

# LECTURE # 5

***IRON (Fe = Ferrum)***

# METALS

## Year of Discovery

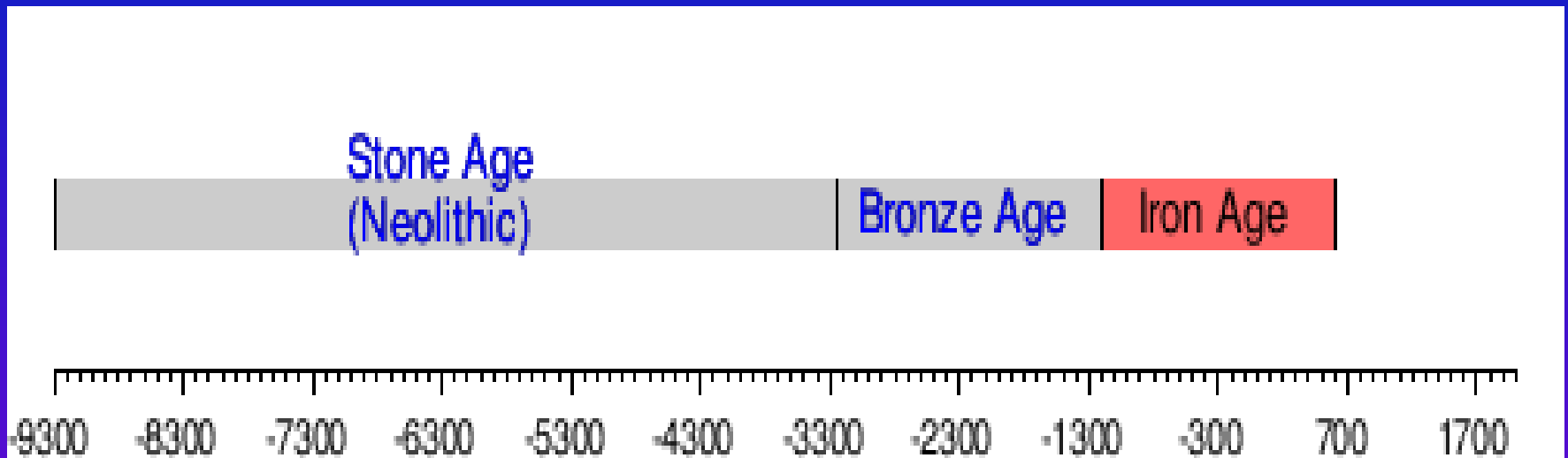
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# Metals in Earth Crust

Parts per million

<b>Iron</b>	<b>50,000</b>
Copper	70
Lead	16
Tin	2
Silver	0.1
Gold	0.005

# Bronze and Iron Ages



# IRON

35% of Earth's mass as Fe-Ni alloy

5% of Earth's crust

**Fourth most abundant** in the Earth's crust

Found as oxides: *hematite* (oxide), *limonite* (hydroxide),  
*magnesite* (carbonate), and *siderite* (carbonate)

Large deposits of iron sulfate (*pyrite*)

Easily oxidized ⇨ rust ⇨ red spots and bands on rocks

Pure iron is soft. **Hardened with addition of coal**

**Important element in human body (hemoglobin in the red blood cells, myoglobin in muscle cells)**

# Iron Timeline

3,500 BC - Egypt - Meteoritic iron (7.5% nickel) soft

3,000-2,700 BC - Mesopotamia - First iron production

Heating and hammering was used

~1,500 BC - Melting point was too high for ancient  
furnaces:

- Copper's melting point = 1,085°C
- Tin's melting point = 232°C
- Iron's melting point = 1,538°C

1,500-1,200 BC - **Hittites** - Made high temperature kilns

First to smelt iron ⇨ **IRON AGE**

# Iron Timeline (cont'd)

India 1,200 BC - Greece 1,100 BC - Roman Era - Celtic expansion - Europe

Large scale iron production – 1,200-1,000 BC

**1,000 BC** - Charcoal was added to iron ⇨ **steel**

513 BC – Chinese made furnace capable of melting iron

18<sup>th</sup> Cent. England - **Industrial Revolution** - Refining pig iron to wrought iron (less carbon) ⇨ **steel**



# Iron Age

Started in Anatolia ~1,200 BC

**Changed the civilization and culture because of the new tools introduced**

- **Agriculture methods - Metalsmithing**
- **Lifestyle** – many new objects
- Alphabetic characters ⇨ **Written language**
- Religious practice – Vedas, Hebrew Bible
- Artistic styles ⇨ decorations, designs
- Weapons, wars ⇨ destruction

# Diffusion of Metallurgy from Asia Minor in the Neolithic Era



# Copper, Bronze, and Iron Ores in Sub-Saharan, Central, and South Africa



# Iron furnace



# Alloys of Iron

Mixture of two or more elements in which the main component is a metal

Modifying the properties for a desirable effect: **Harder, non-corrosive, luster, color, cost**

**Alloys of iron: Steel, stainless steel, cast iron, tool steel**

Stainless steel: carbon steel + chromium, nickel, molybdenum

Cast iron: iron + silicon

Tool steel: Iron + tungsten, chromium, vanadium, molybdenum

High strength-to-weight: Alloys of aluminum + titanium + magnesium

# Iron Uses

Found in a wide variety of oxides (rust)

Relatively soft metal

Smelting process carbon added (2.1% = **steel**)

Made possible our **progress** in construction and modern life. All means of **transportation**, appliances, etc.

