water. Then tap the glasses with a spoon to hear the different pitch that each one makes. If possible, see if the pitches from the glasses correspond to any of the notes on the toy xylophone.

Ask the students to predict whether adding or taking away water will make the pitch higher or lower. Adjust the amount of water in each glass so that all 8 approximate the pitches of “do re mi fa so la ti do.” Have students attempt to play a simple tune on the glasses.

Lesson: Objects vibrate based on their design and structure. Adding water to a glass changes the glass’s ability to vibrate throughout its structure. When the glass is empty, the entire structure vibrates when it is tapped. As water is added, less of the glass is able to vibrate freely. Fewer vibrations mean that the frequency is lower, which produces a lower pitch. When the glass is almost full, the vibrations of the glass are about as low as they can go.

Adjusting the level of water adjusts the frequencies produced by the glass. This is the same as covering the holes on a flute, or fretting the strings on a guitar.

STUDENT ACTIVITIES

Activity # 11

The Ear Drum

Overview: The human ear is composed of a number of small parts that react to the pressure from sound waves. These parts work together to create signals that the brain interprets as sound.

Materials: Large mixing-style bowl, two dozen or more grains of uncooked rice, plastic wrap, large rubber band, metal cooking sheet.

Instructions: Stretch the plastic wrap tight across the opening of the large bowl. Hold it in place by pulling the rubber band around the mouth of the bowl. Place twenty or more grains of rice on top of the plastic wrap. In this example, the rice represents small elements in the ear such as the anvil and stirrup, and the shrink wrap is the delicate membrane known as the eardrum.

Have a student place the cookie sheet right next to the bowl and hit it with his or her hand to make a loud noise. The vibrations from the cookie sheet will hit the “membrane” and cause it to vibrate, which will bounce the rice around.

Have other students shout next to the bowl, or clap their hands, or even whistle and snap their fingers to see how gently or violently the rice reacts.

Lesson: Sound waves enter the ear and vibrate the eardrum (the tympanic membrane) and small bones (the anvil and stirrup). The eardrum and the anvil and stirrup pass the vibrations into the inner ear where nerve endings are stimulated and transmit signals to the brain that it interprets as sound.

Note that the louder the noise, the more the rice jumps. This is an example of the effects that loud music and explosive sounds can have on the ear. Too much exposure to loud noise damages the ear—almost as if the rice were bounced around so much as to leap off the shrink wrap.

STUDENT ACTIVITIES

Activity #12

Moving The Sound

Overview: Sound waves move through the air and water—and other objects—at different speeds.

Materials: Tuning forks of different sizes (at least two), rubber mallet, two shallow pans or trays of water, water, corn oil.

Instructions: Strike the tuning forks with a rubber mallet (or the sole of a sneaker or a plastic spatula—hitting the forks against a hard surface like a tabletop can crack them) to get them vibrating. Note how—even though they are the same shape—the forks create different pitches. Ask the students to determine why this is the case.

Next, fill one shallow pan with water; the other with a thick liquid like corn syrup. Have students strike one of the tuning forks again, and quickly touch it to the surface of the water. Watch the vibrations and make note of their general speed and size. Once the ripples have stopped, use another tuning fork and repeat the procedure. Have students identify the differences. After wiping off the tuning forks, repeat the entire process with the pan of corn oil. Watch how the waves are different in this liquid than in the water.

Lesson: The bigger the tuning fork, the lower its frequency and lower its pitch. When touching the larger fork to the water, bigger vibrations resulted than when the smaller fork was used.

The corn oil pan produced slower moving waves because it is more dense than the water. It takes more energy from the forks to push vibrations across the molecules in the corn oil than it does in water. More energy is spent just moving the initial molecules so there is less movement overall than in the water. This also causes the energy to dissipate faster in the corn oil, so the waves don't travel as far.

STUDENT ACTIVITIES

Activity #13

Seeing The Sound

Overview: Sounds produce very specific waves that can be interpreted as visual waves using an oscilloscope.

Materials: PVC pipe or metal soup can , duct or masking tape, balloon, rubber band, small mirror (no more than an inch wide), glue, LED penlight or small pen laser.

Instructions: Note: requires prep time to let glue dry.

Use either a short six-inch length of two-inch (2") wide PVC pipe or a soup can (If using a can, carefully cut the ends out using a can opener and cover the remaining edges with masking tape for safety.) Cut the neck off of a balloon and stretch the remaining section of the balloon over one end of the pipe or can—leaving the other end open. Secure the balloon in place with a rubber band. Attach a small mirror to the balloon-covered end of the tube with glue and let it dry. Now there is a tube with a balloon with a mirror covering one end, and the other end is open.

Have students work in pairs. Instruct them to stand in a dark area next to a wall, or a wall with a dark surface(the darker the lighting, the better). Instruct one of the students to face the wall and talk into the open end of the can, with the balloon and mirror end out towards the wall. Instruct the partner to shine the penlight or pen laser onto the mirror so that it is bounced back to the dark wall. The shape of the waves should be visible on the wall. Watch how the vibrations change when the speaker uses a deeper or higher-pitched voice. Try using other sounds with the tube (like whistling, or a harmonica, if available).

Lesson: The sound waves created by speaking into the tube cause the balloon to vibrate. The mirror vibrates on the balloon, so the light bouncing off the mirror shows the exact manner in which the mirror and balloon are vibrating. All of those vibrations are caused by sound waves from the student's voice. Oscilloscopes are devices that measure waves and provide a visual interpretation of those waves. Oscilloscopes are regularly used by scientists and engineers to view the vibrations coming from machines and other devices.

TUNE AMPS
 TUNE **AXE**
 TUNE DANGEROUS
 TUNE **WOOD**
 TUNE HISTORY
 TUNE **LOUD**
 TUNE **SCIENCE**
 CUTAWAY
PUNK
 DREADNOUGHT
 AMPLIFIERS
POP
 POWER
 EFFECTS
PICK
 FINGERBOARD
 6 STRING
SOUND
 ARCHTOP
BLUES
STEEL
 DISTORTION
SOLO
 RHYTHM
NECK
 12 STRING
 POWER
 FRETS
 DREADNOUGHT
SHRED
 CLASSICAL
 FLAT PICK
HARD
 STRINGS
 SCIENCE
 AMP PICKUPS
JAZZ
 AXE MUSICIANS
 HISTORY
FOLK
 COUNTRY
METAL
ROCK & ROLL
 SOLIDBODY
 MELODIC
ICONIC
INVENTORS
MUSICIANS
GUITAR:
THE INSTRUMENT THAT
ROCKED THE WORLD
REVOLUTIONARY
ELECTRIC
HOLLOWBODY
BLUEGRASS
MAGNETIC
 HISTORY

DRAWING ACTIVITIES

(Varying age levels)



DRAWING ACTIVITIES (All Ages)

