LECTURE # 4
The World, its Resources, and Humankind
Topics of Study

The World

Place, History, Economy, Politics, Diseases

Resources METALS

Humankind
METALS
An Opinion on the Discovery of Metals

Need + Serendipity
Observation ⇔ Imagination +

THINKING OUTSIDE THE BOX
HUMANKIND and METALS

Metals made possible advances in

• agriculture,
• transportation,
• communication,
• technology, and
• warfare

The industrial revolution has been entirely dependent on metallurgy
METALS

Metals - Greek: “metallon” = mine, quarry

Definition: Materials hard, dense, opaque, shiny, with good electrical and thermal conductivity

Fusible, malleable, ductile

Gold leaf transmits green light

Lithium = least dense; Osmium = densest
Metals and Ore Imports - 2005
# Metals in Earth Crust

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Metal Ores and Properties

Prospecting techniques ⇒ exploration ⇒ examination ⇒ mining (surface or subsurface)

**Metals are found in ores (mixed with other metals)**

Pyrometallurgy or Hydrometallurgy – purifying methods

**Melting temperature:**
- Tin 231°C
- Lead 328°C
- Silver 961°C
- Gold 1063°C
- Copper 1083°C
- Iron 1538°C – not possible in antiquity
Timeline of materials in human life and technology (1)

29,000 BC – First pottery – Mesopotamia
28,000 BC – First jewelry
3,000 BC – Copper metallurgy
2,000 BC – Bronze for weapons and armor
1,600 BC – Crude iron metallurgy – Hittites
1,300 BC – Steel invented (iron + charcoal)
1,000 BC – Glass invented – Phoenicians
1,000 BC – Pewter used in China and Egypt
1,000 BC – Vegetable dyes – Phoenicians
50s BC – Glassblowing - Phoenicians
Timeline of materials in human life and technology (2)

3rd Cent. – **Cast iron** – China

671 CE – **First missile weapon** (“Greek fire”) – Byzantium

8th Cent. – **Porcelain** invented – China

1000 – **Gunpowder invented** – China

1340 – **First blast furnaces - iron production** – Liège, Belgium

1540 – First book on metallurgy – *Della Pirotechnia* – V. Biringuccio

1555 – *De Re Metallica* – G. Agricola - Mining, metallurgy

1590 – **Glass lenses** – Netherlands. Antonie van Leeuwenhoek – Father of Microbiology (1632-1723) made first microscope

1664 – **Water pipes of cast iron** - Versailles
The Fertile Crescent in Mesopotamia
Assyria 2500 – 612 BC

The Assyrian kingdom was well organized
Major source of metal ore, as well as lumber
The priesthood became a major power in the Assyrian society
Long wars fought that helped build Assyria into a warrior society
Social position of women was lower than in the neighboring societies.
Assyria was open to homosexual relationships between men
Assyrian domination spanned from the Caucasus Mountains in the north to Egypt, Libya, and Arabia in the south, and from Cyprus in the west to Persia and the Caspian Sea in the east
Decline due to civil wars and political instability
Assyria conquered by Alexander Macedon in 322 BC
The Akkadian Empire and the direction of its military campaigns
Akkadian Empire and Sargon of Akkad (2334–2279 BC)

Trade extended from the silver mines of Anatolia to the lapis lazuli mines in modern Afghanistan, the cedars of Lebanon, and the copper of Magan.

Consolidation of the city-states of Sumer and Akkad

Growing economic and political power

The empire's breadbasket was the rain-fed agricultural system of Assyria and a chain of fortresses built to control the imperial wheat production.

Many cruel battles

Sargon: “God of Akkad” ⇒ destruction of Akkad

Resources ⇒ Trade ⇒ Dominance
Metal Production in Ancient Middle East
Mycenaean Civilization

Innovations in: Engineering, Architecture, Military infrastructure

⇒ **Metal work**, defensive walls

⇒ The **script** = first written record of the Greek language

**Gold** ornaments

Homer’s *Iliad* written in 8th cent. BC

Extensive trade and political influence in Asia Minor (Hittites)

Well-defined three classes:

• King and his court
• People
• Slaves
6000 BC - the early inhabitants of Mesoamerica were domesticating plants

Barley and wheat cultivated

All regions of Mesoamerica cultivated the base crops of maize, beans, and squashes