**Core of modern civilization**

# Iron in Humans

From nutrition, iron passes into blood – attached to **transferrin**

Iron deposits in **bone marrow** where red blood cells are formed

**Hemoglobin** in red blood cells and **Myoglobin** in muscles

cells  $\Rightarrow$  oxidation

**Hemoglobin** = **heme** + globin (a protein)

Heme has iron in its molecule

In the lungs: Blood red cells (hemoglobin + oxygen) = oxyHb.  $\Rightarrow$

tissues  $\Rightarrow$  carboxyHb.  $\Rightarrow$  lungs  $\Rightarrow$  oxyHb.

Chronic loss of blood  $\Rightarrow$  **Iron deficiency anemia** (heavy periods, lack of iron intake by children). Treatment: Iron by mouth for 1 yr.

- Overdoses of Fe by mouth are not recommended  $\Rightarrow$  iron overload + peroxides  $\Rightarrow$  free radicals  $\Rightarrow$  DNA damage

***MERCURY [Hydrargyrum (Hg)]***  
**(also Known as Quicksilver)**



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# MERCURY



# MERCURY

Only **liquid metal** at standard temperature. Heavy.

Found in the mineral **cinnabar** (mercuric sulfide) -  
**red pigment - vermilion**

**Extremely rare.** Mines in Italy, USA, Mexico

Does not blend with other metals. May be kept in iron  
containers. Concentrated in ores.

Dissolves gold and silver

**Extremely toxic – uses declined b/o environmental**

**safety.** Water through **abandoned** mines ⇔

ecological danger. Minamata disease in Japan.

# Cinnabar



# Mercury – Timeline

Found in Egyptian tombs ~1500 BC

500 BC - **Amalgams**

Used in Egypt, Greece, Rome as cosmetic

Medieval Age Alchemists : **Hg = “First matter”**

Widely used by alchemists to obtain gold

1558 – Mercury used in silver extraction by Spain in  
Peru

2005 - Mines in China  $\Rightarrow$  2/3 of world producer using  
prison labor

# Minamata Disease

1936-1968 - Industrial pollution of water with methyl-mercury in Minamata Bay.

Severe neuro-muscular symptoms.

2000+ affected, 2000 died.

Chisso Corp. (chemical industry) not cooperating with the investigation.

Paid financial compensations

**Cause:** Methyl-mercury released in water ⇒ poisoned fish and shellfish ⇒ eaten by fishermen

1965 – Second Minamata disease in Niigata

# Minamata Bay and Chisso Factory



# Mercury - Uses

**Dental filings** – Amalgam with silver

**Mercury-vapor** lamps – electricity – Hg. vapor  $\Rightarrow$  S/W UV  
light waves light  $\Rightarrow$  phosphor in tube  $\Rightarrow$  **fluorescence**

High temp. thermometers

Many medical uses have been **discontinued**:

- *Thimerosal* (vaccine preservative)
- *Mercurochrome* (topical antiseptic)
- Diuretics, anti-syphilis medications
- Glass thermometers
- Blood pressure cuffs



# Dental Fillings

## 1. Dental amalgam fillings:

- Mercury 50%, silver, tin, and copper.
- 150 years experience,
- Solid, easily prepared, low cost.