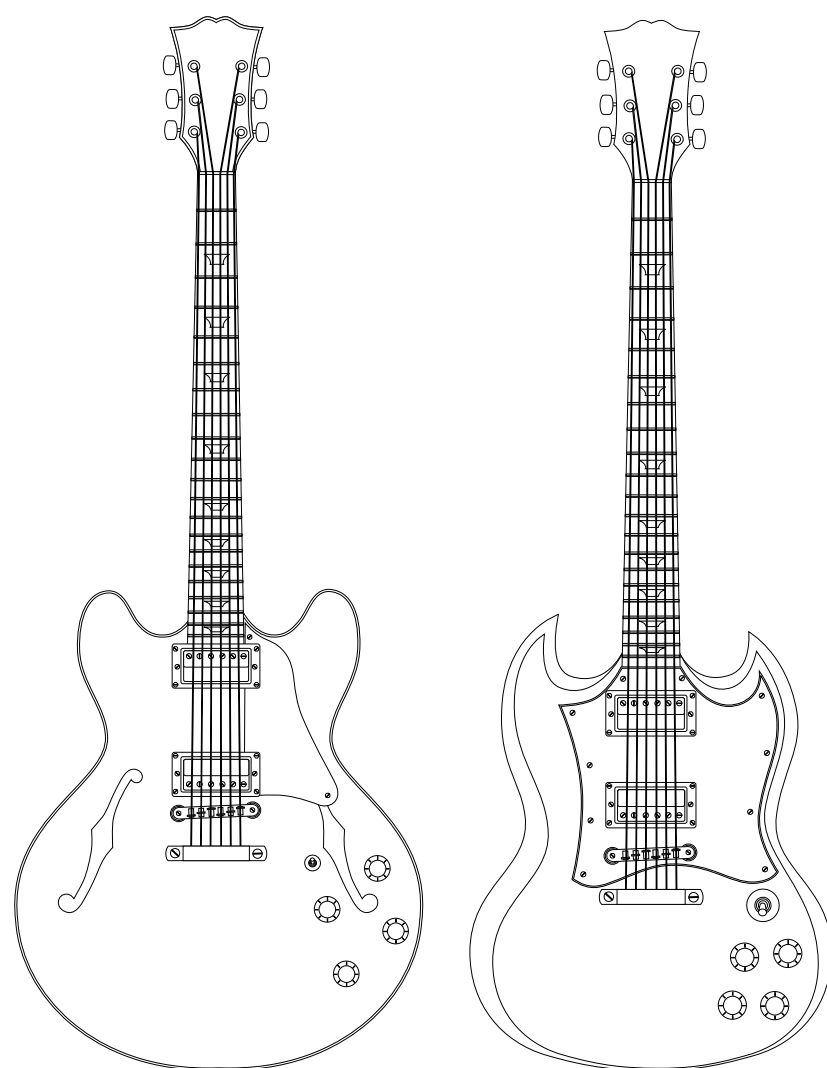
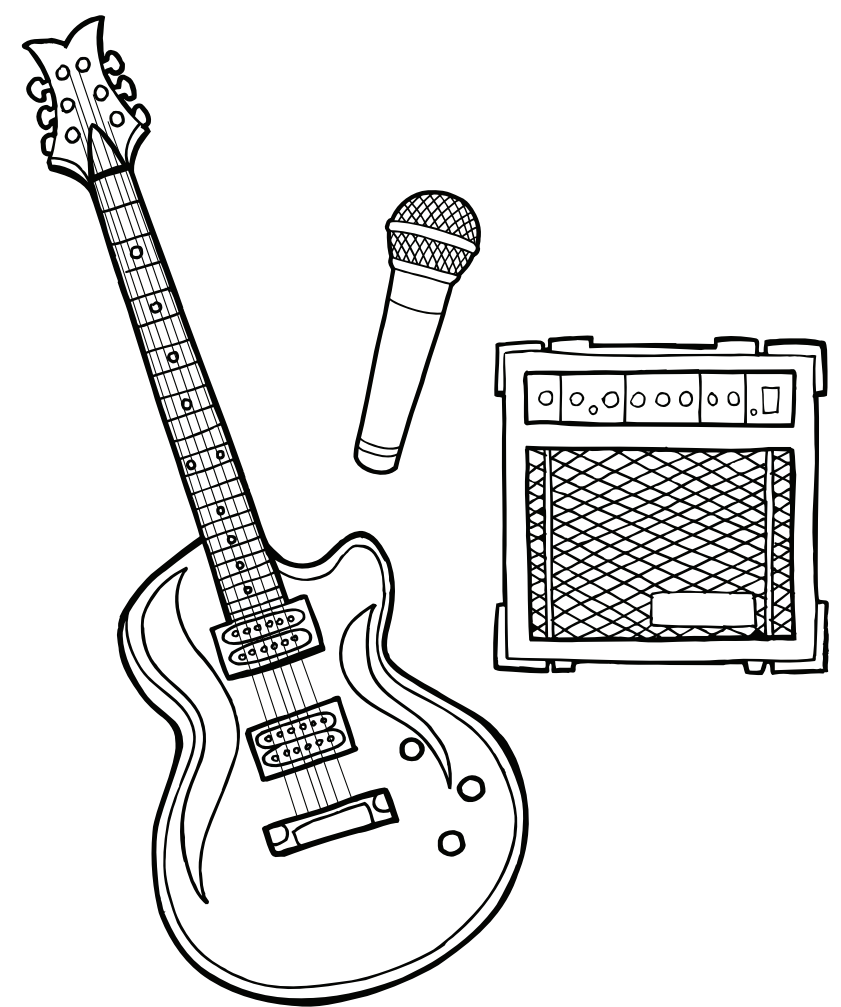
Playtime and Creative Drawing

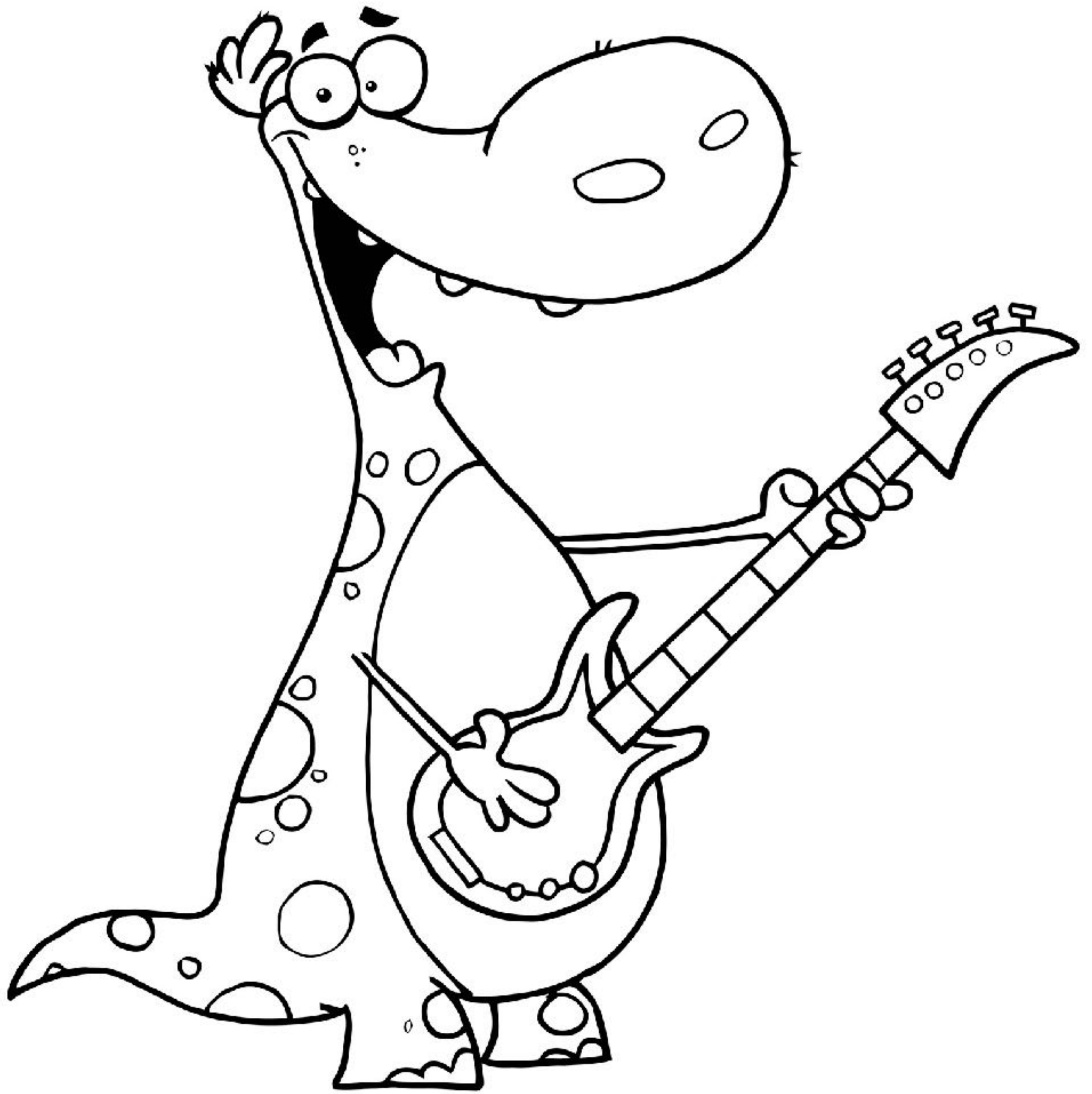
The following pages contain images that can be printed out and colored in by children of all ages. They are all in black and white and do not require a color printer.

