



CIVILIZATION AND
COPPER



THE CODELCO COLLECTION

Foreword

COPPER: COMPANION OF HUMANKIND

Copper's future is as bright — and its timeline as long — as a reel of newly drawn wire. True to its remarkable uninterrupted record as an integral part of human life and civilization, copper continues to build on its legacy, as we find new and improved ways to use copper to advance progress and well-being.

In a world that demands enhanced energy efficiency, technology, better homes, factories, offices, a cleaner environment, and improved health, copper continues to shine. It is in this spirit that the National Museum of Natural History in Santiago, Chile, has showcased copper's role as an essential element, inseparable from mankind's material and physical development.

We acknowledge with admiration the National Copper Corporation of Chile (CODELCO) and the museum's enterprise and effort in helping preserve and display the heritage of copper. By their efforts, these organizations are helping a wider audience gain a fresh view of copper as a vital resource manifested in diverse forms, including art, and as a universally recognized element that is useful, durable, beneficial, and aesthetic.

It is our sincere hope that this project stimulates the creative talent of our artists, jewelers, and craftspeople to use copper as a core material in their creative efforts.



Jan A. Smolders

President

International Copper Association, Ltd.

Bronze containers have been used in China for over 3000 years for the religious purpose of providing food for the deceased.



Civilization and Copper

THE CODELCO COLLECTION

The International Copper Association, Ltd., together with the National Copper Corporation of Chile (Codelco), proudly present this catalogue raisonné of heritage objects crafted from copper and its alloys and used by people for thousands of years. Composed of original copper objects from various periods, cultures, and places around the world, this display highlights the close and historic relationship between copper and civilization. Information is also included that provides connections between the multiple uses of copper, the evolution of its alloys, and its principal applications.

This collection, over 10 years in development, was initially conceived and organized by Alexander Leibbrandt, a Codelco executive.

The objects in this catalogue are on display at the National Museum of Natural History in Santiago, Chile.

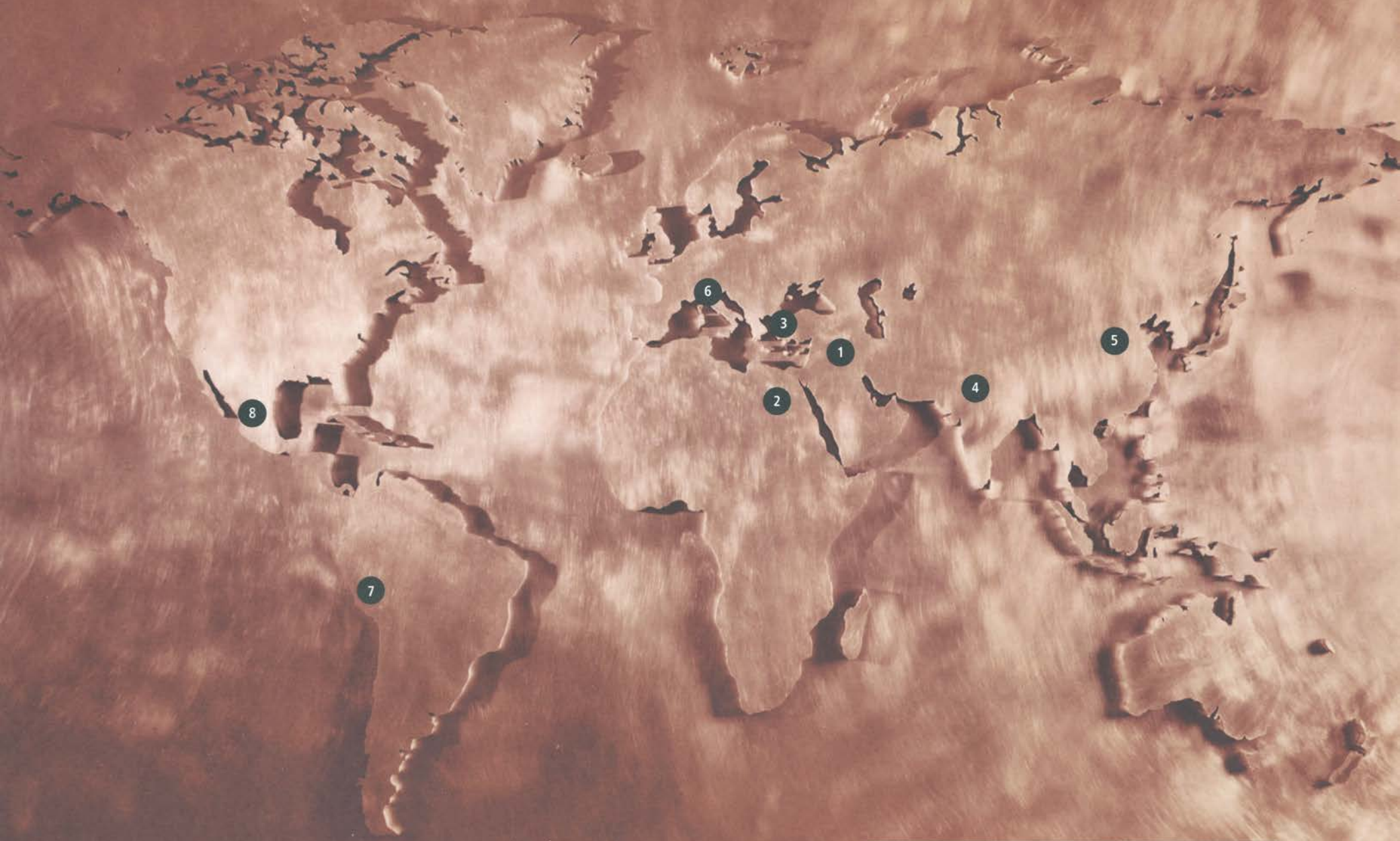
COPPER

IN THE WORLD



None of the great cultures of Antiquity that gave birth to our civilization would have prospered without mastering the metallurgy of copper and bronze.

CULTURES THAT USED COPPER AS A FOUNDATION FOR THEIR DEVELOPMENT



- 1. Mesopotamia: Sumerians, Babylonians, and Assyrians
- 2. Egypt and the Sudan
- 3. Aegean Sea: Crete, Mycenae, Greece
- 4. India
- 5. China
- 6. Roman Empire
- 7. Andean Cultures: Vicu, Moche, Nazca, Tiwanaku, Chimu, Inca
- 8. Central America: Mixtecs, Aztecs

Copper in history

THE MAIN INVENTIONS THAT INCREASED DEMAND



3500 BC

Copper smelting: increased the supply of metal, Asia Minor.

2500 BC

Bronze: allowed the production of weapons, tools and cast objects.

100 BC

Brass: use expanded to decorative and practical items for the home, Roman Empire.

850

Gunpowder: used only for fireworks in China. The bronze cannon was invented in Europe in the 14th century.



1510

Pocket watch: brass case and gears, Germany.

1550

Screws and nuts: mainly of brass, copper and bronze, France.



1698

Steam pump: made possible the drainage of water from mines and increased usable copper reserves.

1710

Piano with bronze strings.

1752

Lightning rod: made of copper wire, American colonies.

1795

Corkscrew: made of brass, England.



4000 BC

3000 BC

2000 BC

1000 BC

0

1000

1100

1200

1300

1400

1500

1600

1700

1800

1500 BC

Bells, gongs: bronze came into use as a source of sound, Asia.