## 2. Resin Composite fillings:

- 10 years experience,
- Durable, cosmetic
- Expensive

# Dental Filing = Amalgam of Mercury and Silver



# Mercury lamps



# ***NICKEL (Ni)***

# NICKEL

Rare metal in Earth's crust

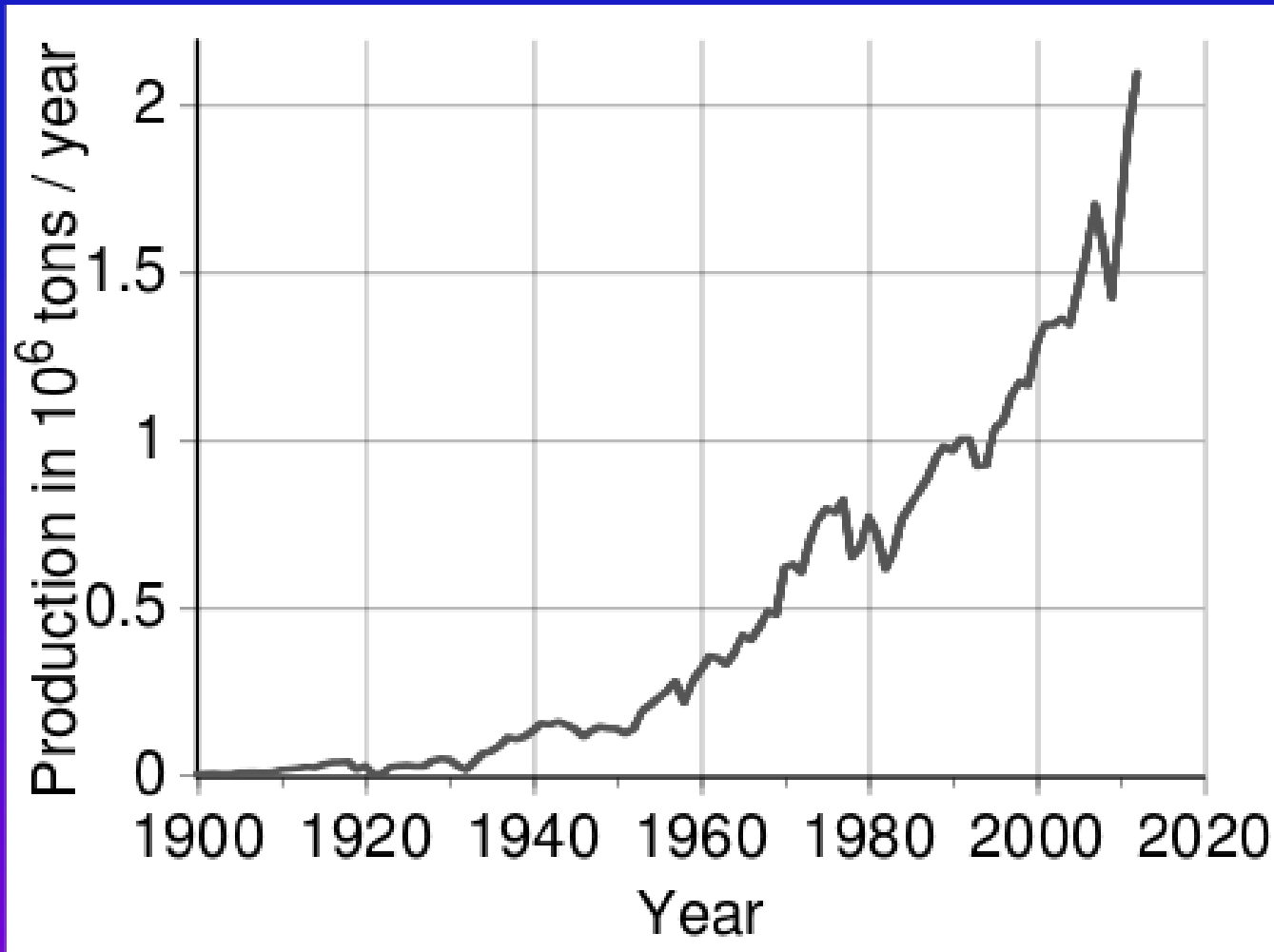
Usually iron-nickel mixture

Corrosion-resistant

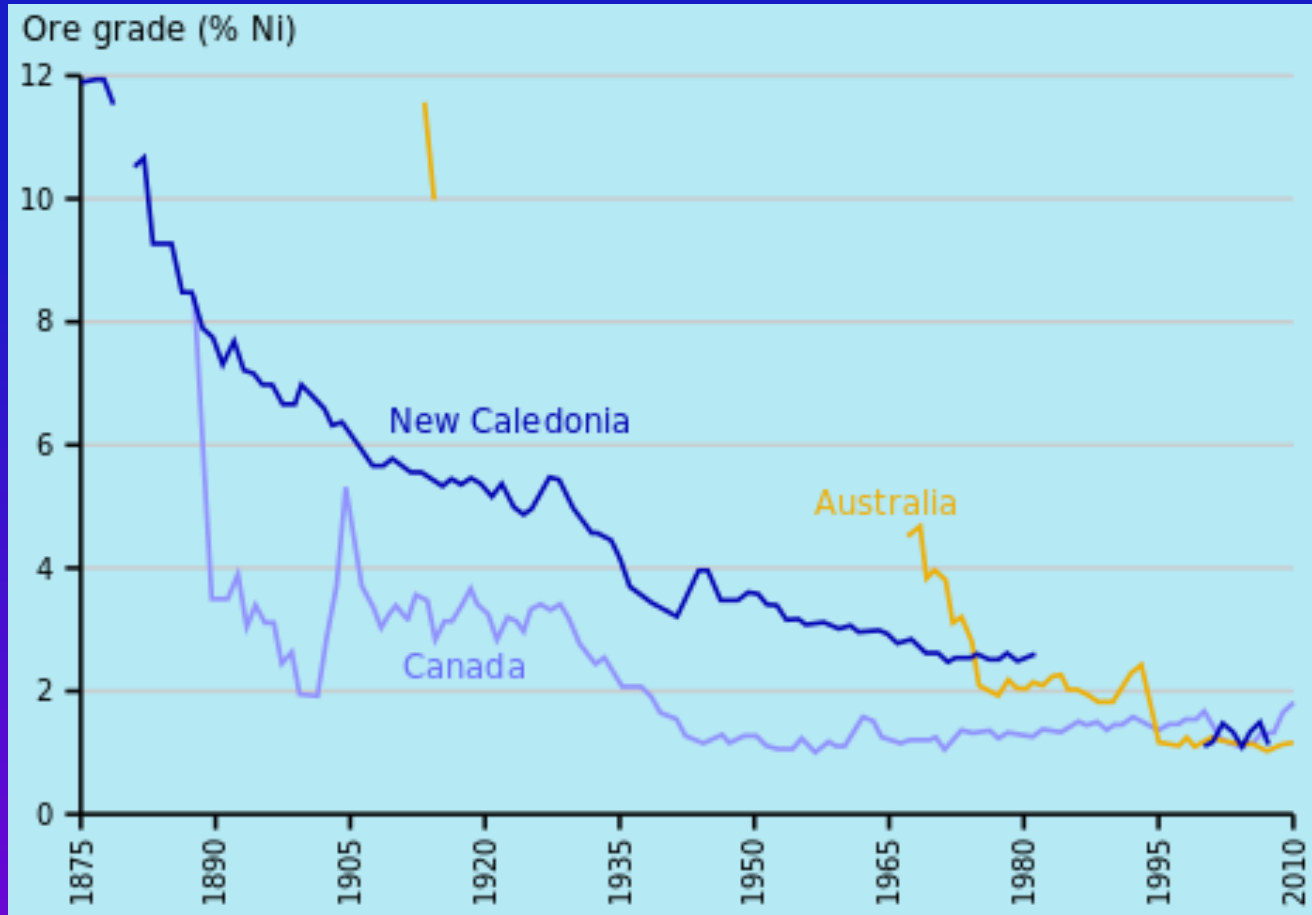
Used in alloys

Necessary in industry, metallurgy

# Nickel Production



# Nickel Ore Reserves



# ***CHROMIUM (Cr)***



# CHROMIUM

Known to Chinese 3<sup>rd</sup> cent BC – Xi'an weapons without erosion because of chromium oxide coating of the bronze

