

METALS AND THEIR PROPERTIES

An overview of ferrous and nonferrous metals

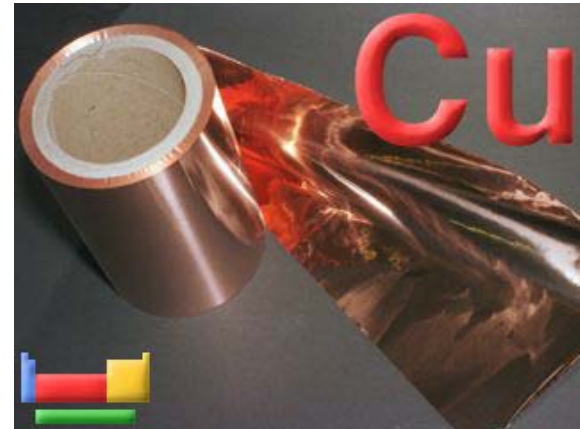


An important question....

- Gold, silver and copper were some of the first metals used by ancient peoples. Why these metals and not others like iron, steel, aluminum, and zinc?

Properties of Metals

- sometimes quite **dense**
- reflect light — **shiny**
- **conduct** electricity
- conduct heat

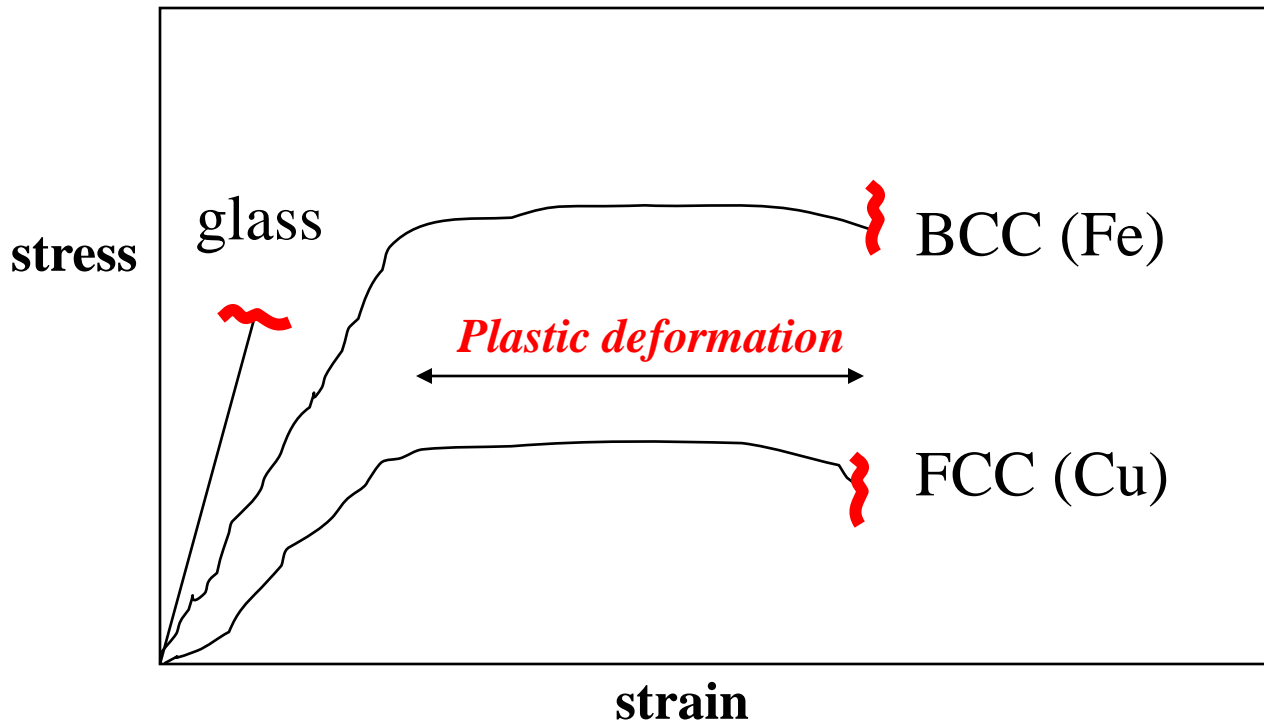


- **malleable** — pounded into thin sheets
- **ductile** — pulled into wire
- **Crystalline** solids
 - Except for mercury (Hg)



Manipulation of Structure...