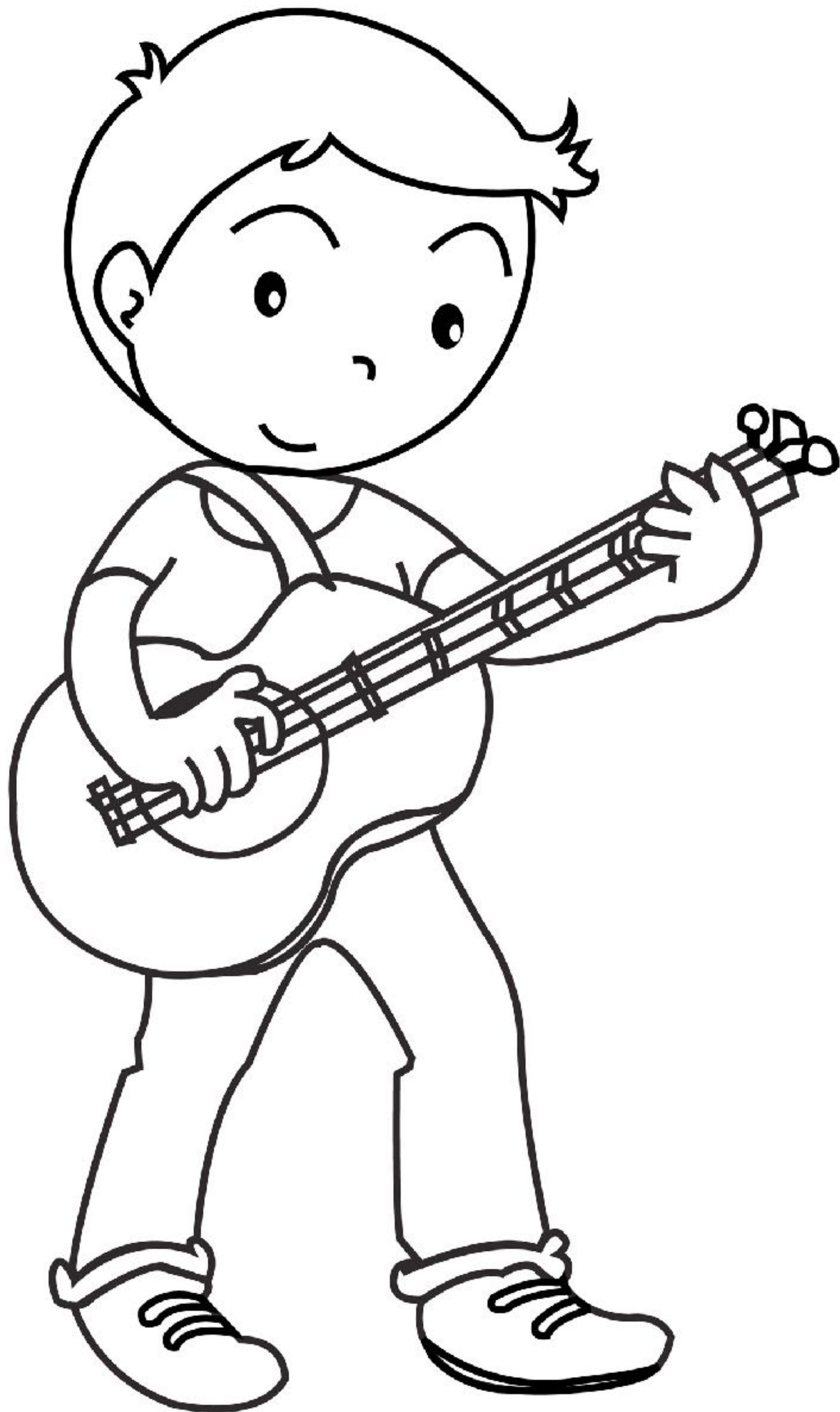
Some are simple cartoon drawings while others are very precise instrument outlines that allow children to create the designs for their own guitars. These images can be printed out as necessary. They have no copyright attachment so they may be used for a variety of activities.

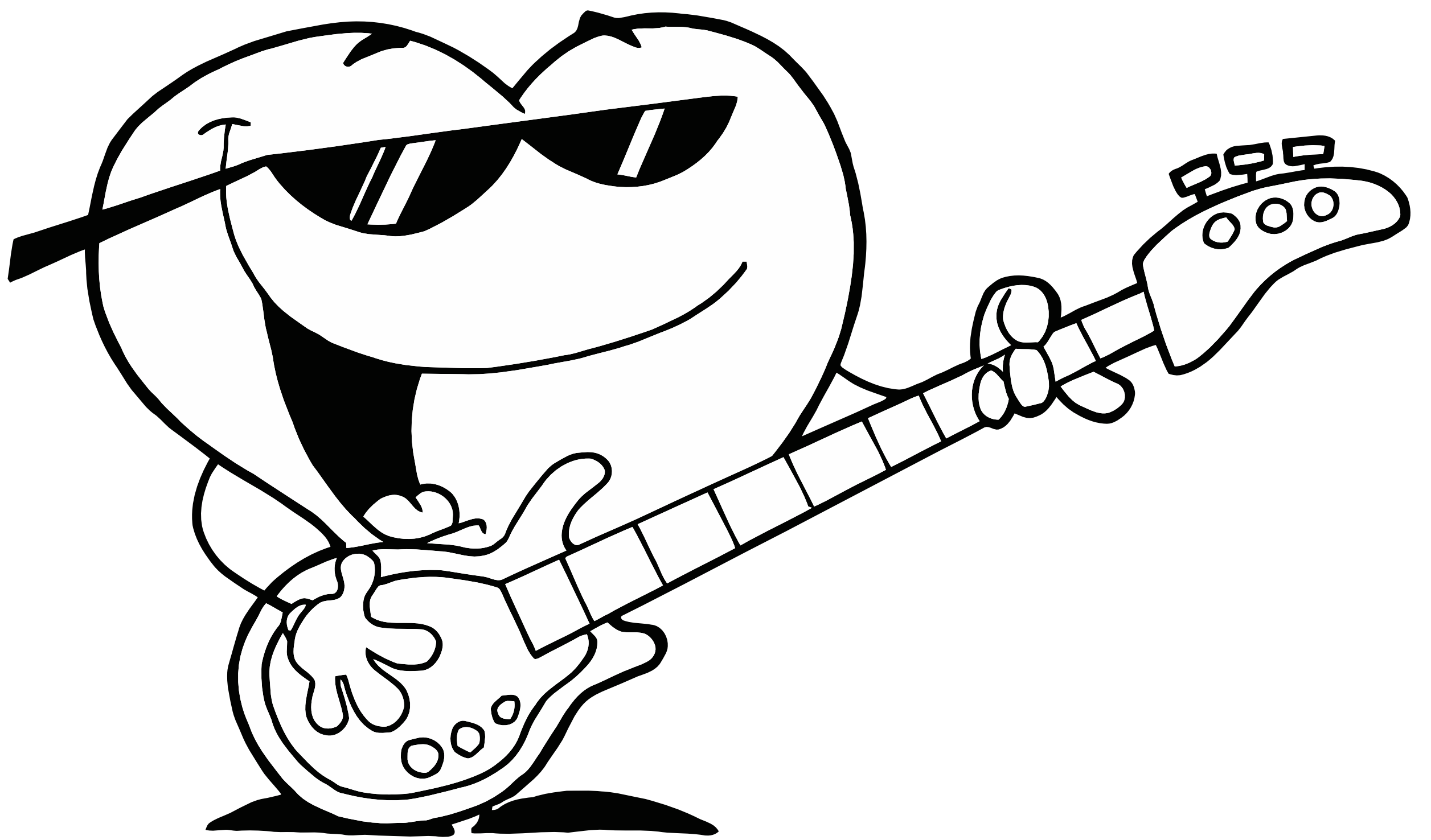
Crayons, colored pencils, or thin non-toxic markers are recommended.