Found in mineral **crocoite** (1761)

Extracted as iron chromate oxide

Resists tarnish

# Chromium - Uses

Stainless steel and plating = 85% of commercial use

Dye and pigment **chrome yellow** - aerospace

Diet - not sufficient information

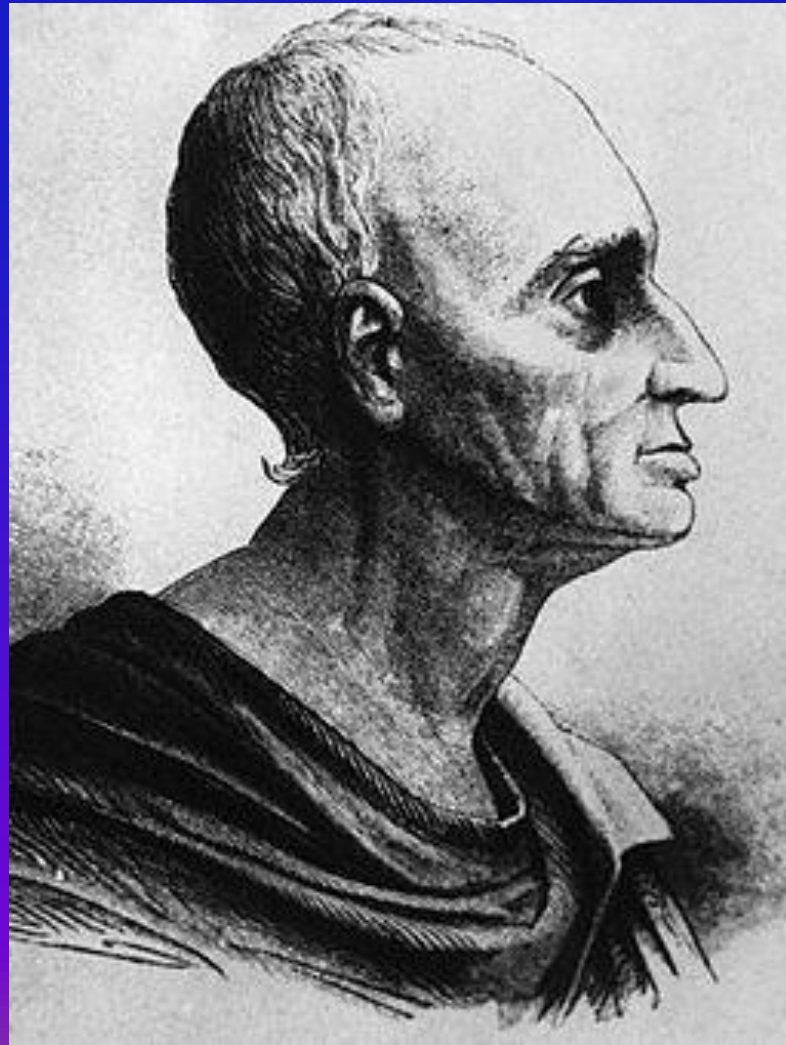
Chromium in drinking water: 25/35 cities = higher  
than the California proposed limits

# Chromium World Production



**ZINC (Zn)**  
**(from German “Zinke” = prong)**

# Andreas Sigismund Marggraf Discovered Zinc - 1746



# ZINC

Found as zinc ore **sphalerite** (zinc sulfide)

Ores, associated with other metals (copper, lead)

Large deposits: Iran, Australia, Canada, USA

Refined zinc production increased 80% in 2009

Reserve lifetime is OK

**Corrosive-resistant zinc plating of iron = galvanization**

Important for humans “**Exceptional biologic and public importance**”

**Zinc deficiency:** Exercising, childhood growth, pregnancy, and diarrhea increase utilization

**Zinc toxicity known**

# Zinc - Timeline

## Alloy with copper ⇔ Brass

- 3,000 BC - Aegean islands, Mesopotamia, Caucasus
- 2,000 BC - Persia, Mesopotamia, Judea, W. India