700 BC

Coins: the use of bronze as a means of payment became widespread, Asia Minor, Lydia.



1400

Astronomy: brass navigation instruments invented, Europe.



1447

Printing press: use of bronze and brass to cast lead type; engraved copper plates, Germany.



1608

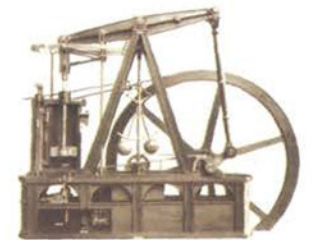
Optical telescope: made of brass, Holland.

1656

Pendulum clock: gears and pendulum made of brass.

1670

Table utensils: initially made of brass and bronze, Italy.



1795

Steam engine: revolutionized the industrial world and, as a result, boosted copper consumption, England.



1821
Harmonica: made of brass,
Germany.

1830
Ship propeller:
made of bronze, England.

1841
Saxophone: made of brass,
Belgium.

1854
Brass shell (bullet), USA.

1851
First underwater telegraph cable
from Dover to Calais.



1837
Electric telegraph: transmission along
copper cables, USA.

1879
Electric train engine, Germany.

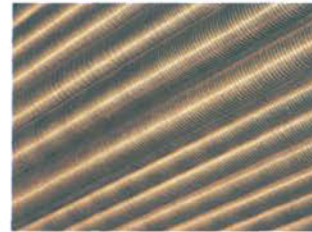
1881
Light bulb: fed by electric current
carried by copper wires, USA.



1909
Electric toaster: requires
electrical power.

1917
Electric drill: powered by a small
electric motor.

1920
Floatation process: made it possible
to extract low-grade ores.



1985
Ultrasonic washing machine, Japan.

1998
Copper chip: processing speed
increased.



1825

1850

1875

1900

1925

1950

2000

1866
Electric dynamo: with copper
wire coil, Germany.



1876
Telephone: voice
transmission along copper
wires, USA.

1878
Electric generator and
transmission along copper
wires.

1882
First alternating current electric
generator, USA.

1884
Steam turbine: reduced electric
generating costs, England.

1885
Motor car: components and parts
made of copper, bronze and brass,
Germany.



1886
Washing machine: with an electric
motor, USA.

1901
Washer with electric motor, USA.

1906
Radio: powered by electricity.

1931
Television: powered by electricity.

1945
Microwave oven: powered by
electricity.

1954
Solar cells: convert sunlight into
electric energy.



2000
Third generation of
copper chips.

PERSONAL

DECORATION

Spiral bronze brooch, Greece, 7th century BC. In Antiquity, this figure symbolized both the sun and life.



Metal

IN SEARCH OF BEAUTY

The oldest copper object ever found was a simple pendant made from a native copper nugget over 10,000 years ago, somewhere in Asia Minor. This is where the triumphal career and increasingly diversified uses of this metal all began. Its long history evidences its versatility and the ease with which it can be worked.

For a long time, pure hammered copper was used to make amulets or jewels, until the discovery of alloys made possible different kinds of cast objects, such as necklaces, bracelets and rings in a variety of styles.

Bronze (an alloy of copper and tin) was mostly used as the basic metal in jewels used for personal decoration, and, much later, brass (an alloy of copper and zinc). Andean cultures, unlike those of Asia Minor, developed jewelry making based on *tumbaga*, a gold and copper alloy.

Later, the use of earrings, belts, buckles and mirrors (especially of bronze) became widespread. These objects were all present in the great cultures of the past, among them Egypt, Greece, Rome, India, China, and Peru.

With mirrors came many accessories for makeup (spatulas, jars, tweezers). Techniques for gilding copper and bronze with gold and silver, initially practiced in Egypt and Greece, made jewelry more accessible to growing numbers of people.

In Africa, it became the custom to associate objects used for personal decoration with the value of the metal and to employ them as a means of payment. This was one reason why the size and weight of individual pieces became fundamental.

Even today it is possible to find in craft fairs all over the world, rings, bracelets, and necklaces made of copper, just as in the bazaars of Antiquity.



Bronze mirrors, like this one from Greece, can be found in all the great cultures of the past. These were among the objects most highly prized by women of Antiquity.



► Brass bracelet, necklace, pendant and ring, Naga tribe, state of Assam, India.



► Set of pre-Columbian copper pieces from Chile's Atacama Region (bracelet, ring, necklace, earring, and tupa).

► Pendants (amulets) from the Tuareg tribe, Western Sahara.



► Indonesian comb, 20th century, and Etruscan combs, 6th century BC.



► Roman fibulas (brooches), bronze.



► African rings of copper and brass.



► Bronze buckle with silver filigree, China, 5th century BC.



► German copper buckle, Roman period.



► Greek brooch of bronze, 7th century BC.

DOMESTIC

UTENSILS



These thimbles belonged to a wealthy Byzantine family. Today they still serve the same purpose they did 2000 years ago.

Historical presence

IN THE HOME

When primitive people noticed that the repeated hammering of a piece of native copper could shape, harden and change it, it didn't take long for them to discover that they could punch a hole in leather or cut wood and meat using a point formed from this metal.

Thus began the crafting of copper axes, knives, chisels and bowls, all of which marked an improvement over those of stone and clay used until then and which were more fragile.

Bronze made it possible to harden objects and pieces cast in different shapes, broadening the use of agricultural tools such as the sickle and the hoe; in carpentry, axes and different kinds of chisels; at home, pots, bowls, lamps, mugs, as well as needles, thimbles, and scissors for sewing.

In Roman times, decorative nails, hinges, locks, table legs, chairs and hooks of bronze became common. Even couches were made with this alloy.

The introduction of brass as a universal alloy gave new life to the domestic uses of copper in the Middle Ages. It was used to make candelabras, trays, plates, and decorative figures in general.

In Colonial America during the 18th and 19th centuries, copper items were widely used, especially in kitchens. Copper bowls, pots, kettles, ladles, heaters, braziers, and portable ovens were common, as people even then recognized the metal's germ-fighting qualities.

Today, copper remains as important as ever to domestic life. It is broadly used in the home — in electrical systems, faucets, pipes, taps, locks, and all kinds of electrical appliances and equipment, as well as in ornamentation.

► Copper and brass pot, Tibet, 20th century.



► Brass foot massager, India, 20th century.



► Bronze kettle, China, 19th century.

► Brass inkwell, India, 19th century.



FORMATION OF COPPER DEPOSITS

Origins of the raw material

Copper occurs naturally in different kinds of deposits, depending on the geological processes that led to their development.

One type occurs when copper dissolved in magma (molten rock) is absorbed by hot springs and carried to the earth's surface through rock fractures. In this case, copper appears as veins of high-grade ore or even native copper. This was the first source of copper used by man.

Another form of copper, also from magma, comes from underground hot springs, which are really metal-rich geysers. When they emerge and mix with cold seawater, the metals precipitate as sulfurs that remain concentrated in the sediment on the sea bottom. Millions of years later, as a result of the lifting of the earth's crust, these sediments reached the surface in the form of deposits.

Porphyry deposits are especially abundant in the Andes mountains, where they typically contain large rock masses of usually low-grade copper sulfides. These result from the rise of molten rock when the ocean crust moves under the continental crust. Examples in Chile include deposits at Chuquicamata, El Salvador, Andina, and El Teniente.



► Copper and bronze thimbles and needles, Roman and Byzantine Empires.