All Mesoamerican cultures used stone age technology

c.1000 AD copper, silver, and gold were worked

Mesoamerica lacked draft animals. Did not use the wheel, and possessed few domesticated animals

The principal means of transport were on foot or by canoe
OLMEC – Southeast Mexico (Veracruz and Tabasco)

Well-watered alluvial soil \(\Rightarrow\) **High soil productivity** \(\Rightarrow\) Rich class

The elite class demanded the production of the symbolic and sophisticated luxury artifacts

Luxury artifacts made from materials such as **jade, obsidian, magnetite (iron oxide)** \(\Rightarrow\) extensive trading network in Mesoamerica

Colossal heads and **jewelry**

- Bloodletting
- **First writing** 900 BCE - 650 BCE
- The concept of **zero**
- **Calendar**

Decline caused by earthquake
METALS
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- 1898 - POLONIUM
- 1898 - RADON
ALLOYS

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: **Bronze, brass**

Hundreds of alloys have been produced

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

- **Cast iron:** iron + silicon
- **Stainless steel:** carbon steel + chromium, nickel, molybdenum
- **High strength-to-weight:** Alloys of aluminum, titanium, magnesium
Alloys for Different Colors of Gold
## Metals in Earth Crust

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Noble Metals

Gold, silver, platinum, palladium, rhodium, iridium, osmium, rhutenium

Precious metals: Rare

Do not oxidize

Uses: Investment, art, jewelry, medicine, dentistry
GOLD (Au = Aurum)
A Gold Nugget
GOLD

5000 BC. - **Sumer civilization** used gold for jewelry
4600 BC - **Oldest thesaurus of gold** – Lake Varna, Bulgaria
2800 BC - Egypt **first miners of gold** in Nubia – gold for international trade
610 BC - Coinage in Lydia (Asia Minor)
1091 CE - China – First to introduce **gold coins**
Roman empire 25 BC - 106 CE: Hispania and Dacia (Rosia Montana, Romania)
Gold History (cont’d)

Middle Ages: Gold for coinage and jewelry
Alchemists trying to make gold
European colonization of Americas: Gold shipped to Spain
Legends of El Dorado cities filled with gold
Western Europe fairytales: Bro. Grimm’s
  *Rumpelstiltskin* (hay ⇒ gold) and
  *Jack and the beanstalk* (hen ⇒ golden eggs)
Uses: Royal crowns, temples, statues, decorative, rings, valuables
Top prizes: Olympics, Nobel Prize
Gold Sites

Gold as flakes or micro particles or nuggets. Usually found in **Ores** - mixed with silver or other metals or minerals

Earthquakes ⇒ gold, water, and silica through faults

Oceans and seas contain gold = 15,000 tonnes (?)

Gold-mining: China, Australia, USA, Russia, Peru, South Africa

- Witwatersand basin in South Africa had the **richest deposits** ⇒ 1886 Gold Rush
- **Boer War** (1899-1902) - Rights of Boer miners and gold in Transvaal and Orange states
- **Gold rushes** - 19th cent. - N. Carolina, California, Colorado, Klondike
Relative size of an 860 kg block of gold ore and the 30 g of gold extracted
Gold malleability – A 5 mm (1/5”) nugget may be expanded by hammering into a 0.5 m² (~ 5 sq ft) foil
Different Colors of Gold
Gold Production
Gold Economics

Precious metals measured in troy ounces

One **troy ounce** = 1.09714 regular (avoirdupois) ounces = \(31.1034768 \text{ g}\)

Karat indicates the gold purity \(24 \text{ k} = \text{pure gold} (0.995)\)

For many years money had to be backed by gold

1930 - **Gold Standard Act** established gold as international trade standard (USA Dollar = 25 8/10 grains of 90% gold)

1944 – **Bretton Woods Conference**: USA major influence

**US dollar = International Standard. No more gold standard**

Price fluctuated. Since 1975 gold price depends on free market inflation and bear or instable markets increase its price.
Gold price per troy ounce - 1940-2015
Mycenaean Gold Earing – 1600 BC
Mask of Agamemnon – 1600 BC
National Archeological Museum, Athens
Funerary Mask of Tutankhamun c.1325 BC
Gold bullion
The Largest Gold Bar – 250 kg
Toi Museum, Japan
More About Gold