## Pure zinc:

- 900 CE - Rajasthan, India
- 1,300 CE - India
- 1,600 CE – Europe

## Alloy of copper + zinc (zinc identified only in 1746)

1746 – Isolated and described by Margraf, a German chemist

1800 – Galvani & Volta discovered electrochemical

properties of Zn ⇔ **Plating of iron = “galvanization”**

# Zinc Uses

**Brass** - Superior corrosion-resistant

- More ductile and stronger than copper

Many industrial and home appliances, musical instruments

Various alloys, semiconductor (ZnO) white pigment

**Batteries** - Luigi Galvani experiment and Volta's pile.

- Plates of copper and zinc  $\Rightarrow$  static **electricity**

**Galvanization** - Zinc coating iron to protect from rust

**Dietary supplement** - Effect in prostate cancer (?)

**Topical uses** - Calamine lotion

- Sickle cell disease skin ulcers



# Zinc – Intake

Present in many body enzymes - 1940 - carbon anhydrase  
contains zinc

Present in most organs; highest in prostate, eye, brain

US IOM – **Est. Ave. Requirements = 8-11 mg/day.**

**RDA = 11 mg.**

Tolerable Upper Intake Level (UL) = 40 mg/day

**Dietary intake:** Oysters, meat, fish, fowl, eggs, dairy,  
wheat (bran), seeds, beans, nuts, fortified cereals

# Foods Containing Zinc



# Zinc Deficiency

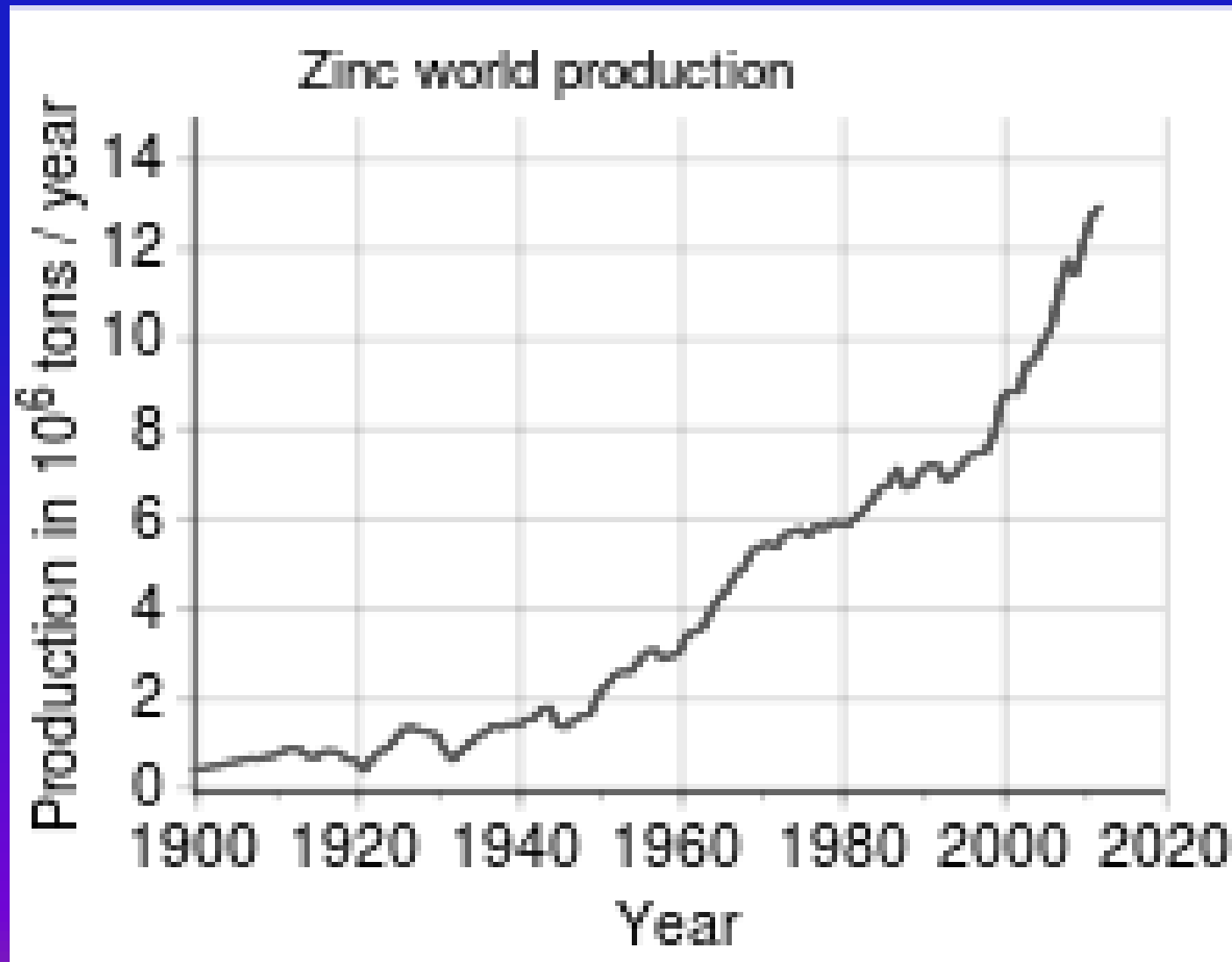
**Deficiency – Malabsorption**, chronic liver and kidney diseases, sickle cell disease, elderly,  
Low intake **< RDA = 15 mg/day**

USA – Less than EAR: Women - 17%; Men -11%

2.2 Bil. people are deficient. 800,000 children  
dead/year

**Symptoms:** Retarded growth of children, diarrhea,  
skin lesions, depression, cognitive and  
immune system impairment, anosmia

# Zinc world production



# ***MAGNESIUM (Mg)***

# MAGNESIUM

Name comes from *Magnesia*, in Greece

Eighth most abundant element in Earth's crust

Highly reactive – found in minerals

Very important in industry

**Essential for life: human body and plants**

Important structural metal (3<sup>rd</sup> after iron and aluminum)

Highly flammable, intense white light

# Magnesium – Production

1618 – Farmer in Epsom, England, had water rich in Mg. which healed skin lesions

1808 – Isolated in England

China is greatest supplier (80% of world supplier)