► Brass pencil holder, Turkey, 18th century.

► Brass bottle openers used today in India.



► Three Chilean copper bed warmers from the early 20th century. The anatomically shaped one was used to ease back pain.



Other surface deposits are found where copper has been altered by atmospheric agents over millions of years. These are called copper oxide deposits and are also very common in Chile, with examples including Radomiro Tomic, El Abra and the upper part, now thoroughly mined, of Chuquicamata.

Close to half of the world's copper resources are concentrated in the geological environment of the Andes Mountain Range.

COPPER AND ITS PRODUCTION PROCESSES

From native copper to today's processes

The way copper deposits developed had and has a direct influence on how it is obtained. Initially, when suitable furnaces were still not available, people gathered native copper and gave it the desired form (pendants, knives, needles, and axes) by heating and hammering.

As the first urban cultures developed and with them, better brick furnaces, it became possible to smelt malachite (copper carbonate) or copper oxide using carbon to obtain small copper nuggets. This innovation, as well as generating growing demand for the metal and the depletion of surface

► Copper and iron padlock, Tuareg tribe, Africa, 19th century.



► Copper and bronze axes used in Europe during the Bronze Age.



► Replicas of Greek oil lamps, 5th century BC, used to light up temples and palaces in Asia Minor and Greece.



native copper, led to improvements of a process that dominated production for over a thousand years, until high-grade surface copper oxide ores also began to run out.

The higher cost of mining from ever-deeper veins, combined with the growing complexity of processing increasingly impure ore, required new alternatives. This led to the "roasting" or slow heat process, which eliminates sulfur, thus providing access to the much more common sulfide ores.

This form of extraction, however, lasted until the 19th century only, as by then high-grade sulfide ores were also beginning to run out.

Explosive demand for copper resulting from the Industrial Revolution (the telegraph, the telephone, general electrification), demanded a new method that would permit the mining of low-grade sulfide ores such as those in Chile's abundant copper porphyry deposits.

This was the floatation process, which concentrates the copper in low-grade ores for later smelting and refining.



Chinese brass doorknocker, over 1000 years old, and very similar to those used today.

WEAPONS

AND DEFENSIVE IMPLEMENTS

The tip of the lance was used in battle throughout the Bronze Age. For thousands of years, it remained the deadliest weapon known to man.



The essence

OF BATTLE

The discovery of bronze (which is harder than copper) in the third millennium BC, fueled the widespread use of this alloy for warfare and protection.

Lance and arrow tips, daggers and knives, quickly replaced their counterparts of silex and obsidian. New, deadly weapons were invented, among them battle axes, the sword, and attack carriages with bronze wheels and axles. Defensive elements such as shields, helmets, armor and leg-coverings were also developed.

This was the main use of copper through the first millennium BC, until iron began to displace bronze as the raw material for weapons.

During the Middle Ages, the appearance of gunpowder (14th century) led to the development of more sophisticated weapons, such as the bronze cannon, used until the 19th century, and, later on, brass bullets and cartridges, used to this day.

Unlike the Old World, in the Americas, battle objects were simpler and typically involved weapons for beating and bludgeoning adversaries. Amongst Andean cultures, heavy wooden clubs and bludgeons were the main weapons. Battle swords remained unknown until the arrival of the Spanish conquistadors.

Modern weaponry is strongly dependent on electronics and communications, fields where copper is also indispensable.



► Bronze lance tip, pre-Columbian period, Peru.



► These bronze arrow heads were used by the great cultures of the Bronze Age (third and second millennium BC).



► Bronze swords from China and Afghanistan, first millennium BC.



► Bronze lance tip and dagger, Mediterranean area, second millennium BC.



► Replica of the tip of a lance used in Europe and Asia.

PROPERTIES OF COPPER (Cu)

- Aesthetic.
- Ductile, malleable and relatively soft.
- Highly resistant to corrosion.
- Antiseptic.
- An essential micronutrient in all forms of life.
- Stable, green coating on surfaces exposed to the environment.
- Maintains its properties after recycling.
- High thermal conductivity.

- Can be alloyed with other metals.
- Its most important property is its high electric conductivity and its ability to transmit voice and data.

MAIN COPPER ALLOYS

Bronze: (copper - tin)

The percentage of tin results in bronzes with different properties. For example, bronze with 5-10% tin will form the hardest product (used in the past in swords and cannon). Bronze with 17-20% tin is ideal for making bells, as it produces very high-quality sound. Above 27%, it offers optimum properties for polish and reflection (used in antiquity to make mirrors).

► Brass sword hilt, India, 19th century.



► The club or *macana* was the main defensive weapon among Andean cultures.



► Copper breastplates, symbols of hierarchy in the Roman Empire.



► Bronze and tin gunpowder holders, from Turkey and Morocco, 19th century.



Bronze alloys are used in bushings, bearings and supports in heavy machinery, and for springs in electrical applications.

Brass: (copper - zinc)

Brass is soft and can be easily lathed, engraved, and cast. It is highly resistant to a saline environment, making it particularly suitable for marine applications.

There is a wide range of brass alloys. The most common contain 30-45% zinc and are used in a variety of household objects: screws, nuts, locks, ashtrays, and candleholders.

Copper, bronze, and brass are suitable for a wide range of gilding treatments with gold and silver.

Other alloys

Today copper is used in a wide range of alloys, among them, copper with lead, manganese, beryllium, aluminum, nickel, and iron.

Helmets were widely used in the eastern Mediterranean for protection in battle and for ceremonial purposes.





OBJECTS

OF WORSHIP



Byzantine brass cross, from the Black Sea, 8th century AD, decorated with orthodox crosses on each end. The custom of using crosses of bronze and other materials as signs of devotion became widespread as Christianity spread across Europe.

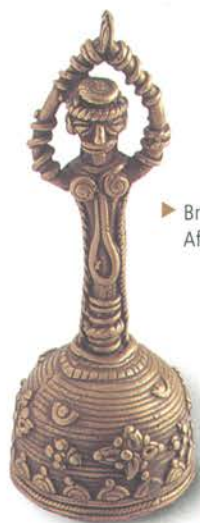
In honor

OF TRANSCENDENCE

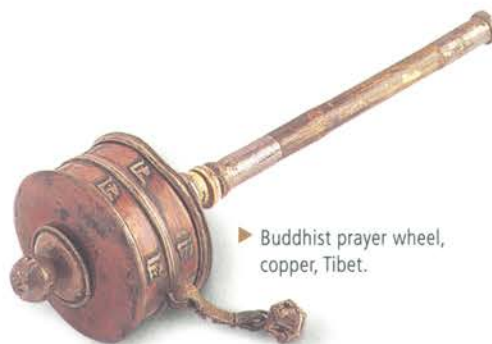
The religious fervor of ancient peoples and some forms of theocratic government influenced the way they worshipped their gods. Offerings to sacred figures, generally made of bronze, were common. Large monuments, such as the Colossus of Rhodes in Ancient Greece and the statue of the Buddha of Nara, in Japan, were also built.

In Asian temples, bells, gongs, and other sources of sound were part of religious rites. Meanwhile, Christian churches began to use bell towers, baptismal fonts, and crosses made of bronze. In America, Andean cultures adopted ceremonial knives called *tumis*.

Today, churches and temples continue to be decorated with a wide range of objects made of copper, bronze, and brass.



► Brass bells, Western Africa, contemporary.