**Toxicity:** Gold salts are toxic to liver, kidneys, skin (Chrysiasis)

**Drinks:** *Danziger Goldwasser* - flakes of gold are inert

**Medicine:** Much used in the past for treatment of tuberculosis—ineffective

Some gold salts have been used in the treatment of rheumatoid arthritis

**Symbolism:** “Gold standard”, “golden rule”, “golden age”, “golden years”

Wedding rings – *eternal vows*
SILVER (Ag = Argentum)
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Native Silver
SILVER - History

4000 BC - Separated from lead. One of the 7 metals of antiquity.
1500 BC – Egypt – Silver more expensive than gold
700 BC – Kingdom of Lydia (Asia Minor) coins of silver alloy with gold (“electrum”)
Silver sources: Phoenicians - Spain, Greeks - Laurium, Romans - Sardinia
Silver in the money of many nations in Europe, China, India, Japan
Pound sterling of UK (£) = Sterling silver
In many languages the word “silver” = money
19th cent. - Much silver mined in Americas
1947 - Most coins made of cupro-nickel
1970 - Last circulating silver coin (US half-dollar)
Silver - Uses

More abundant than gold. 94%-pure = “0.940 fine” **sterling silver** (0.925)

**Old use:** currency, ornamental, silverware, jewelry, coins and medals

**Modern use:** Solar panels, photo film, X-ray film, jewelry, (plated with a coat of .999-fine Ag), tableware, silverware. Antiseptic (silver nitrate)

Best electrical conductivity

Silver compounds - Silver + oxygen + hydrogen sulfide = **silver sulfide (tarnish)** + H₂O

WW2 - Electromagnets for enriching uranium - Manhattan Project
Silver in Technology

**Solar energy** - Photovoltaic panels
2015 - 100,000,000 oz. used in solar energy

**Air Conditioning** - Mirror-like panels on buildings

**Electrical conductivity** - Highest of all metals

**Water purification** - Eliminates the need for chlorine

**Dentistry** - Alloy with mercury for dental fillings

**Telescopic mirrors** - for thermal or infrared telescopes

**Windows** - “Sputtering” silver is applied to glass $\Rightarrow$
  
  high-performance insulated glazing.

**High-quality musical instruments** – Best flutes
Silver production
Silver bowl, Persia, 6th century BC
Silver 1000 troy ounce (~31 Kg) Bullion Bar
Silver Solar Panels
Canada's Maple Leaf 1 troy ounce Silver Bullion Coin
PLATINUM (Pt)
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PLATINUM

16 cent. - Spaniards found it in Mexico but thought that it was impurity of gold and discarded it.

Spanish “platina” = “little silver”

1748 – Antonio de Ulloa discovered platinum in Colombia

Rare element – major precious metal

Dense (heavy), malleable, ductile, highly unreactive

Mined in South Africa ⇒ 80% of world production

Alloy with palladium, rhodium, iridium, osmium, and ruthenium
PLATINUM

Uses: Jewelry
Catalyst for auto and industrial plant emissions
Organic chemicals
Cancer medications
Platinum World Production
1,000 Cubic Centimeters of 99.9% Pure Platinum, Worth About US $696,000 at 29 June 2016 Price
COPPER (Cu = Cuprum)
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COPPER

Discovered ~ 9,000 BC in 99.9% pure form

Found by serendipity - “Some stones” being fired
melted and new objects could be cast

*Replaced stone tools:* crude knives and sickles

The “Chalcolithic Age” or “Copper Age”

4000 - 1000 BC – “Old Copper Complex” of the
Western Lakes - copper 99% pure

Old use: Spearpoints, tools, decorative objects
2700-1200 BC - The Minoan Civilization

A Minoan copper ingot

The Snake Priestess
Native Copper
Timeline of Copper

5,000 BC - World oldest copper smelting - Rudnic Mt. (Serbia)

3800 BC - Copper mines in Sinai peninsula

3000 BC - Ores of copper in Cyprus and in Cornwall - Phoenicians bring copper to Judea for the Temple of Solomon (~1000 BC)

2800 BC - Ores of **copper and tin** \( \Rightarrow \) harder metal \( \Rightarrow \) **Bronze Age**

2800 BC - Sinai \( \Rightarrow \) Sumer \( \Rightarrow \) Anatolia \( \Rightarrow \) Europe \( \Rightarrow \) Indus valley

2500 BC \( \Rightarrow \) China (Shang dynasty) - 1500 BC

2750 BC - Copper water pipes in a temple in Egypt
World Production of Copper
LEAD (Pb = Plumbum)
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Lead nuggets
LEAD

Great availability (16 ppm). Found in ore (galena)

Mined since 7000 – 6500 BC

Ancient civilizations - Various uses: Cosmetics, currency, contraception

Mined in China 1000 BC

Rome great producer of water pipes. Lead intoxication (?)