Pages can be printed out from Pages 51-61 on your printer.

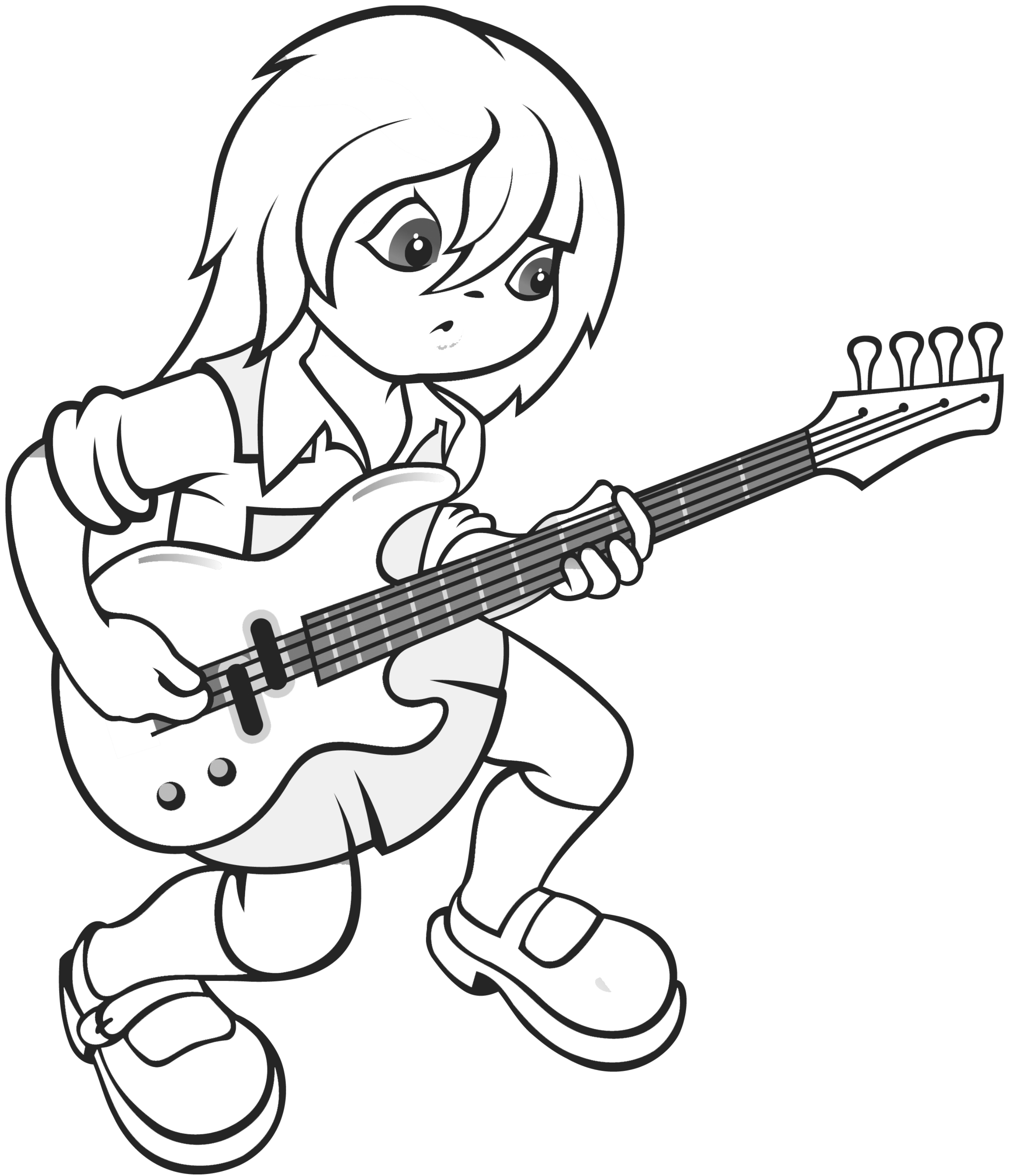




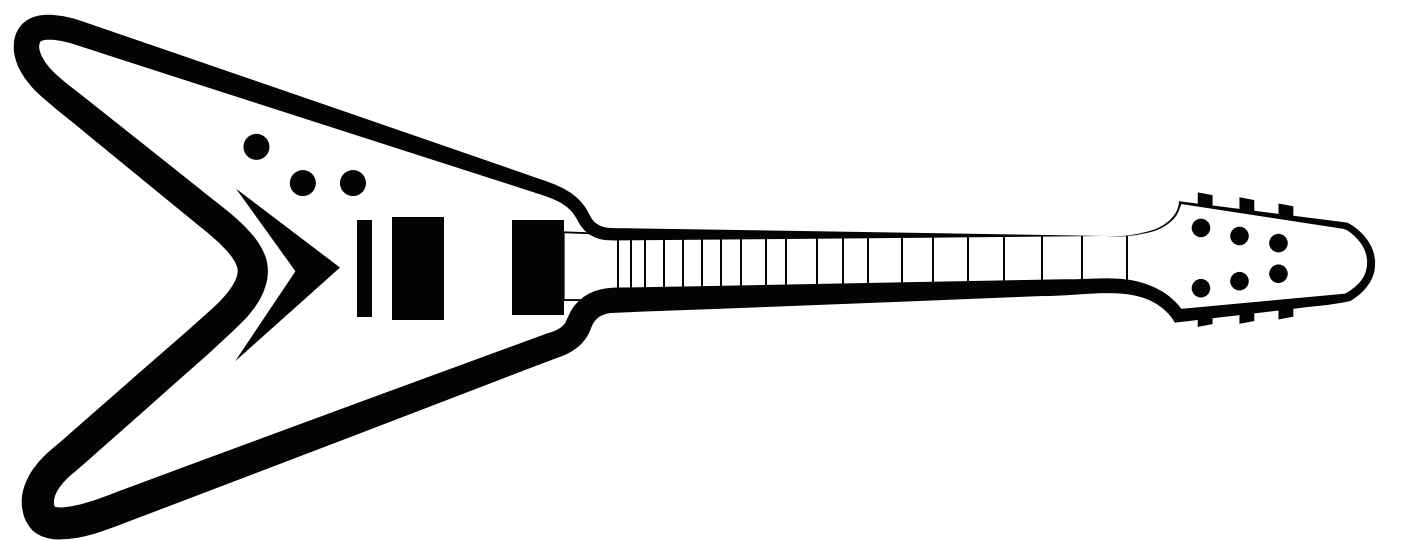