► Buddhist prayer wheel, copper, Tibet.

► Byzantine incense burner, bronze, 9th century, Istanbul.



► Ceremonial bronze knife, China, 8th century BC.



► Orthodox Byzantine cross, bronze, 8th century.

COPPER ROUTES

Native copper

Mining of native copper began in Asia Minor before the sixth millennium BC. There are signs of its use in Europe beginning in the 5th millennium BC and in India since the 4th millennium BC. In Eastern Asia (China) this metal in its natural form remained virtually unknown.

The native peoples of North America mined native copper from the second millennium BC, but never developed copper metallurgy.

Meanwhile, Andean cultures used native copper sporadically. Their leap into metallurgy came about early in the first millennium BC, as an offshoot of gold metallurgy.

Copper

The first copper produced from smelting copper oxide ores (malachite) and reduced using charcoal appeared about 4000 BC in Asia Minor, somewhere in Anatolia, Turkey.

This technique reached Europe towards 3500 BC and the Indus Valley (today Pakistan) around 3000 BC. Over a thousand years passed before copper metallurgy reached China, which started up directly with the production of bronze.

In the Americas, copper metallurgy developed in the area now known as Peru, while the Chavin culture was dominant in the 10th century BC. In Central America, there are signs of copper production during the first millennium AD, while for the pre-Columbian period there are no signs of this process anywhere in the vast region of North America.



► Copper spoon for sacred water, India, 20th century.



► Orthodox brass icon, Russia, originally enameled, 19th century.



► Bronze plaque, Cathedral of San Zeno, Italy. Replica of an 11th century original.



► Brass oil lamp, India, contemporary.



► Replica of a bronze incense burner, Korea, 7th century.

Bronze

Once again it was Asia Minor that developed the first alloys. Early alloys were copper-arsenic (3500 BC). Around 3000 BC the great discovery of bronze (copper-tin), which was to have such a major impact on human development, was made.

Over 500 years went by before bronze reached Europe and India. It came to China one thousand years after appearing in the Middle East.

In the Andean world, it turned up around the 6th century, during the Chimu culture, which lifted non-ferrous metal metallurgy up to a level of extraordinary development. In Central America, the first bronze objects were created around the 13th century AD, during the Mixtec, Huastec and Aztec cultures.

Brass

This was the second copper alloy with significant influence on our civilization. It first appeared in Asia Minor, on the shores of the Aegean Sea, generating enormous expectations because of its gold-like appearance.

The Romans, in the first century BC, were the first to mass-produce brass using cost-effective techniques. At the same time, it appeared in India, then spread to China, and from there to the rest of Asia.

Like bronze, brass came to Central Africa with the caravans of Arab traders, but it did not reach the Americas until the arrival of the Spanish conquistadors.

WEIGHTS AND MEASURES

TO SET A STANDARD



This lovely system of
brass weights is from
Peru and dates back
to the 19th century.

New forms

OF EXCHANGE

The development of ancient societies and the growth of trade required more dependable methods for measuring the weight and volume of goods.

Systems of weights and measures had to be permanent (that is, not rust), easily reproduced and inexpensive to produce. Thus copper, bronze and brass came into use for scales and weights all over the world, a process that began in the Bronze Age and continues to the present.

Although the principle of measurement was the same everywhere, its forms varied by region. In China, for example, weights were represented by dragons, while ducks were used in Burma, lions in Mesopotamia, and geometrical figures in the Roman and Byzantine empires, and Africa.

Today, brass weights remain in use as standards for calibration. In fact, today's electronic measurement systems use circuits and conductors made of reliable copper.



► Two Roman bronze weigh scales.



► Bronze weights from Burma, 19th century. In Asian countries, these were commonly in the shape of mythical birds or animals.

THE RULE OF BRONZE

Copper was initially used as native copper in the making of talismans, pendants, bracelets and domestic articles such as knives, axes, punches, and awls.

The discovery of bronze opened up broad new fields of usage, including tools, weapons and the casting of objects and figures. The prevalence of this metal in a range of products was so great that this period became known as the Bronze Age (3000-1000 BC).

Virtually all objects made during this period were of bronze, with iron beginning to replace it in part during the first millennium BC.

The discovery of gunpowder in Europe (14th century), however, boosted demand for bronze again, as this was the metal most commonly used to make cannons.

Applications using pure copper were rare and reserved mainly for household items such as pots, ladles, plates and trays, all made out of thin sheets that could be obtained through hammering.



► Chilean brass weights, 19th century.

► Brass and copper units for measuring volume, India, 20th century.



► Various weights:
a. Brass, India.
b. Bronze, Byzantine Empire.
c. Brass, Africa.



FROM BRASS TO PURE COPPER

Brass, introduced by the Romans, was originally used for jewels and coins, given its similarity to gold. Later, during the Middle Ages, it was also used for dishes, candleholders, mugs, and many other household utensils.

The "golden age" of brass began with the Industrial Revolution (18th - 19th centuries), as many mechanical parts were cast and shaped using this material. Moreover, virtually all scientific



instruments (telescopes, astrolabes, compasses) and tools were made using this alloy. It became the most widely used metal after iron and steel.

Revolutionary technologies developed during the second half of the 19th century, however, required metals with a high capacity for carrying voice and data and high electrical conductivity, properties only available in high purity copper. Since then, copper wiring, whether for power or data transmission, is recognized across the world as a safe and efficient conductor.

From then on, demand for copper wire began to grow, a trend that continues to this day, and which accounts for more than 50% of world copper consumption.

Rice containers were used in India for centuries to measure volume.





MEANS OF PAYMENT

S Y M B O L S A N D B A R T E R



Copper and bronze coins were
the most important means
of payment used in China.

A language

FOR TRADE

Progress in trade, along with the development and rise of major cultures during the Bronze Age, turned barter inadequate as a payment system.

This inevitably led to the implementation of a new means of payment based on materials that had to have a high and constant value, as well as being corrosion-resistant, easily reproduced, resistant to wear, and recyclable.

Once again copper and its alloys met these conditions, making it possible for different cultures to develop means of payment using copper, bronze and brass. This trend continues to date, with the minting of coins still based on copper alloys.

The first means of payment appeared in India during the second millennium BC, in the form of copper or bronze axes. In Siberia and China bronze knives were used from the 8th century BC on. In Iran, bronze bars became very common. Around 700 BC, the King of Lydia in Asia Minor coined copper, silver and copper/bronze coins for the first time. This was precisely the system that with time became the common means of payment worldwide.

In Italy, before coins were introduced (4th century BC), copper and bronze bars, along with scrap, were carefully catalogued and weighed for the purpose of payment.

In Africa, copper and brass bracelets and necklaces were used as a means of payment until the middle of the 20th century. In America (Mexico) the Aztecs used imitation copper axes to exchange merchandise.



► Katanga crosses, copper. These were used as payment in the Congo region, Africa, from the 12th to the late 20th century.



► Brass coins, shaped like peanuts, Western Africa.



► Knife-shaped, Chinese bronze coins, 5th century BC. These were the first means of payment, common at the same time as the coin-based system still used today was taking over in Asia Minor.

► Copper and brass bracelets, Western Africa. These were the typical money until they were abolished in the middle of the 20th century.



COPPER IN THE ANDEAN WORLD

Metallurgy at the service of worship

In what is today Peru, the Chavin and Mochica cultures of the 10th century BC learned to use copper as a complement to gold in jewelry for religious purposes.