(saturnism)

16th cent. CE - Important for the Gutenberg printing press

Gun bullets

Whitened face ⇔ Lead poisoning ⇔ Lead teeth ⇔ Lead intox.

1621 - Lead mining in Virginia

1841 - Lead mining in Australia
Lead Uses

Production increased 31%
Primary by extraction & by recycling
Lead-acid batteries – Environmental hazards:
  Vernon, CA
Alloys of copper + lead
Construction industry
Shielding from radiation – Radiation therapy rooms
Ballast keel of sailboats
Lead production

- Discovery of cupellation
- Use of coinage
- Exhaustion of Roman lead mines
- Industrial revolution
- Rise and fall of Athens
- Roman Republic and Empire
- Silver production in Germany
- Spanish production of silver in New World
Water lead pipes
Emperor Vespasian Villa - Rome
Multicolor Lead-glaze Paint
Tang Dynasty 8\textsuperscript{th} Cent. CE
Elizabeth I of England
White Powdering of Face and her Cause of Death
Lead Blocks Used for Radiation Protection
Dioscorides (Greek physician) noted lead’s effects on the mind (1st Cent. CE)
LEAD POISONING

Lead poisoning by air, dust, water, food

Brain is the most sensitive
10% of cases - intellectual disability
Memory problems, anemia, sterility
Various multi-system symptoms
Children more affected (by ingestion of paint)

**Diagnosis:** Gums colored blue and anemia

**Treatment:** Chelating agents
Symptoms of Lead Poisoning

General
Central nervous system
Vision
Neuro-muscular
Intestinal
Kidney failure
Anemia
Reproductive
Skin
Testing kit for lead detection
The swab turns red in lead presence
The Timeline of Flint Water Crisis

Feb. 2015 - Oct. 2015 - **high levels of lead**: 104 ppb (threshold is 15 ppb) = HHS - Violation of the Safe Water Drinking Act

Oct. 2, 2015 - State officials publicly announce **high lead content in drinking water of Flint**

Dec. 14, 2015 - Flint Mayor Karen Weaver: State of emergency

Jan. 16, 2016 - President Obama: Emergency Declaration

Apr. 20, 2016 - Michigan AG: charges against DEQ employees

June 2, 2016 - DEQ Chief Deputy Director Jim Sygo: “**Flint water crisis ‘was overplayed’**”

June 2016 - Gov. Snyder: Apologies to citizens: $28 Mil. for medical supplies; $30 Mil. for water bills; + $165 Mil. for water pipes replacement
Prof. Mard Edward from Virginia Tech:

“Authorities' actions expose a new level of arrogance and uncaring that I have never encountered”
The Story of Exide Technologies

Manufacturing and Recycling of Automotive and Industrial Batteries – USA, Pacific Rim, Europe, and Australia

Vernon, CA - 2015
Exide Technologies
Batteries Recycling Plant, Vernon, CA

JOSE GOMEZ at his home in the 1100 block of South Hicks Avenue in East L.A., which is being tested for lead contamination. Crews sample soil from about 15 locations on each property and analyze them for lead.

‘SOMETHING IN THE SOIL’

Brain-damaging lead levels near Vernon battery plant were as much as 100 times above health limits
Exide Technologies
Batteries Recycling Plant, Vernon, CA

in East Los Angeles, including several property owners who shared their testing results with The Times.