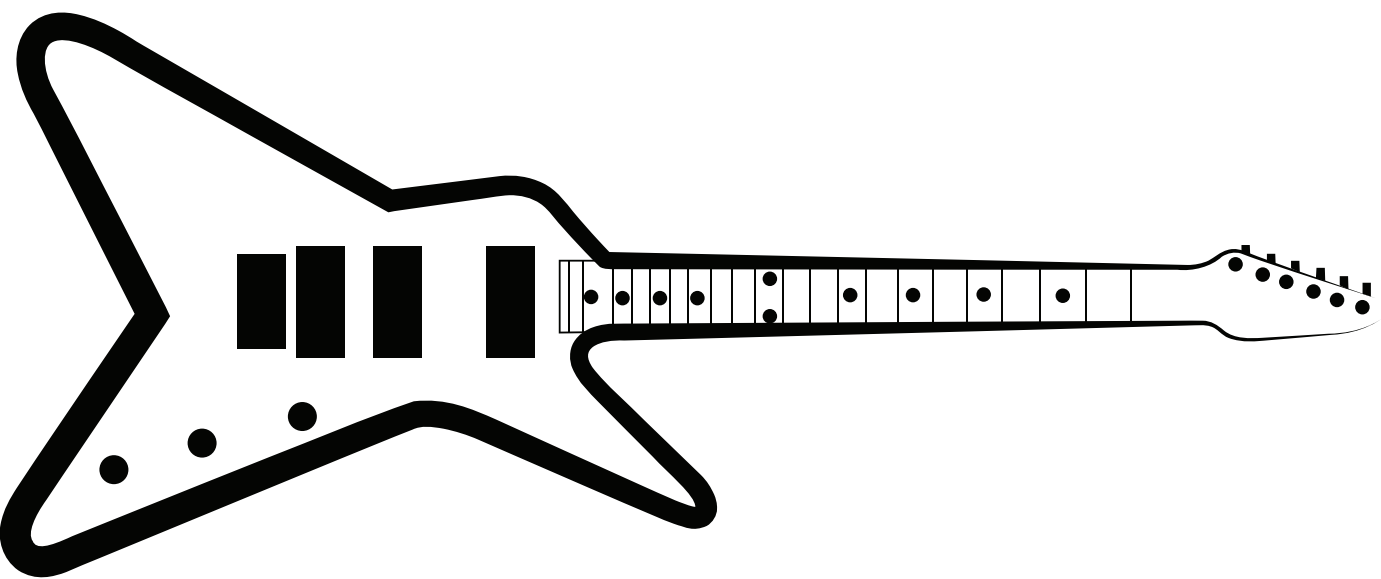
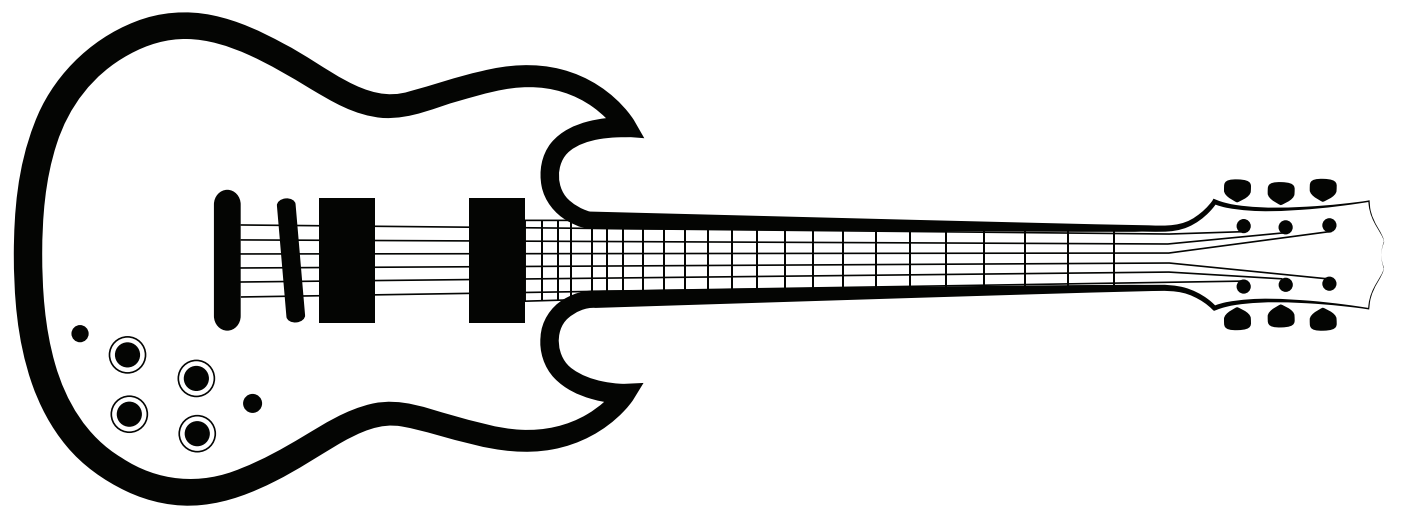
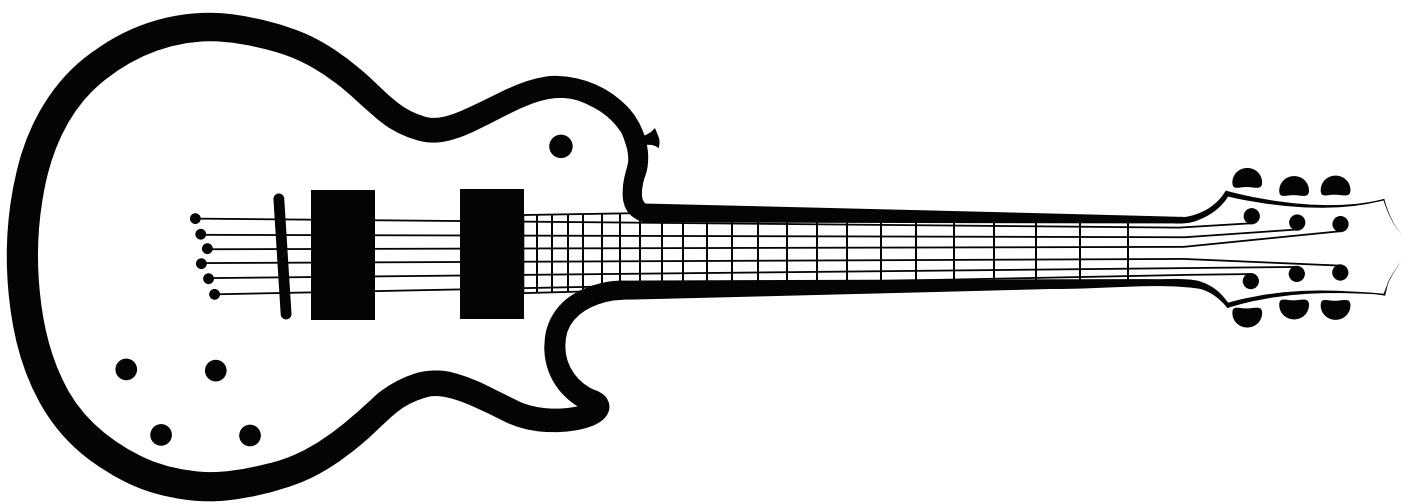