This inclination to use metals for representation and worship meant that color rather than hardness was more important to the manufacture of objects. Similarly, new alloys using gold, silver, copper, lead and tin were created, offering a much wider range of materials with more refined techniques than those of the Old World, while production of weapons and tools became less important.

Metallurgical development in the Andes reached perfection during the Chimu and Inca periods (12th to 15th centuries AD). However, unlike the Spanish, they never mastered iron metallurgy.

The main alloys used by Andean peoples:

- | | | |
|---------------------------|--------------------------|--------------------------------|
| • gold - copper (tumbaga) | • gold - silver | • silver - copper |
| • copper - tin | • silver - tin | • copper - lead |
| • copper - antimony | • gold - silver - copper | • gold - silver - copper - tin |



► This copper wire chain was also used as a means of payment in Western Africa, 19th and 20th centuries.



► Coins from Thailand, 19th century.



► Copper wire belt used to seal contracts and as money, Sumba Island, Indonesia, 20th century.

COPPER IN CHILE

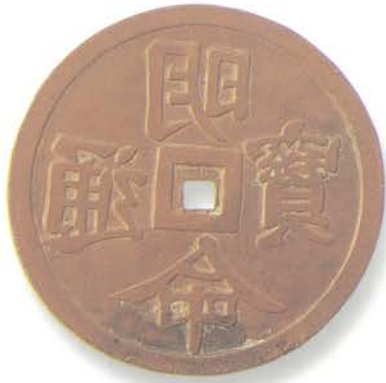
The first steps

The Chinchorro culture (3000 BC) was the first to use copper as part of the process of wrapping mummies in metal sheets, probably made from native copper.

However, the first sign of metallurgical activity as such is to be found among the Atacamenians, in San Pedro de Atacama, northern Chile. In the 5th century BC they began to use copper in a rudimentary form. Thanks to the influence of the Tiwanaku culture (5th century), their metallurgical and jewelry techniques became more sophisticated.

Further south, the Molle culture (1st century) developed, using mainly copper in sheets, tweezers and needles, although it also worked with gold and silver.

Early in the 8th century, the rule of the Diaguitas began in the Elqui Valley, in Chile's northern 4th Region. These people were familiar with copper metallurgy, producing ornaments, tools and hooks. The Diaguita culture was absorbed by the Incas, starting in 1470, and they began to adopt the techniques and uses for copper typical of the Incan world.



► This type of bronze coins were used in China for over a thousand years.



► Set of ancient copper and bronze coins from different countries.

► Different types of Chilean coins using copper alloys.



COPPER IN THE NEW SOCIETY

Steel arrived with the Spanish conquest, diminishing copper's importance to emerging Chilean society. The Spaniards' main interest focused on producing gold and silver, and they began to systematically mine both metals.

Copper production continued, but on a reduced small scale, because it wasn't profitable. Only high-grade oxide ore was mined.

This changed with the Industrial Revolution, which led to a greater demand for copper and higher prices. By the early 19th century, Chile was producing around 10% of the world's copper.

By the 1820s, Chile was the world's fourth largest producer, becoming its second after England toward 1840. From 1850 to 1880, Chile led the market, producing 30-45% of the world's copper.

In 1882, production began to drop due to the gradual exhaustion of high-grade ore and the lack of technological innovation.

Early in the 20th century, with the arrival of new foreign investors, new technologies such as leaching and floatation revitalized Chilean copper production and the country became the world's main producer again during the 1980s.

In Nigeria, bracelets, bangles and necklaces, besides being personal ornaments, were also used as means of payment, raising the social status of their wearers.



MUSICAL

INSTRUMENTS



Although Japanese culture developed under Chinese influence, the Dotaku ritual bell, representing the development of an autonomous identity, was an exception. The first ones were manufactured more than 2000 years ago.

Unique properties

FOR THE ART OF SOUND

Musical expression is an activity inherent and unique to human beings from time immemorial. In some cases, it has served to facilitate relations with the gods and in others to make social activities more agreeable.

Copper has played a major role in the development of instruments, because of its excellent sound-producing properties. There is virtually no culture that has not used copper, bronze, and brass to make these instruments.

This is due to the fact that vibration generates sound, which is particularly sustained in bronze. Nonetheless, brass and other copper alloys also have a high vibratory index, which has led to their use in the manufacturing of instruments, especially percussion and wind.

From a therapeutic perspective, scholars have also demonstrated the powerful effect of sound vibrations, which have formed the basis for an ancient practice known as "music therapy", used successfully in the West today.

► Flute and trumpet of copper and brass, Asia.



► Tibetan flute, decorated with brass and copper (Kangling). This instrument, made with a human bone (tibia), is played as part of a ritual to chase off evil spirits.



► Bronze bell, China, Zhou Dynasty, 3rd century BC. This was part of a musical instrument called a Zong, composed of a series of similar bells of different sizes.



► Buddhist bronze bell from Tibet. This bell represents the feminine side of tantric rituals. During ceremonies, it is always used with the Vajra (lightning bolt), an instrument associated with masculinity.



► Bronze cymbals, China, typical of Buddhist temples.



► Japanese Dotaku Bell. This was the first bronze object to be made in Japan.





*Tibetan copper trumpet, 19th century,
finely decorated with brass repoussé.*

PRINTING

SYSTEMS



Printing presses originally used lead type that was cast in bronze or brass matrixes.

Shaping

THE WORD

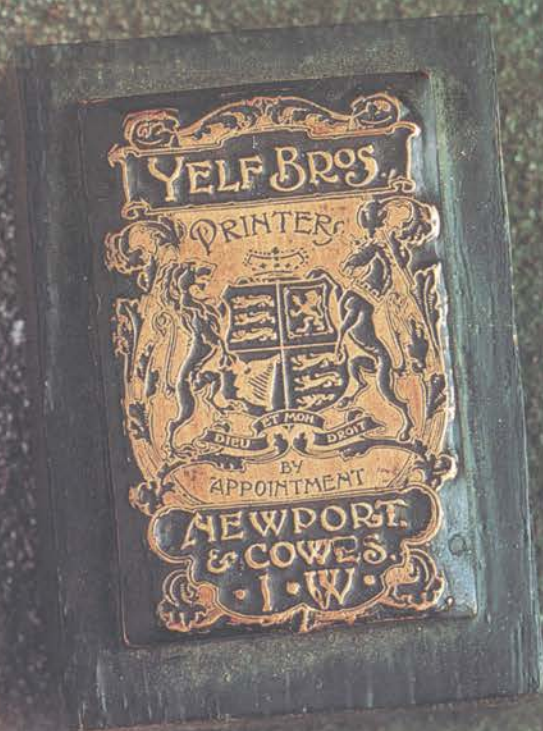
Copper came into use in this field relatively late, with the invention of the printing press in the 15th century, when it was used to make bronze or brass matrixes for casting type.

Earlier, however, it was already used for bronze seals and stamps that certified the official or real nature of letters and documents.

Copper etchings were used to reproduce illustrations, in a technique very similar to color printing. Only in recent years have new technologies replaced traditional copper engraving.

Other ancient reproduction techniques that remain in use include bronze molds of different kinds to make artistic objects in copper and brass and repoussé technique.

Copper plates were used to reproduce pictures and drawings on the pages of books and periodicals in past centuries.



► Bronze and copper seals and stamps from India, Syria, and the Roman and Byzantine Empires.