- by heating and cooling
- by physical deformation — “working”
 - metals undergo *Plastic deformation* due to *slip*



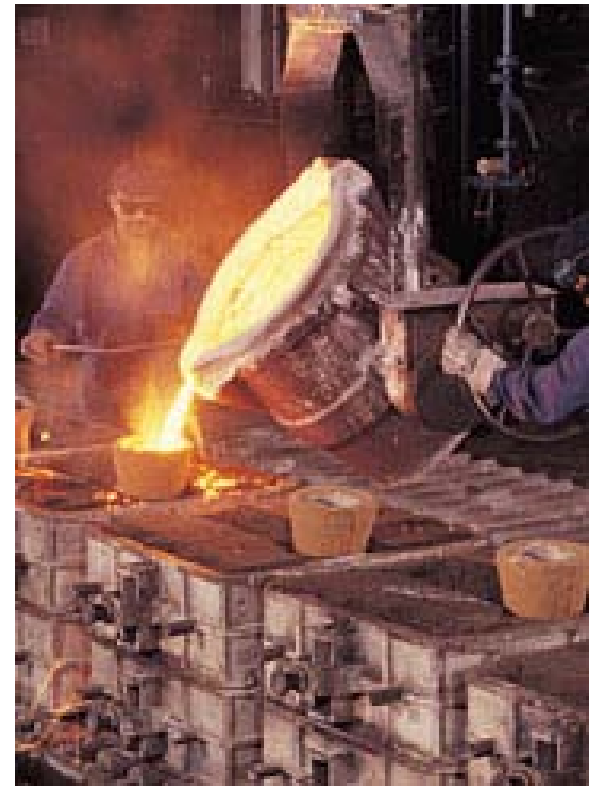
Native Metals

Gold Silver Copper

Occur in a “native” or free elemental state

Metallurgy

- Science of separating metals from their ores and preparing them for use
- One of oldest sciences
 - **molding** of native metals by Chinese, Egyptians, American Indians
 - “**smelting**” of lead, iron by Egyptians
 - making **alloys** — bronze, brass, steel