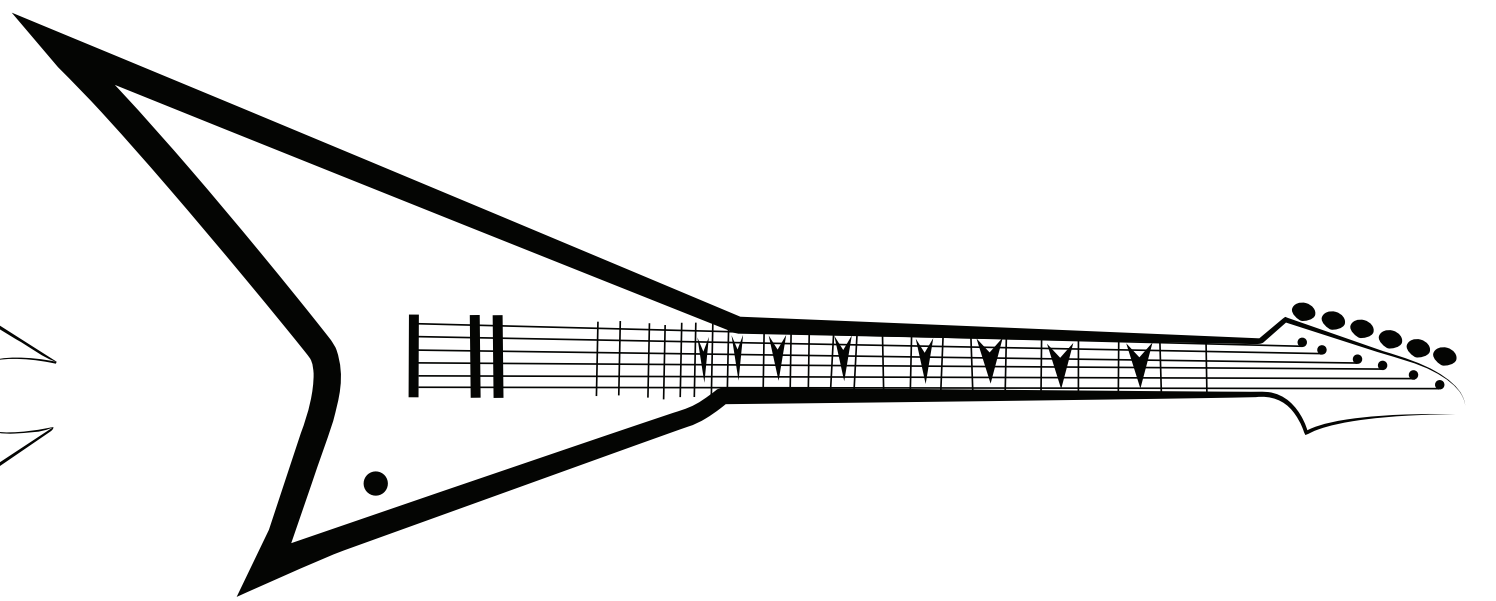
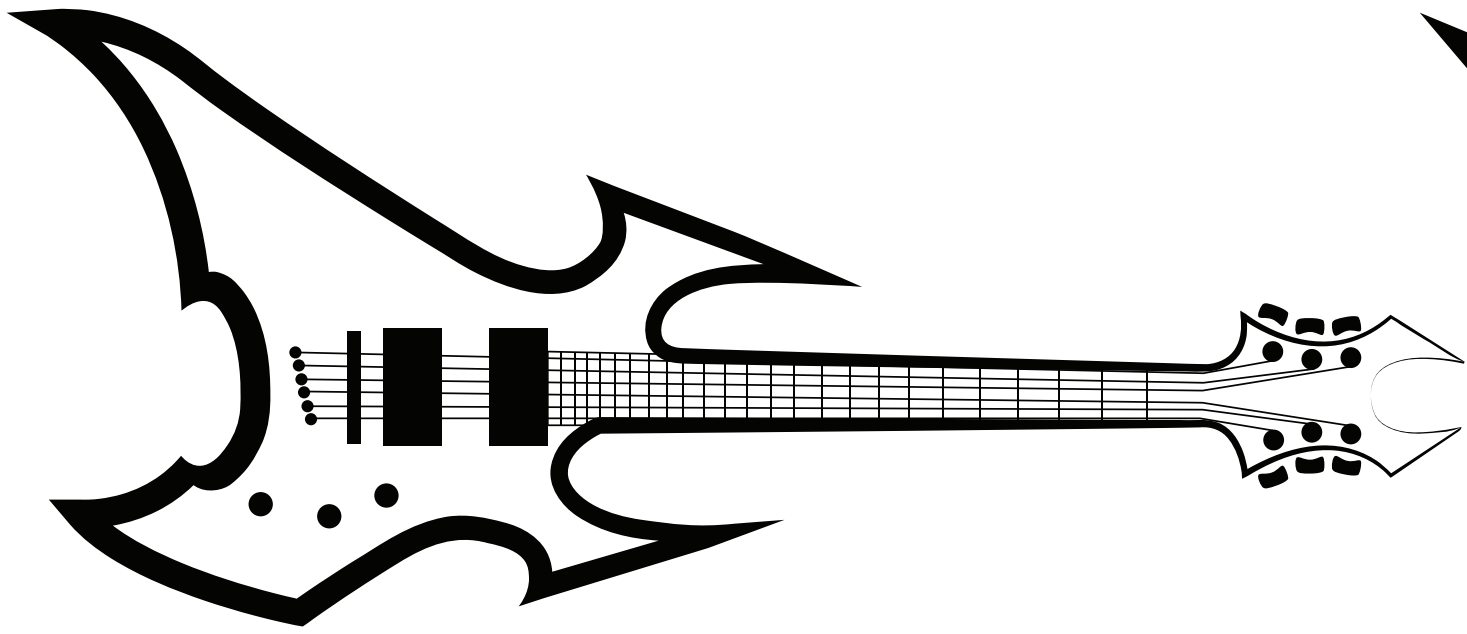
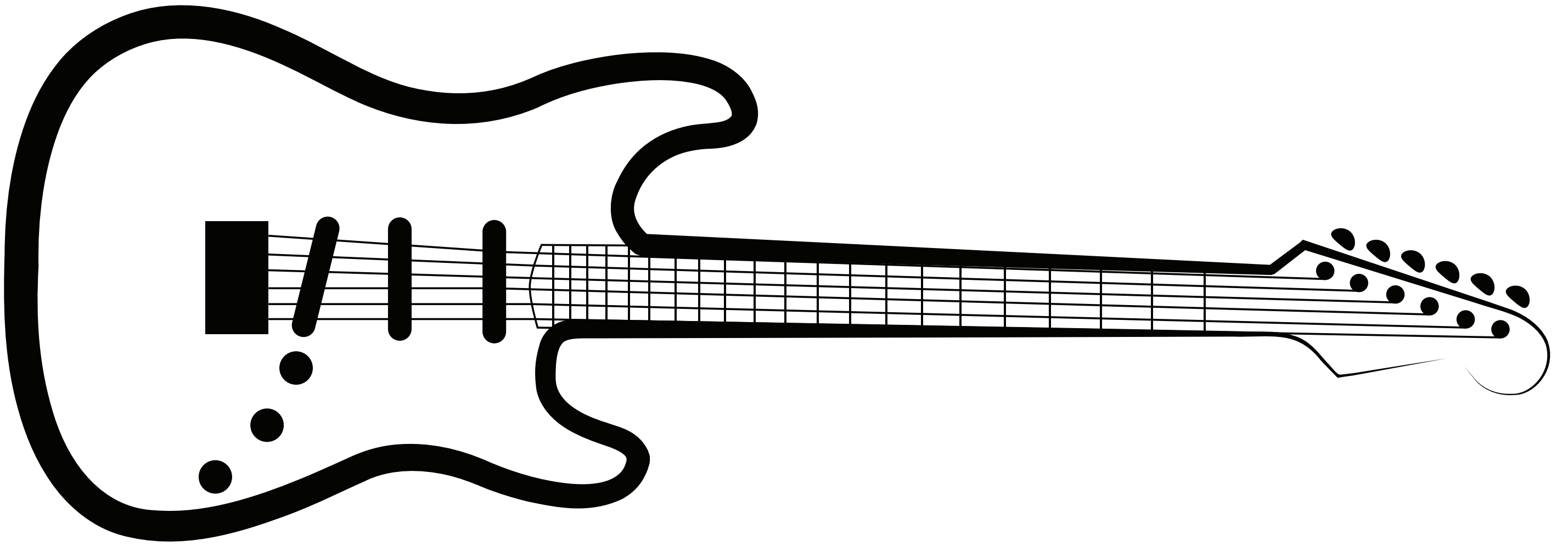