# Magnesium

**Uses: Super-strong lightweight alloys:**

**Aircraft** - (engine, airframe)

**Automotive** (engine blocks,  
magwheels)

**Electronics**

**Photography, printing**

**Batteries**

**Roofing**

**Medicine** - important electrolyte

**Plants** - chlorophyll



# Magnesium - Biomedicine

## Essential to cell functions

>300 enzymes require magnesium ions

60% in the skeleton; **39% intracellular**

RDA = **300 mg/day**; only 32% of US people meet the RDA

**Sources:** Green leafy vegetables, cereals, nuts, spices

Level maintained by GI absorption/loss, and kidney excretion

**Magnesium deficiency: Common life threatening –**

↓ intake, GI or kidney dysfunction,

↑ intracellular shift, antacids, alcoholism, diabetes

**Symptoms:** Neuromuscular and cardiac dysfunction

# Foods rich in magnesium



# *ALUMINUM (Al)*

# ALUMINUM

**Third most abundant** in the Earth's crust

Chemically reactive  $\Rightarrow$  mostly in minerals

Chief ore = **Bauxite**

Found as oxides and silicates

**Feldspars** are aluminosilicates

**Aluminum is corrosion-resistant**

**Best known “strength-to-weight” alloy**

**Essential for the aerospace industry, structures,  
building, transportation**

# Bauxite – A major aluminum ore



# Aluminum - Uses

- **Transportation** (aircraft bodies)
- Packaging
- Containers (food, beverages)
- **Construction**
- Household items
- **Electronic appliances**
- **Electrical transmission lines**
- Cooking utensils
- Coins
- Metal instruments (guitar resonators, and electric guitar speakers)

# Aluminum - Economics

2005 – Major producers: China (1/5), Russia, Canada, USA

**Recycling:** Very active

Melting aluminum saves electrical energy

**Aluminum recycling: 42% - 95% in Europe**

# World Production of Aluminum





# Aluminum - Biomedical

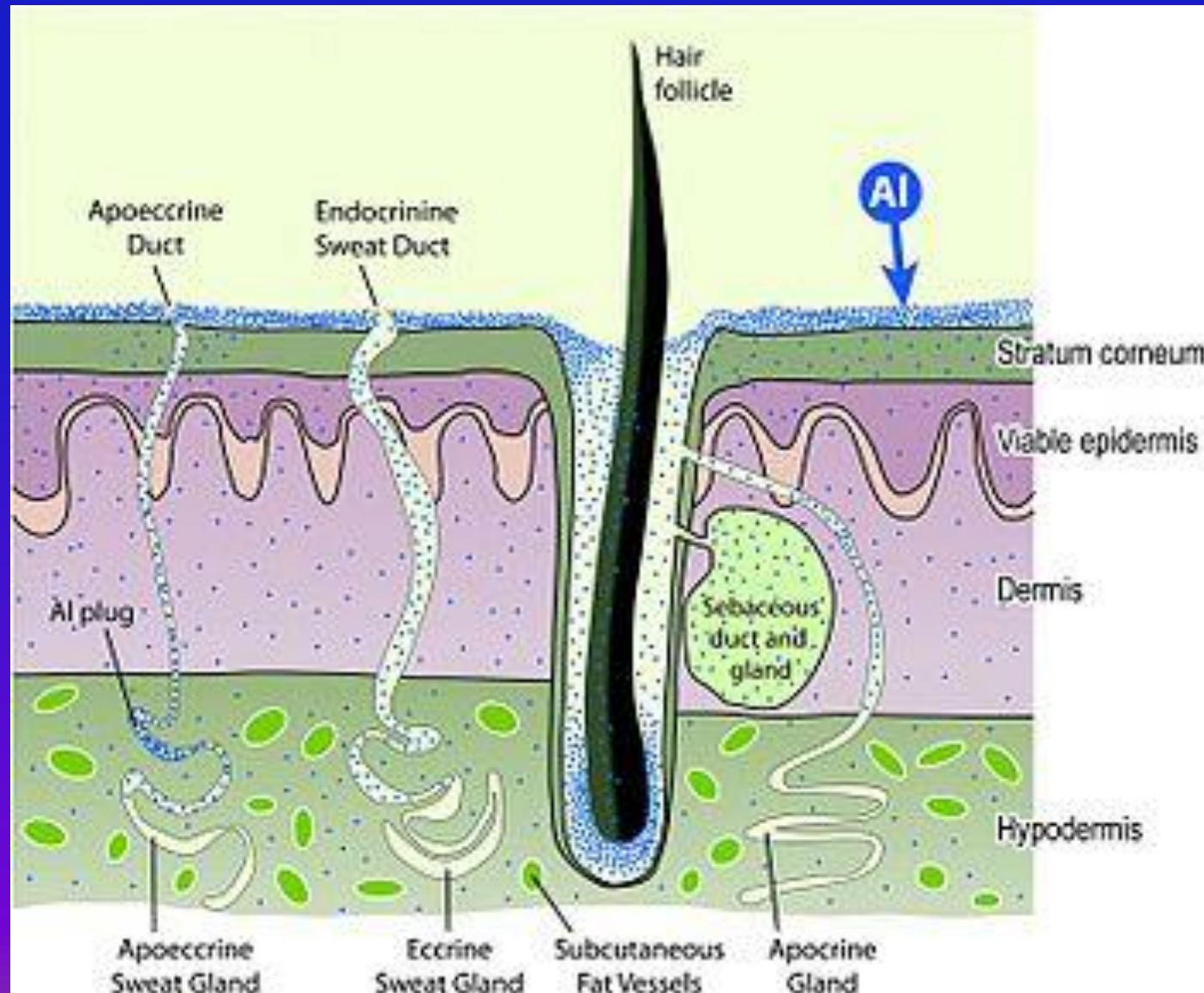
No known function in biology

Excessive use of antacids and antiperspirants ⇨  
toxic effects – nervous system and bones