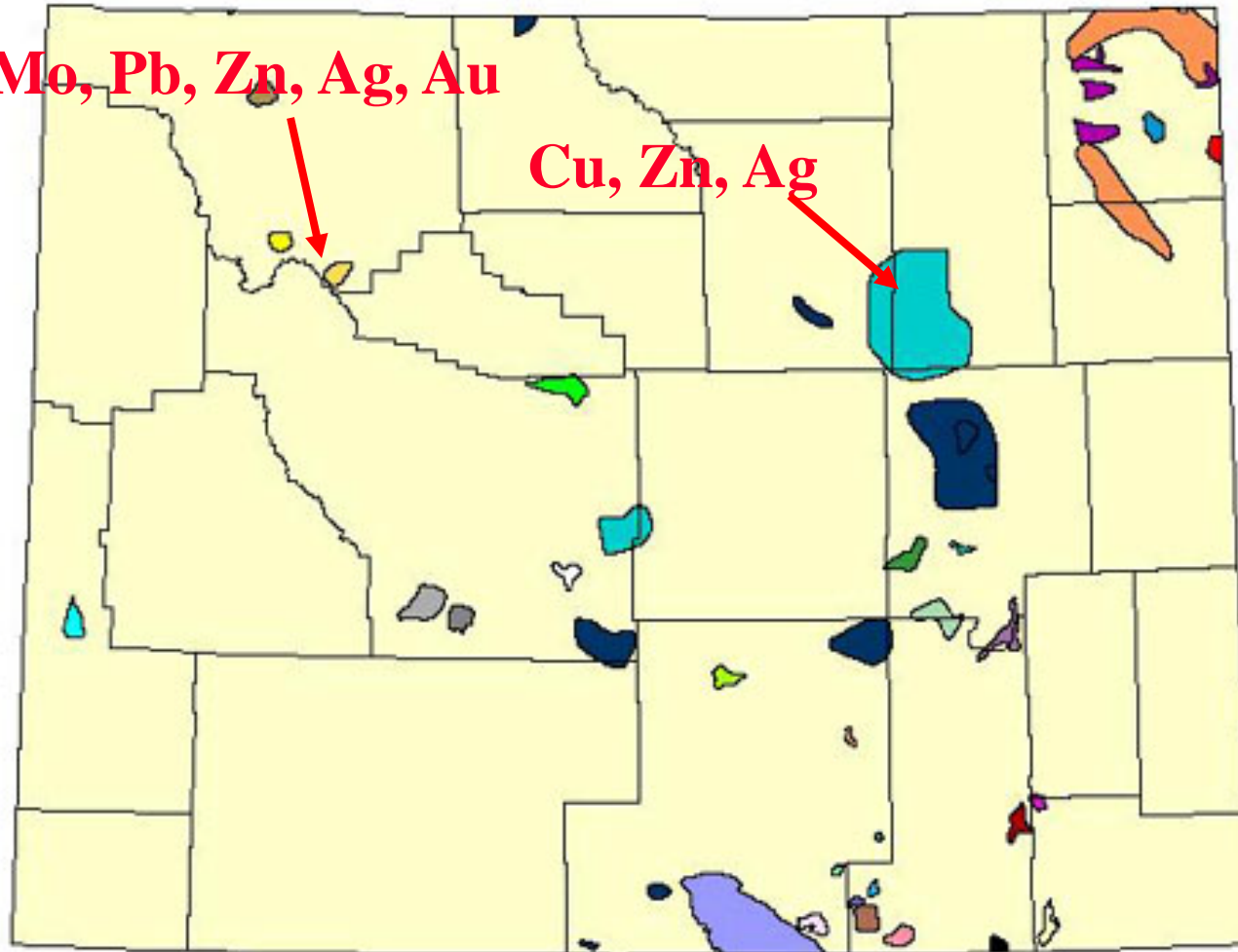
80% of the known
elements are metallic

Colorado

Base and precious metals

Cu, Mo, Pb, Zn, Ag, Au

Cu, Zn, Ag



- Base and precious metals
- AG, AS, GARNET, CU, AU, B
 - AU
 - AU, AS, AG, CU, FE, U
 - AU, FE, CU, PB, AG
 - AU, PT, AG
 - AU, W, AG, AS, FE
 - BENTONITE
 - CU
 - CU, AG, AU, U, VERMICULI
 - CU, ASBESTOS, VERMICUL
 - CU, AU, AG, PB
 - CU, AU, AG, PT, PD, AS
 - CU, AU, AG, PY, JADE, RUB
 - CU, AU, AG, ZN
 - CU, AU, FE, W, U, AG
 - CU, AU, U, AG, PB, ZN, BA,
 - CU, CO, U, AG, AU, ZN, C, P
 - CU, FE, AU, JADE
 - CU, MO, PB, AG, ZN, AU
 - CU, MO, PB, ZN, AG, AU, HG
 - CU, ZN, AG
 - F, REE, TH, U, CU, MN, AU
 - FE, CU, AU, AS BESTOS, JA
 - FE, TI
 - K-S PAR, KIMBERLITE, U
 - KIMBERLITE
 - PB, MN, AG, CU, AU, ZN
 - TH, REE, U, VERMICULITE
 - U
 - U, AU, CU, PB, AG, SN, K-S
 - U, V
 - U, ZEOLITES
 - Counties

Source: U.S. Bureau of Mines (1994)

Categories of Metals

- **Ferrous** and **nonferrous** metals
- **Precious** and **base** metals
- **Pure metals** and **alloys**