► Arabian seals of bronze and copper.

► Bronze matrix to cast type for a printing press.



► Copper plate, Pakistan.



COPPER MONUMENTS

- Colossus of Rhodes, island of Rhodes
- Statue of Marcus Aurelius, Rome
- Buddha of Nara, Japan
- Giant Bell of Beijing
- Quadriga of San Marco, Venice
- Pantheon, Rome
- Austerlitz Column, Place Vendôme, Paris
- Quadriga, Brandenburg Gate, Berlin
- Paris Opera House (roof)
- Saint Paul's Cathedral (cupola), London



- Imperial Palace (roof), Tokyo
- The Little Siren of Copenhagen
- Cathedral Portal in Cologne
- German Fountain, Santiago
- Piccadilly Circus Eros Fountain, London
- Lions and Statue of Admiral Nelson, Trafalgar Square, London
- Statue of Liberty, New York
- Figure of "Manneken Pis", Brussels



SCIENTIFIC

I N S T R U M E N T S

19th century brass astrolabe of Arabian design, used to interpret the horoscope from the position of the stars.



A new view

OF THE UNIVERSE

The first scientific disciplines, particularly astronomy and medicine, emerged when societies reached a more advanced level of development.

Special dedication to the study of the stars and their influence on life on earth led to the early creation of bronze instruments such as the astrolabe (2nd century BC) used in ancient Egypt, Asia, and the Greco-Roman world.

The Romans also used pocket sundials, made of bronze or brass, while the Chinese, by the 4th century BC used a bronze compass to navigate due to its anti-magnetic properties.

With travel across oceans and the development of astronomy in the 15th century, a wide variety of instruments, mostly of brass, were developed, among them the telescope, the clock, the sextant (to measure angles and distances), and many others.

With the practice of medicine came the first surgical tools. Bronze scalpels were used in ancient Egypt to prepare mummies, but it was the Greeks and Romans who used bronze to create most of the basic medical instruments we know today.

Andean cultures used small bronze chisels for cranial trepanation, a common practice in the Andean area, extensive to the Atacamenian people of San Pedro de Atacama in northern Chile.

Copper remains present in modern medicine. Electronic and computer instruments use conductors and other pieces made of this metal or some of its alloys.

*An Indian astrolabe of brass with the
signs of the zodiac engraved on its rings.*





► Set of medical instruments made of bronze, Roman Empire.



► Brass tweezers and scissors, India, 19th century.



► Bronze instrument for bleeding patients, Afghanistan, 12th century.



► Arabian astrolabe of brass, Morocco, 19th century.



► Bronze pocket sundial, used by Roman aristocrats.



► Brass sextant and level, 20th century.

ART AND COPPER

THE MATERIAL OF CREATION



This copper Buddha was found in the sacred corner of a Tibetan lodge. Besides depicting the serene inner look of the deity, it also shows two key symbols of Buddhism: the lightning bolt and the bell.

Aesthetic

TOOL

Copper has been a raw material for the creativity of sculptors, jewelers and designers, who have poured their talents into myriad works: bronze and brass statues dedicated to the worship of divinities and enormous bronze monuments, such as the Colossus of Rhodes, the statue of Marcus Aurelius in Rome, and the Statue of Liberty in New York.

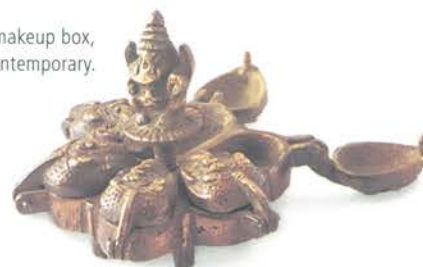
Some baptismal fonts, altars and cathedral portals in Europe, Asia and America represent the best artistic expressions of their period, which would not have been possible without copper and its alloys.

In addition, the palaces and residences of the ancient world were decorated with objects whose main material, after silver and solid gold, was, and remains to this day, copper.



► Brass Buddha's head, China.

► Bronze makeup box, India, contemporary.

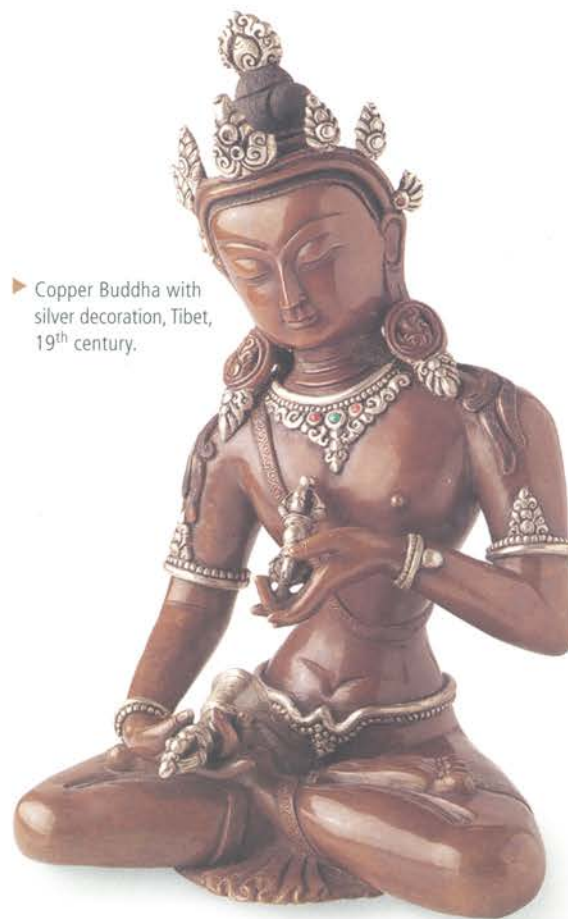


► Brass bracelet, India, 20th century.

► Copper container, of delicate repoussé, to collect the bridal dowry, according to the customs of Kashmir, contemporary.



► Copper Buddha with silver decoration, Tibet, 19th century.





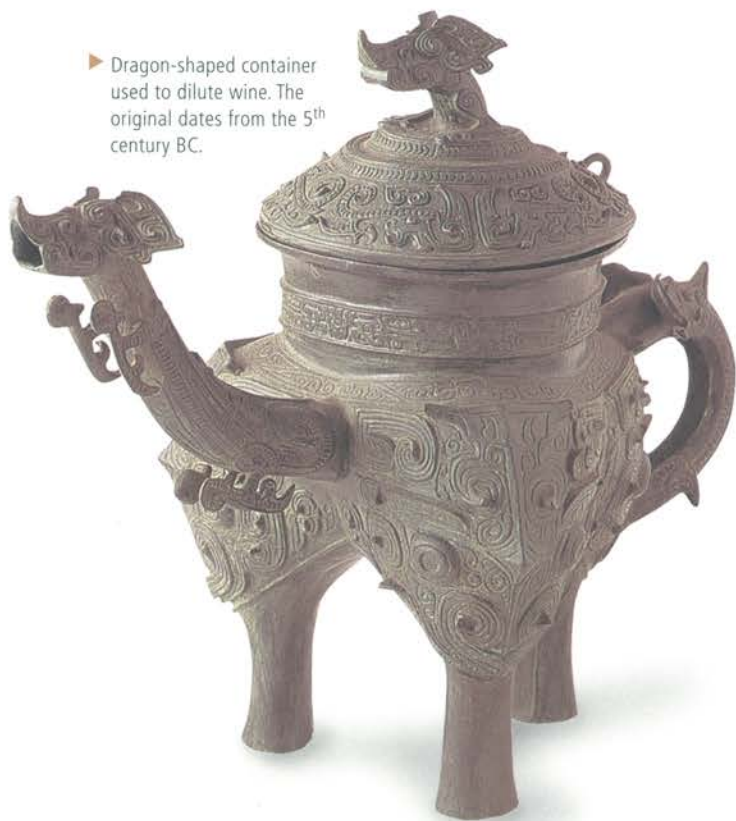
► Brass cup with copper inlay, India, 19th century.