No conclusive evidence on role in Alzheimer disease

Exposure to powdered aluminum ⇨ **pulmonary  
fibrosis**

# Aluminum absorption by human skin



***SAPPHIRE***

# SAPPHIRE

Gemstone variety of the mineral **corundum** (an aluminum oxide)

**Many colors:** blue, yellow, purple, orange, grey, black, clear (white)

Natural or synthetic

Very hard (grade 9/10)

Uses: Jewelry, ornaments, electronics

**Producers:** Australia, Thailand, Sri Lanka, China, Madagascar, E. Africa, Montana

**Uncut Rough Sapphire  
Spokane Sapphire Mine,  
Helena, MT**



# The Blue “Logan Sapphire” 423-carat (85g)



# The Blue Sapphire





# Synthetic Sapphire





# Synthetic Star Sapphire



***CALCIUM (Ca)***  
***from Lat. “calx-calcis” = lime***

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# CALCIUM – NATURAL HISTORY

Earth metal, soft, grey. Very reactive - found only as compounds (salts of calcium)

## Geochemical cycling:

- Calcium-rich rocks erosion  $\Rightarrow$
- Calcium released into surface water  $\Rightarrow$  Oceans  $\Rightarrow$
- Calcium reacts with dissolved  $\text{CO}_2$   $\Rightarrow$  Ca carbonate  $\Rightarrow$
- Limestone is formed

## Essential to living organisms

# Calcium Timeline and Uses

14,000 - 7,000 BC – Used as lime plaster and statues

2,500 BC - First lime kiln - Mesopotamia

1<sup>st</sup> Cent. Romans prepared lime for buildings and  
statues

975 CE - Plaster of Paris (Ca sulfate) to set broken  
bones

1808 CE - Calcium isolated by Sir Humphry Davy

Most abundant metal in many animals

2000 CE - Large scale industry use of various salts

# Some Calcium Uses

Ca carbonate – Lime

Ca hydroxide – for detecting presence of  $\text{CO}_2$

Ca arsenate – insecticide

Ca chloride – ice removal, additive to canned tomatoes

Ca citrate – food preservative

Ca hypochlorite – swimming pool disinfectant

Ca phosphate – suppl. animal feed, fertilizer

Ca sulfate (gypsum) – blackboard chalk, Plaster of Paris

# Green Calcite from Mexico



# Red Calcite from China





# Dolomite (white) + Magnesite (yellow) from Spain



# Orange Mound Spring, Yellowstone



# Travertine Terraces - Mammoth Hot Springs, Yellowstone National Park





# Travertine terraces, Pamukkale, Turkey



# Pamukkale, Turkey



# Calcium - Biomedical

Necessary for life

99.9% of calcium is in the bones and teeth

Necessary as a **neurotransmitter**, for **muscle contraction, cardiac function, and normal blood clotting**

**Deficiency: Rickets, osteoporosis, cardiac dysfunction, clotting abnormalities**

**Vitamin D - necessary for calcium absorption and utilization**

**Intake: Dairy products, nuts, some vegetables**

**Retention in blood = Medical emergency**

# Rickets and Osteoporosis

Diseases of calcium deficiency in the bones

Calcium needs **vitamin D** to be absorbed.

Vitamin D is activated in the skin from an inactive form

If low CA  $\Rightarrow$  Skeletal deformities

Osteoporosis = imbalance btw. production and destruction of bone

**RDA for >70 y.o. = 1,200 mg**

Foods that contain vitamin D include: butter, eggs, fish liver oils, margarine, fortified milk and juice, portabella and shiitake mushrooms, and oily fishes such as salmon, tuna, and herring.

***MARBLE***



# MARBLE

**Calcium carbonate** sedimented in layers (foliation)

Mostly calcite and dolomite (aka. **limestone**)