Nonferrous Precious Metals

- Most often used for jewelry

- Gold
- Silver
- Platinum

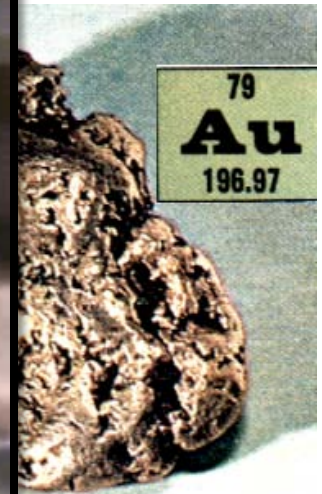


- Very stable and non-reactive

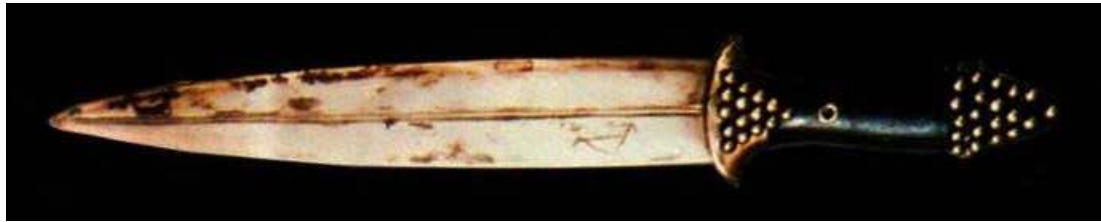
GOLD — Au



worked
(Iraq)



Gold Weapons



Golden Daggers From the Royal Tombs of Ur 2500 BCE , Collection of The Chicago Oriental Institute

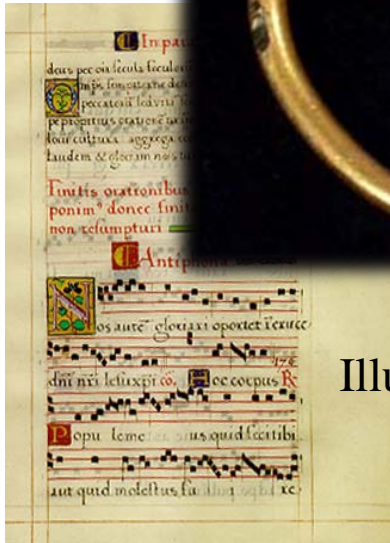
- very soft and **malleable**



Gold in Art Materials

- ornaments, jewelry, utensils made from “native gold”

- gold
incl



Illuminated manuscript
15th century



Tempera Panel Painting
11th-12th century

SILVER

$\Delta \sigma$



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40
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metal occurs
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combined in

compounds (ores)

Nonferrous Base Metals

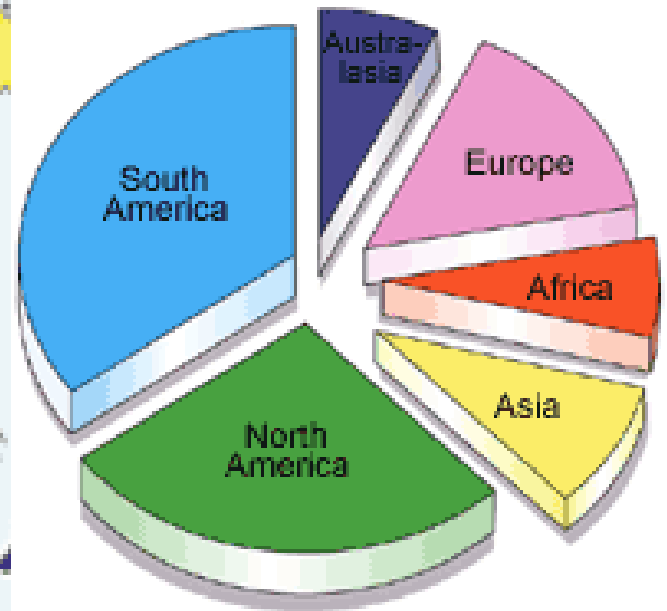
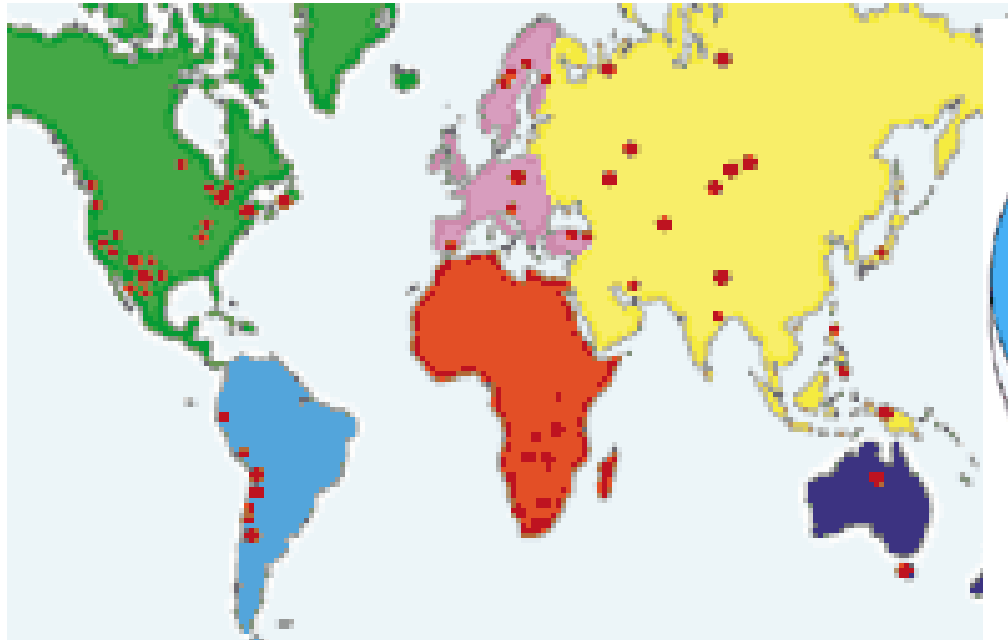
- Contain no iron (Fe) or iron alloys
- Commercially important metals
 - Copper (Cu)
 - Aluminum (Al)
 - Zinc (Zn)
 - Tin (Sn)
 - Lead (Pb)
 - Nickel (Ni)
 - Mercury (Hg)