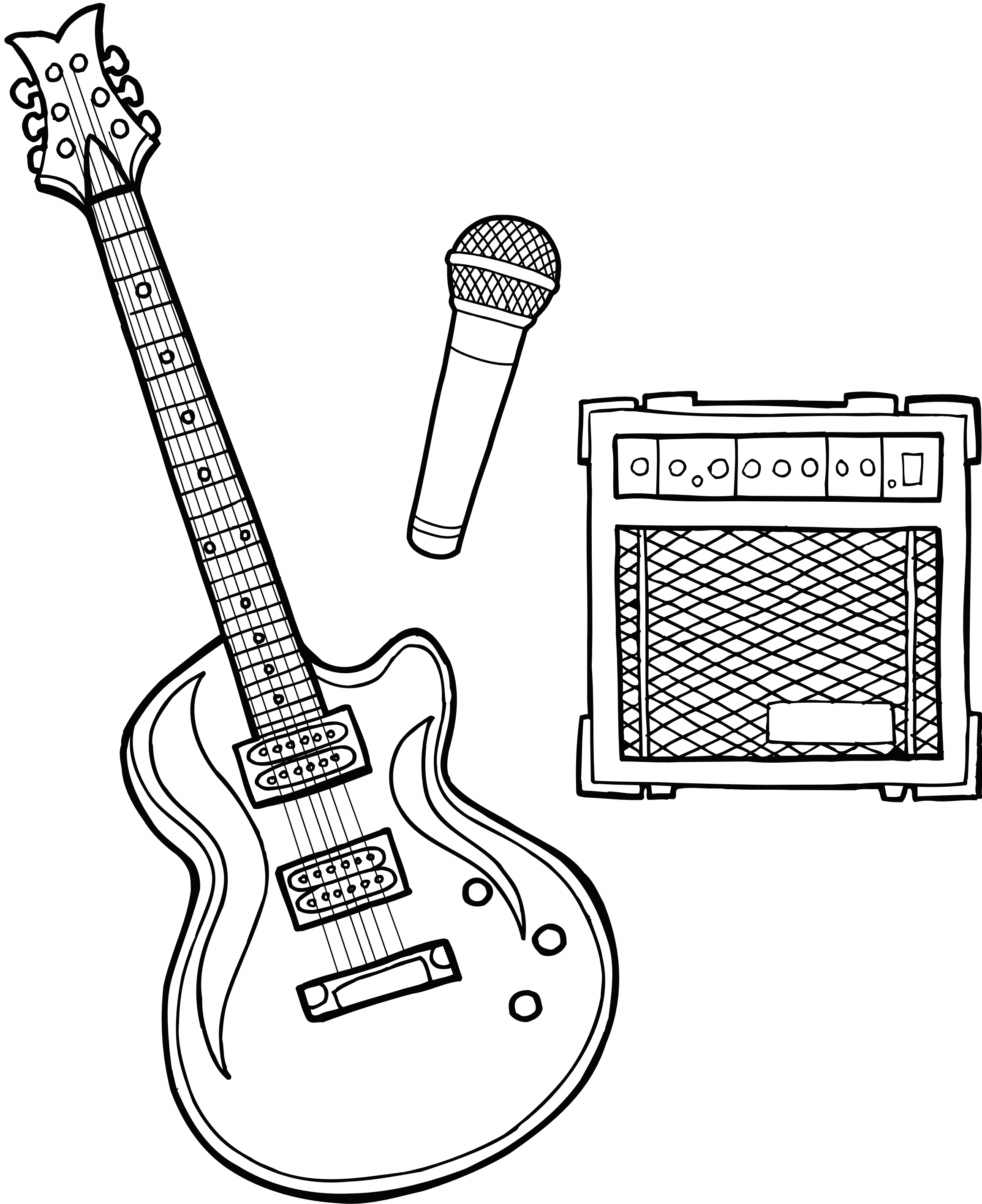


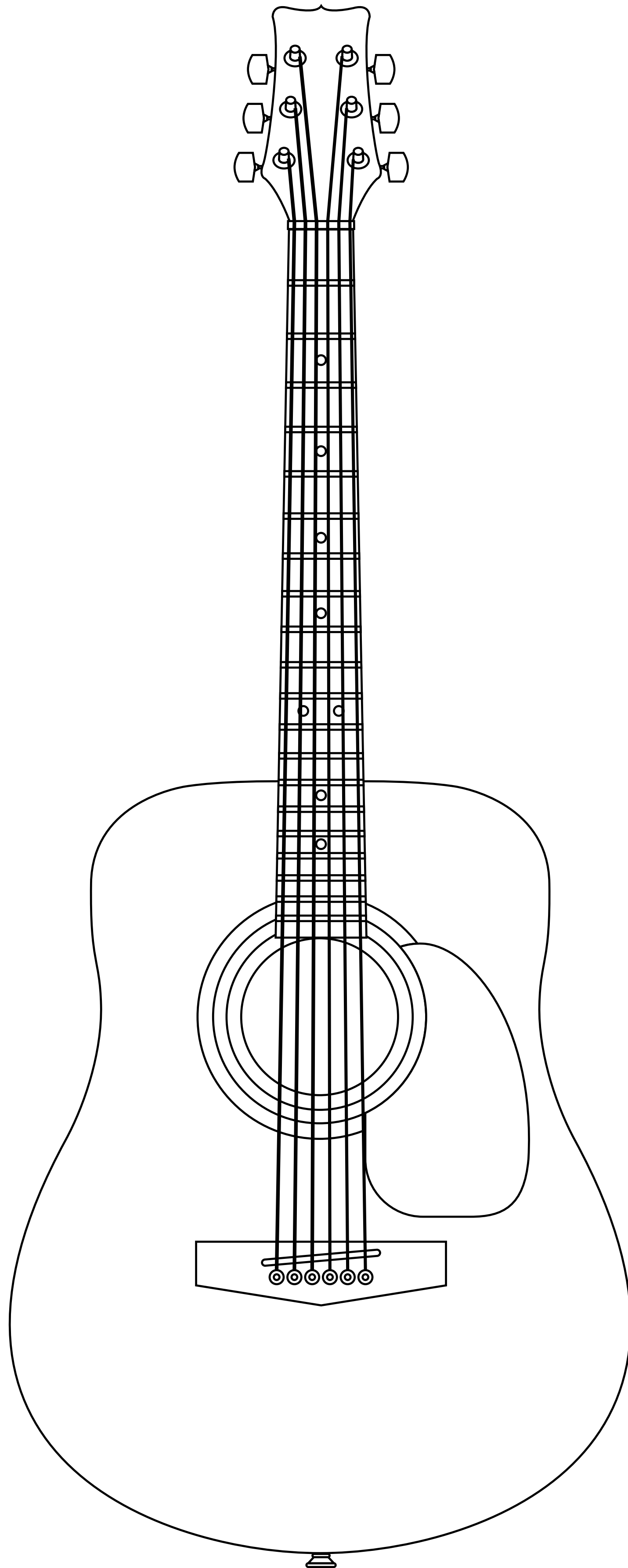


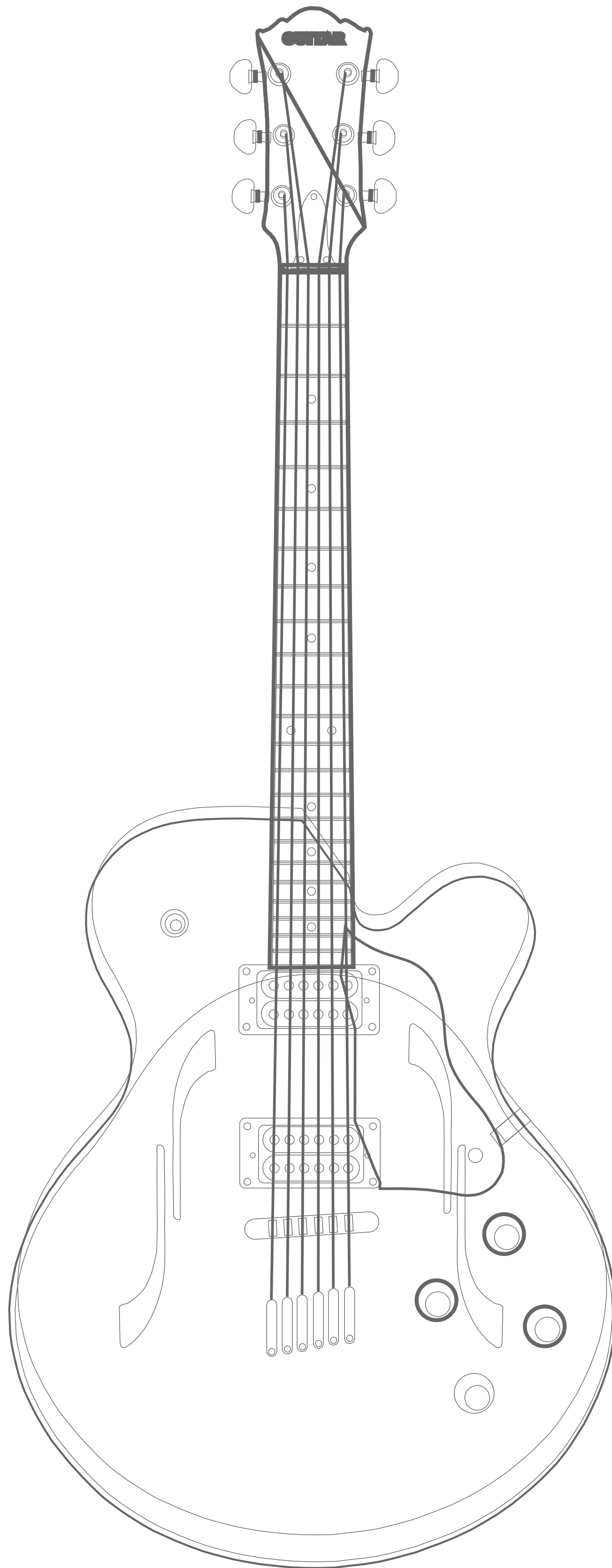


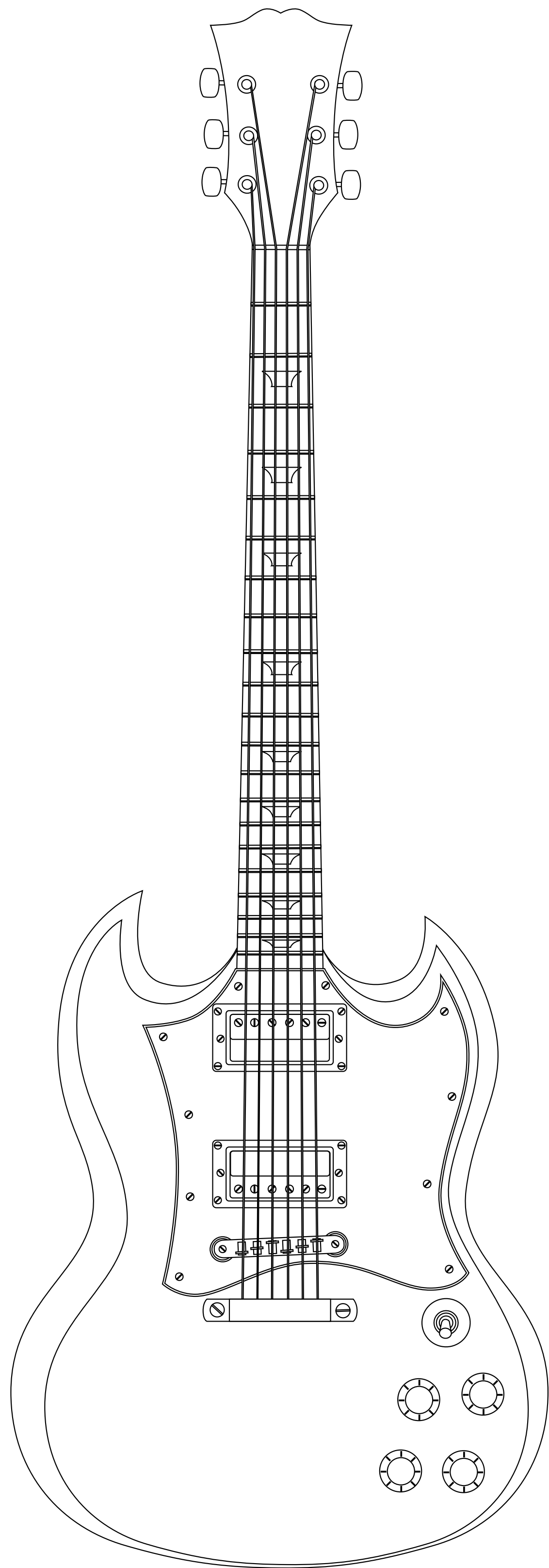
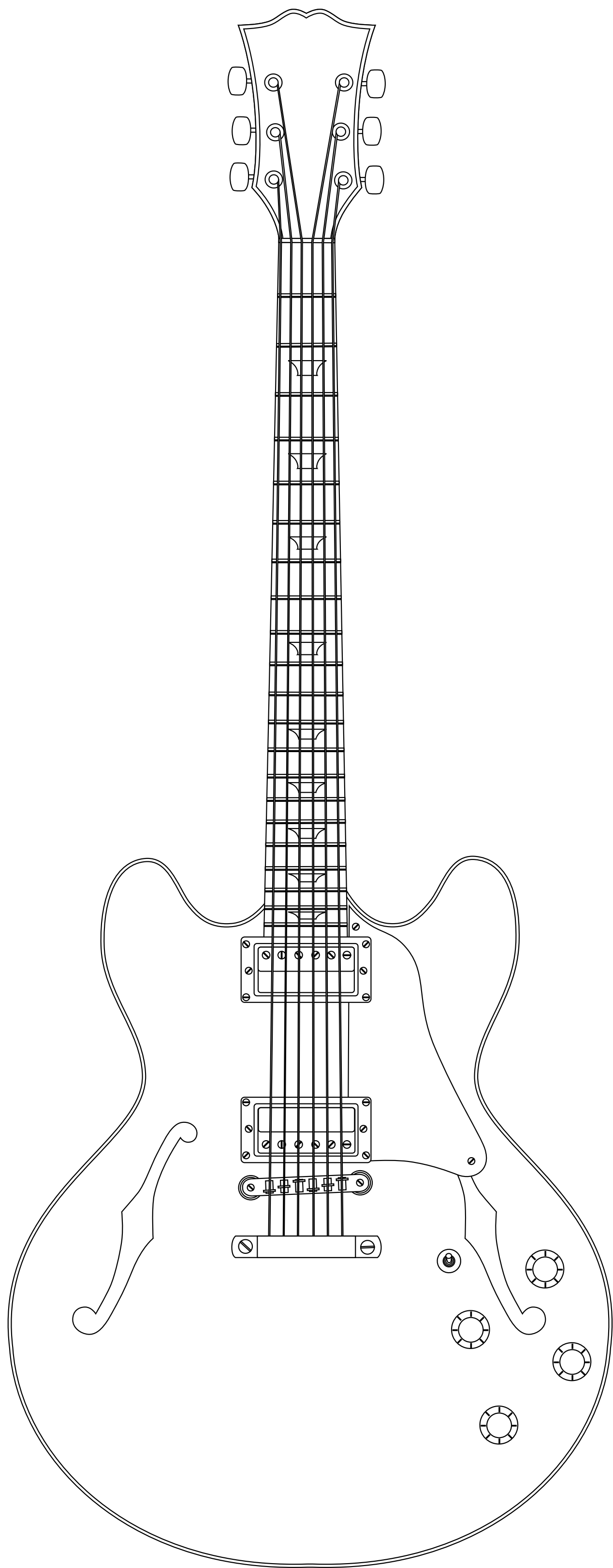












CREDITS



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David B. Hill & Company



The Harvey P. and Patricia S. Newquist Musical Endowment Foundation



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