Effect of water: holes and carving the stone ⇔ caves

**Uses:** Sculpture

Construction

# Carrara Marble



# Foliation (layering) of Limestone

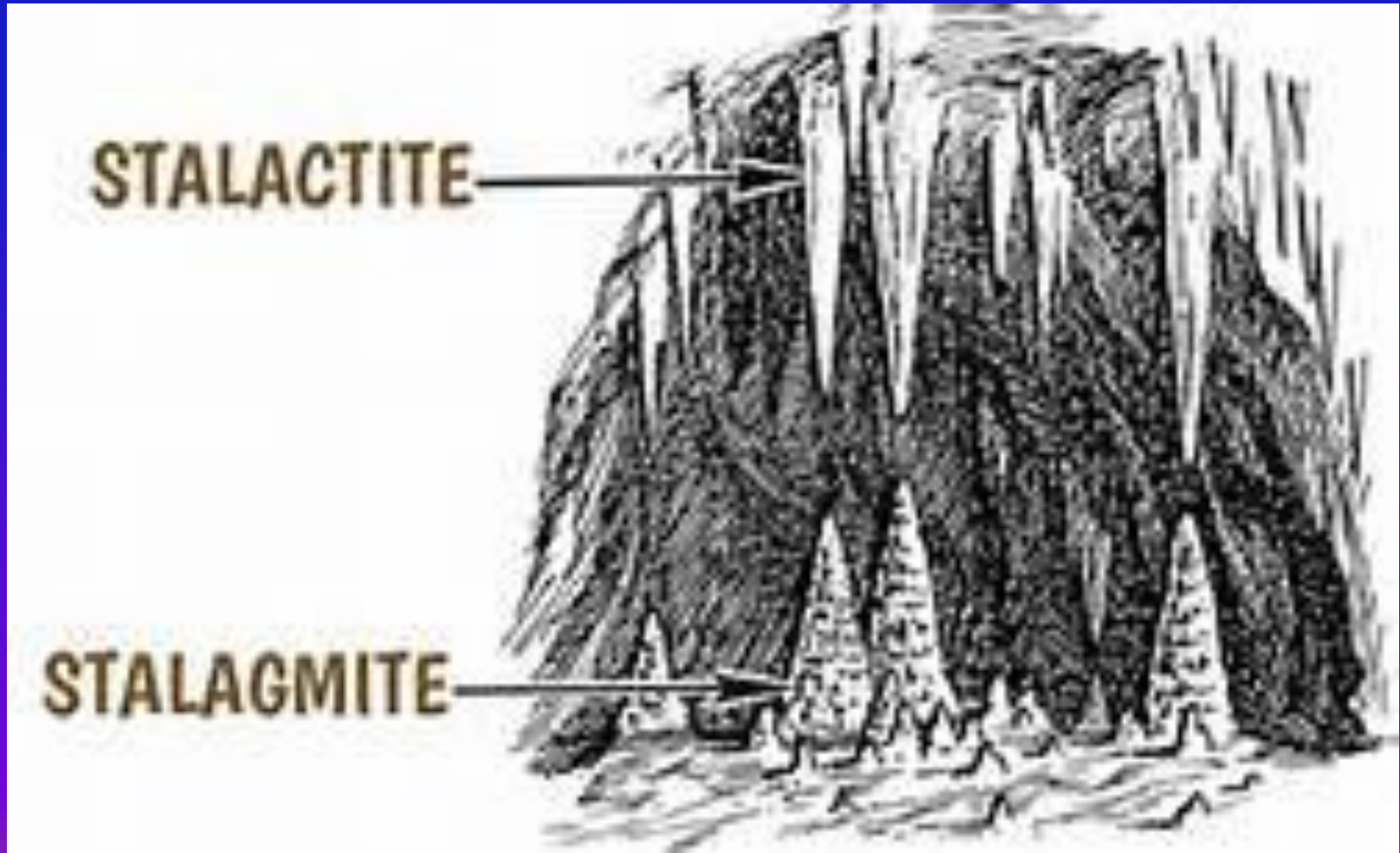


# Limestone – Bridges and arches Piatra Craiului, Romania





# Limestone Art







# Carlsbad Caverns, NM



# Carlsbad Caverns – “Rock of Ages” Photo Ansel Adams - 1941



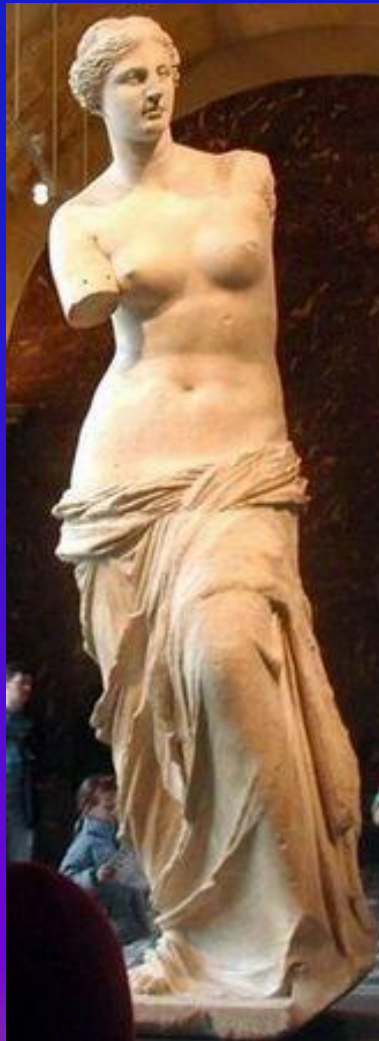


# The Great Pyramid of Giza. Outer layer (veneer) of limestone (Egypt – 2650 BC)



# Venus of Milo - 400-500 BC (?)

## The Louvre Museum



**The Nike of Samothrace**  
**Parian Marble (c. 220–190 BC)**  
**The Louvre Museum**



# Marble Door – Hagia Sophia – 537 CE



# Travertine Vessels Mexico, 600-900 CE





# Italian Renaissance – Statue of David by Michelangelo, 1504



# Taj Mahal - Agra, India – 1648 CE



# *LITHIUM (Li)*



# LITHIUM

1817 - Isolated from mineral **Petalite** (lithium-aluminum silicate)

Lithium is present in ocean water, clays, briny waters

Lightest and least dense metal

Highly reactive and flammable - stored in mineral oil

75% of production used in industry, batteries

Found in grains and vegetables. RDA = 1 mg/day

High content in embryo. Activity related to other biochemicals in the body

Mood-stabilizing drugs - Bipolar disorder in humans. Effect on bone marrow  $\Rightarrow$   $\uparrow$  in the white cell production

# Lithium Floats in Oil



# Launch of a Torpedo using Lithium as Fuel



# World Production of Lithium



# RECYCLING OF METALS

The world use of metals is higher than its production

Mining activities are expanding

1932 - 1999 USA copper used/person 73g  $\Rightarrow$  238g

Lower energy for recycled metals

## **UN Intl. Resource Panel – Environmental Program:**

- 60 metals recycling rates <50%
- 34 metals recycling rates <1%

Battery packs for hybrid cars, mobile phones are in jeopardy

**END OF LECTURE # 5**