COPPER — Cu



A piece of native copper

Copper Mining



Copper ore
Malachite
 $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$



Copper ore
Chalcopyrite
 CuFeS_2

Alloys

- Solid homogeneous mixture of 2 or more metals
- Gives metal more desirable properties
 - Harder or less brittle
 - Higher or lower melting points
 - Less susceptible to corrosion
 - Less expensive

The *Bronze Age* (5000 BC)

- Earliest alloys were formed by accident

Bronze = copper + tin (Cu + Sn)

Egyptian Bronze Dagger with Ivory Handle 1550 BCE, The Louvre Museum, Paris France



Bronze sword of the British Isles from the 2nd Millennium BCE



Bronze Sculpture



Perseus with the Head of Medusa
1545–54

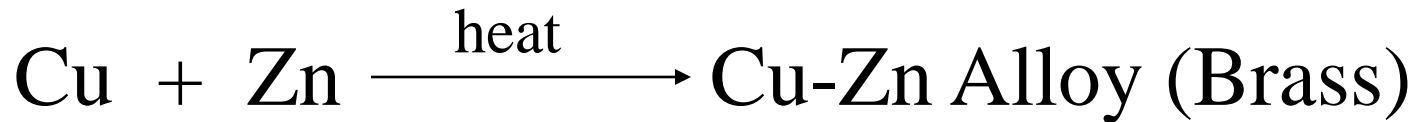
Benvenuto Cellini
(Italian, 1500–1571)

- Bronze is tougher, more easily melted and cast and less susceptible to corrosion than copper
- over 100 different Cu alloys available today

Copper to “Silver” to “Gold”



- Place penny in hot Zn/NaOH
- Pass “silver “ penny through a hot flame



Brass = copper + zinc (Cu + Zn)