► Brass cup and saucer, with copper and silver linings and inlays, India, 19th century.



► Tibetan copper beer mug, with brass and silver appliqué, used for ceremonial purposes in Buddhist temples.

► Dragon-shaped container used to dilute wine. The original dates from the 5th century BC.

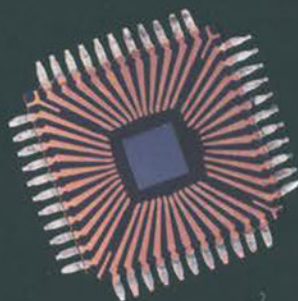


► Copper kettle decorated with brass, China, 20th century.



CURRENT USES

INNOVATION AND CHANGE



Copper, as the main element used in electric and data transmission, decisively opened the doors to progress.

Crucial

TO A NEW ERA

The basis of knowledge about copper's uses in the 21st century is rooted in the Industrial Revolution of the 19th century and its main inventions: the telegraph and the telephone, in the area of communications, and electricity and the generator in the energy area.

Prior to this, copper was used mainly as an alloy (in brass and bronze) for mechanical purposes, because the properties most in demand were its malleability, workability and the ease with which it could be cast into parts.

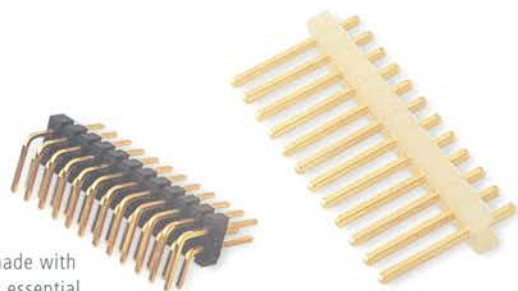
Pure copper was used mainly in household containers (plates, trays, pots, ladles, strainers). This changed with the development of electricity and new communications methods, which required high purity copper wire with excellent conductivity.

While pure copper accounted for an insignificant portion of world metal consumption in the mid-19th century, today it accounts for about 60%. Its exponential rise was due to the fact that it became an essential and irreplaceable part of new technologies essential to modern life.

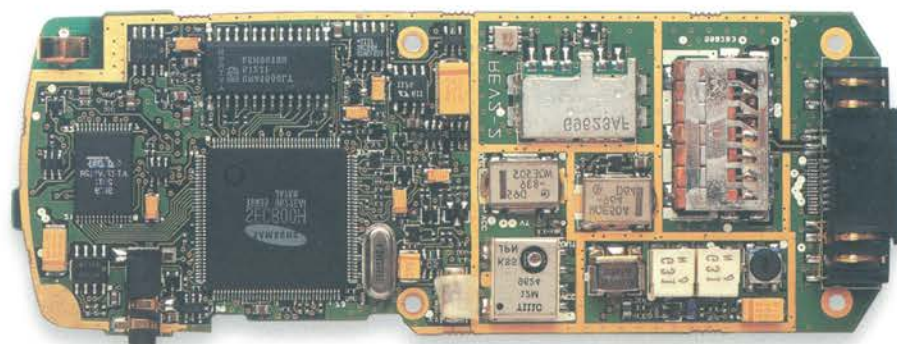
This situation was repeated with the revolution in communications and information technologies, that would have been unthinkable without copper.

The search for a better quality of life and higher productivity demands the participation of copper and its alloys in a wide range of fields: the home, transportation, manufacturing, design, construction, medicine, biotechnology and many others. This, beyond a doubt, ensures a growing and persistent demand for copper.

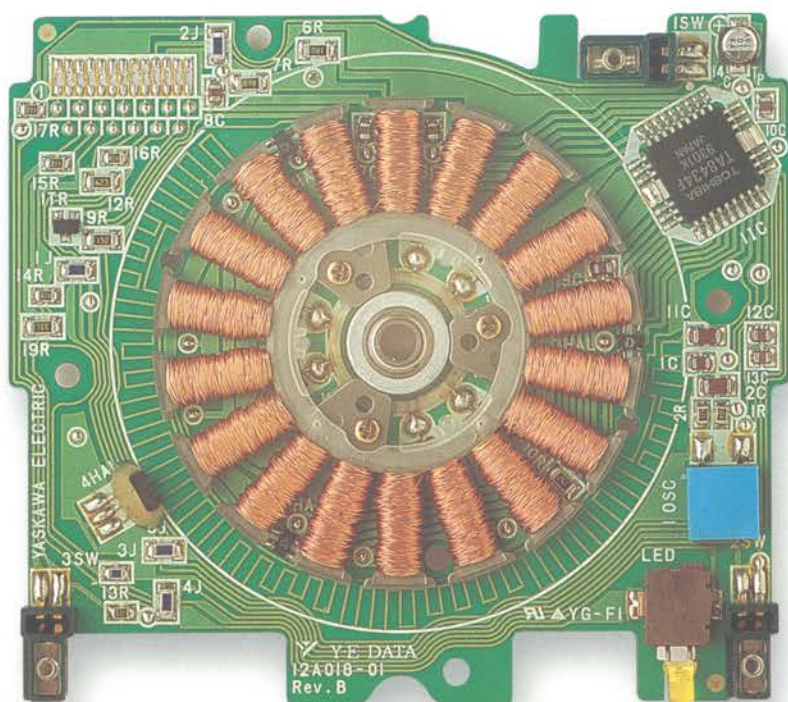
Copper's versatility, its environmental benefits and essential role in life add to its relevance as the material on which much of the 21st century's progress is riding — just as has been the case since the beginning of time, as documented in these pages.



► Connectors made with copper alloys: essential pieces in the world of electronics.



► Did you know that a cellular telephone contains processors, transistors, and connectors all mounted on a printed copper circuit board?



► Driver or data reader from a personal computer, whose central structure contains several copper coils.



► Copper cables fulfill a wide range of functions in the home, office, and industry throughout the world.
 a) data transmission cable
 b) coaxial cable
 c) shielded tension cable

COPPER USES ACCORDING TO ITS PROPERTIES

High electrical conductivity

Throughout the world, copper is the metal predominantly used for wire, cable, and electrical conductors. In addition, coaxial cable is used in communications. These uses require extremely pure copper, which is produced as high-quality cathodes.

Conductivity also increases electrical efficiency by reducing energy loss due to conductor resistance. Thus copper, due to its electrical energy efficiency, also plays a role in lowering the buildup of greenhouse gases emitted into the atmosphere.

High thermal conductivity

This characteristic makes it possible to use copper, usually in the form of tubes and sheeting, in refrigeration and heat exchange devices such as radiators and air conditioners. Copper reels are also used as heat sinks in computer power sources. In hot environments, copper molds are used to obtain rapid solidification of the product in the form of ingots or bars.