Properties sampled: 269

Safe for residential soil
(Less than 80 parts per million)

Unsafe for residential soil – state standard
(80 ppm or higher)

Classified as hazardous waste
(1,000 ppm or higher)

222

11

36
Lead Economics, Health, and Politics

**Industrial Revolution** – Increased demand for plumbing, painting, and gasoline additive

Lead paint – Children lead intoxication

Lead more dangerous if **fumes are inhaled**

19\textsuperscript{th} Cent. – **Lead causes mental disorders**

**Lead causes blindness**

1921 – Tetraethyl lead added to gasoline to avoid “knocking”. Phased out

1930-2000 – Enormous US and European legislation on high lead blood levels ↓ to 2% of population
TIN (Sn = Stannum)
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- 1781 - MOLYBDENUM
- 1789 – URANIUM
- 1791 - TITANIUM
- 1797 – CHROMIUM
- 1803 – PALLADIUM
- 1808 - CALCIUM
- 1817 – LITHIUM
- 1817 – CADMIUM
- 1827 – ALUMINUM
- 1830 - VANADIUM
- 1898 – POLONIUM
- 1898 - RADIUM
Known Tin Deposits Exploited in Ancient Times
TIN

- First alloy to make bronze
- Discovered ~3000 BC - Copper + tin was
  - harder ⇒ Bronze Age
- Found as Cassiterite mineral in river banks
- Soft, malleable, ductile
- Melts at low temp. 232°C (450°F)
- Not easily oxidized in air, not toxic ⇒
  - food packaging in tin cans
TIN ORES

Yunnan province - China
Malaysia peninsula
Peru
Devon, Cornwall – England
Brittany – France
Central Europe – Erzgebirge
Spain and Portugal
Central Africa
World Production and Price of Tin
COPPER ALLOYS: Bronze, Brass, Pewter
BRONZE
The Bronze Age started 3,500 - 3,000 BC (after the copper age called the “chalcolithic period”)

Casting of metal ⇒ Metallurgy is born

- Mesopotamia c. 4500 BC
- Egypt c. 3500 BC
- China c. 2800 BC
- Central America c. 600 CE
- West Africa c. 900 CE
Italian: *bronza* (bell) ⇔ French: *bronze*

Bronze is an **alloy of copper + 12% tin**

**Various alloys** ⇔ hardening the copper

Sumer, India, China and Japan - 4000 BC

Followed by the Iron Age (~1300 BC)

• Harder than iron; does not rust
• Iron easier to find and process but requires higher temps.
• Disruption in tin supply (?)
The Bronze Age of China (2000 – 771 BC)

Started under the Shan dynasty - Henan province

Imported technology or invented locally (?)

**Bronze artifacts**: Utilitarian, rituals, tools, weapons

*Taotie* motifs (animal-like masks)

**Jade carving**

**Irrigation**
Bronze Uses

Tools, weapons, armor, building materials
more durable than copper

Sculptures, bronze statues

Works of high art

Musical instruments: Bells, cymbals, stringed instruments: bass, piano, harpsichord, guitar

Coins and medals
Chinese Bronze Age – Shan dynasty
2500-1800 BC
Mycaenean Civilization Swords and Cups (1600 – 1100 BC)
Hittites – Masters of Metal Work in the Bronze Era (1600 – 1100 BC)
Bronze Sculptures
The Artemision Bronze c. 460 BC
The National Archeological Museum of Athens
Roman cuirass, Grenoble, France
Bronze relief
Wawel Cathedral, Krakow, Poland
Modern Bronze Statues
Degas’ Dancers)
BRASS
BRASS

Alloy of copper + zinc (zinc identified only in 1746)
Several alloys in use
Bright gold-like appearance
Higher malleability than copper or zinc alone
Low melting point
Easy to cast
Antimicrobial (?)
90% is recycled
Brass Uses

Roman empire: Coinage

Medieval Europe: Religious objects

Metal of choice for musical instruments: “the bass section” (trombone, tuba, trumpet, cornet, horn)

Decorative objects

Household items
Brass – 7th Cent. Persian Ewer
Baptismal Font – St. Bartholomew’s Church
Liège, Belgium, 12th Cent.
Brass Cracking by Ammonia
PEWTER
PEWTER

Malleable **alloy. 85-99% tin + copper + antimony + bismuth**

Low melting point 170-230°C (338-446°F)

Used in the Near East, c.1450 BC in Egypt

Many household vessels in the Middle Age, **mugs**

Replaced by porcelain, pottery, and glass

Tin + 15% lead - household items - less used today
Pewter vessels
END OF LECTURE # 4