NuGold® — A brass alloy

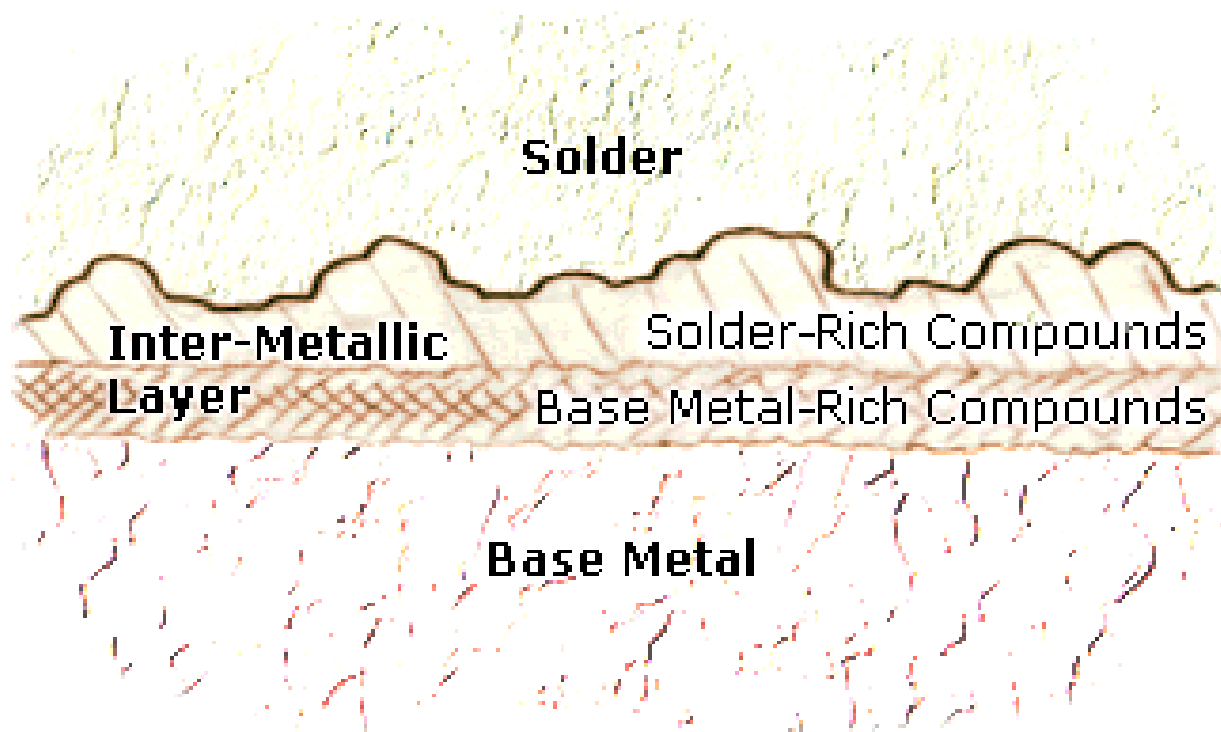
- Jewelry sheet metal
- Red-Brass, Merlin's Gold
- Decorative embossed metal



Copper + Zinc, no Nickel

Solders

- Used to join metals
- Relies on the capillary action of melted metals



Jewelry Solders

- Hard solders — melt at over 1000°F
- Soft solders — melt at under 1000°F

	%Ag	%Cu	%Zn	Flow point
Hard silver solder	75	16	4	1490°F
Easy silver solder	65	20	15	1325°F
Ag	100			1761°F
Cu		100		1981°F
Zn			100	787°F

Precious Metal Alloys

■ Gold Alloys — measured in karats

karat = 1/24 part

- 24 karat = pure gold
- 18 karat = 18 parts pure gold + 6 parts Cu
- 14 K = 58% Au, 24% Ag, 17% Cu, 1% Zn
- 12 K = 50% Au
- 10 K = 42% Au



■ NuGold — contains no gold — it is a brass alloy

Silver Alloys

- Sterling Silver (**92.5% Ag** & 7.5% Cu)
- Coinage Metal (**90% Ag** & 10% Cu)
- Dental Silver (**65-70% Ag**, 3-6% Cu, 25-29% Sn, 0.2% Zn)
- Nickel Silver and German Silver — contain **no silver** (20% Ni, 60% Cu, 20% Zn)
- Nickel Coins — contain **no silver** (25% Ni, 75% Cu)

Coinage Metal Alloys

■ Pennies

- Pre-1982 are Cu
- Post-1982 are 2.5% Cu and 97.5% Zn

■ Quarters

- 91.67% Cu and 8.33% **N**

■ Golden dollar

- 88.5% Cu, 2% **Ni**, 6% Zn, 3.5% Mn



Washington
Quarter



Sacagawea
Dollar



Lincoln
cent



Do coins really smell?

NO, you do!

Other Alloys — *Memory Wire*

■ Ni

—

■ Co

def

■ Ho

Variety

De

Robotics

Joining hydraulic tubes

Thermostat controls



searchers

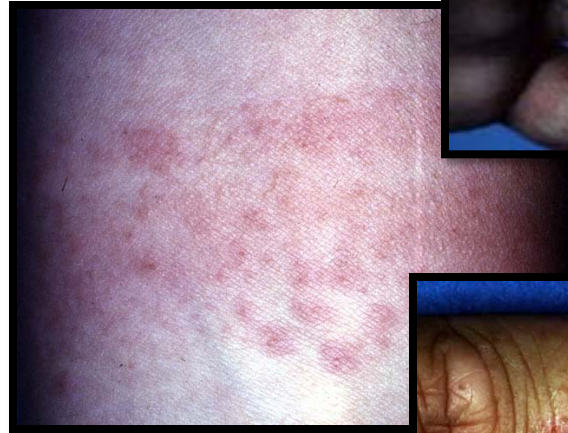
re easily

re more rigid



Nickel Allergy

- Contact dermatitis
- May develop at any age
- Comes from
 - Wearing rings
 - Earrings
 - Watch bands
 - Handling coins



Into piercing?