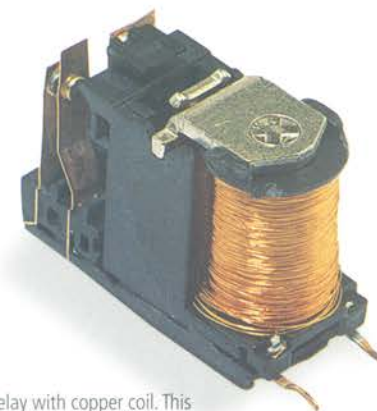
Recyclable

Recyclability allows existing copper wires, plumbing tube, and roofing to be processed into new, high-quality copper cathodes at reasonable cost. This quality of copper has generated an extensive network for acquiring secondary copper resulting in a recycling rate that is significantly higher than that of other products and metals. Currently, almost 40% of the copper consumed is recycled. It is estimated that over 80% of the copper produced throughout history remains in use.



► The old mechanical watch with brass (Cu-Zn) gears, gave way to the electric one using quartz or solar power. The image shows the copper coil from a modern wristwatch.

► This small fan uses a small electric motor to cool the computer processor.



► Relay with copper coil. This piece is an integral part of all electrical equipment.



► Copper coil from a television screen. Without this intricate system of copper wires it would be impossible to project clear television images.



► Copper is fundamental to computing. A hard disk, for example, functions using pieces made completely of copper.

Corrosion resistant

Copper and its alloys protect themselves from rust and deterioration by creating an attractive green coating that completely covers the surface of objects containing this metal. Because of this quality, copper (bronze) has been used to build monuments for thousands of years, and has been utilized for the cladding and roofing of buildings, palaces, and cathedrals.

This property makes it possible to use a wide variety of elements and artifacts without their suffering damage, even when permanently exposed to salty or corrosive environments.

Essential to life

Humans, plants, and animals all require trace amounts of copper to guarantee the healthy functioning of their organs and metabolisms. Copper, a micronutrient essential to life, promotes growth in

children, the correct functioning of enzymes, the transportation of iron in the bloodstream, the formation of bones, brain, heart, liver, and the nervous and immune systems.

Copper is also essential to the optimal development of the fetus during pregnancy.

In addition, copper, in the form of biochemical compounds, is used therapeutically to treat dermatological problems, bacterial infections, and other diseases, such as arthritis and cancer.

Bactericide

Because copper inhibits the growth of fungi, bacteria, algae, and viruses, including legionella, polio, and E-coli , it is used extensively as tubing to transport drinking water.

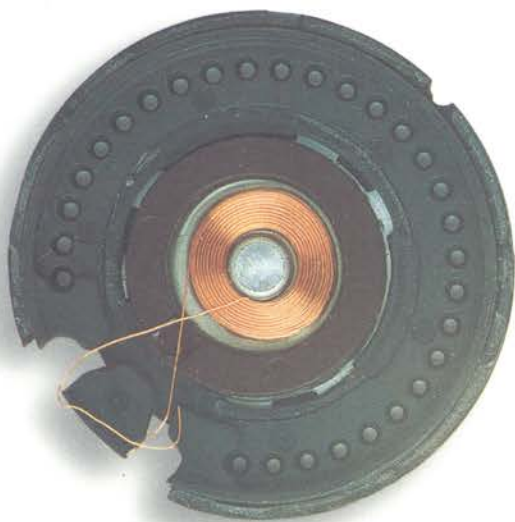
*In search of the stars.
The Planetarium, at the University of
Santiago, Chile, is a clear example of
the use of copper to cover the façade.*





▶ Copper and its alloys have boosted the processing speed of the latest generation of chips, a genuine technological leap forward that will especially benefit the world of information technology and telecommunications.

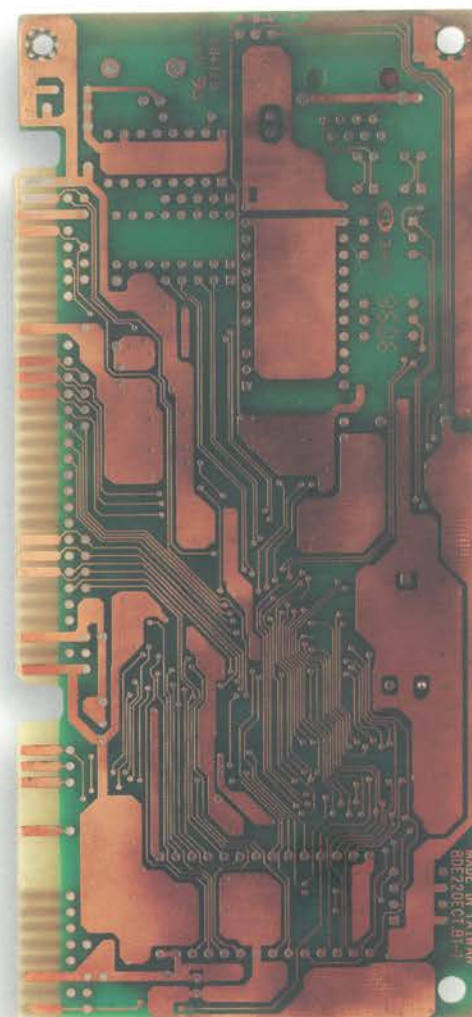
▶ Copper coil from a modem.



▶ Copper coils from a small electric motor.



▶ Heat sinks are used to avoid overheating the motherboards in computers.



▶ For a wide range of appliances, equipment, and instruments the electronic base is a network of copper conductors known as printed circuit boards.

Thus, copper pipes ensure optimum purity and quality of drinking water, thereby protecting the health of millions of people.

In the middle of the 19th century, sheets of copper were used to line the wooden hulls of boats to avoid the adherence of snails and the irreversible damage caused by woodworms.

Aesthetic

Copper is the only reddish metal used in industry that, thanks to its alloying capabilities, can be applied to obtain



a wide range of colors from metallic white and red to different shades of yellow. This has endowed it with an aesthetic value that is, with the exception of gold, unknown in the rest of the world of metals.

Its warm appearance and shades have led to the manufacture of millions of decorative objects and figures using bronze, brass, and other alloys, while copper itself is to be found in the architecture and statuary of palaces, temples, and churches.

The typical green coating that copper surfaces acquire symbolizes the very essence of permanence and beauty, so it is not strange to find that this metal has been chosen to cover the roofs of the most representative and symbolic monuments and buildings around the world.

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The author, a Civil Engineer specializing in metallurgy, studied at the University of Concepcion in Chile and the Technical University of Aachen, in Germany. He began his professional life as an engineer in charge of metallurgical projects and has been an executive with Codelco since 1984 in charge of marketing copper concentrate and blister. In 1990, he was appointed manager of Codelco's subsidiary in Düsseldorf, Germany. His interest in history and his commitment to copper contributed to the fact that during his six-year stay in Europe he became convinced that Chile needed a retrospective vision of its main export product. This is how the idea of demonstrating the importance of copper to human development was born. Codelco accepted the proposal and, ten years later, the exhibition "Civilization and Our Copper" came into being, at the Natural History Museum in Santiago, Chile. Its contents are summarized in this book.

With the ongoing support of Codelco and taking advantage of his frequent business trips all over the world, Alexander Leibbrandt continues to collect the most diverse range of objects made with copper and its alloys, as part of his efforts to complete the existing exhibition and prepare other books on the fascinating history, techniques and culture associated with copper.

COPPER

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