- **Stainless Steel**, Surgical Implant Grade (316LVM CrNiMo, ASTM F-138)
- **Titanium**, Surgical Implant Grade (Ti6Al4V ELI, ASTM F-136)
- **Niobium (Nb)**
- **Solid Gold** (14 karat or higher white or yellow nickel-free gold)
- **Platinum**



Ferrous Metals and Alloys

- Contain the element **iron (Fe)**
- Iron is most often found as **ores**

– Iron oxides

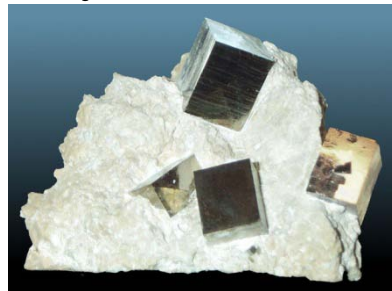
» Hematite Fe_2O_3

» Magnetite $\text{FeO} \cdot \text{Fe}_2\text{O}_3$ or Fe_3O_4

» Limonite $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$

– Iron sulfides

» Pyrites FeS , FeS_2



The *Iron Age*

- 4000 B.C. Egypt (concurrent with Cu/Bronze Age metallurgy)
- 14th century B.C. Hittites (modern Turkey)



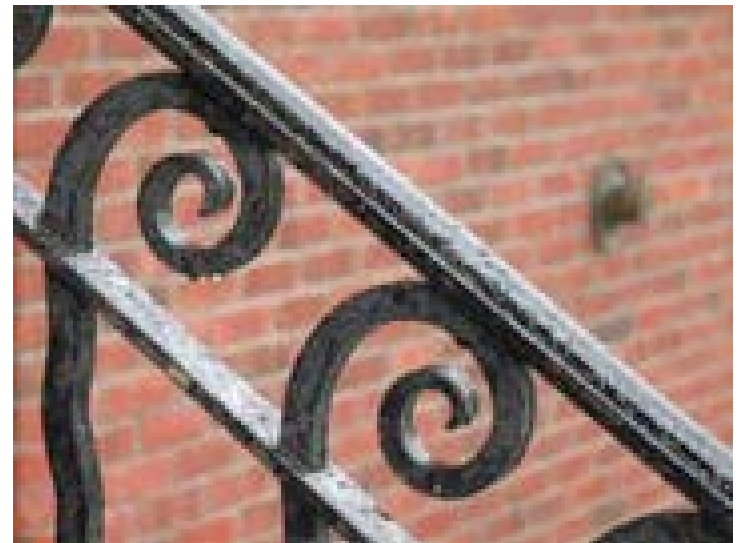
Viking swords



Kirkburn Sword Iron Age, 300-200 BC
From a burial at Kirkburn, East Yorkshire,
England

Common Ferrous Metals

- Wrought iron
 - Think blacksmith!
 - Almost no carbon content
 - Tough, malleable, ductile, easily welded
 - Hammered, heated and worked



Ferrous Metals

- Cast iron
 - Alloy containing more than 2.1% carbon
 - Brittle



Ferrous Metals

■ Steel

- alloy of iron that contains 0.15-1.5% carbon
- Other metals are added to impart certain properties (eg. Mo, Ti)



Categorize the Following Metals

- 18 karat gold
- copper
- steel
- sterling silver
- cast iron
- bronze
- aluminum
- platinum

Abundance of Metals

- Almost **80%** of elements are metals
- Percent of Earth's crust
 - Al = 7.4%
 - Fe = 4.7%
 - Ca = 3.4%
- Native metals — Cu, Au, Ag, Hg
- **Metal compounds** — ores of Pb, Cu, Fe, Sn, Al, Zn