ANCIENT AND CLASSIC WORLS

Until the 5-th Century

CHEMISTRY

Collected and edited by Prof. Zvi Kam,
Weizmann Institute, Israel

INDIVIDUAL PROJECTS

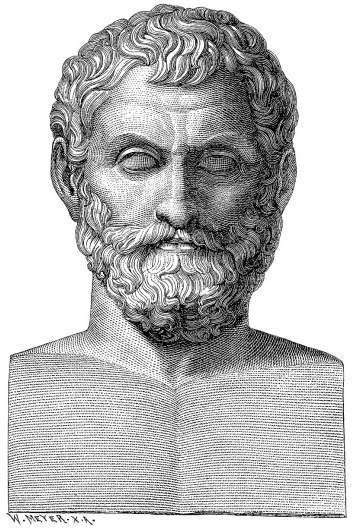
Proposed subjects:

Sources of environmental garbage.
Air pollution.
Solar system and research space ships.
Live creatures at home and around.
Solar energy – solutions and difficulties.
Diversity of living species – importance and human effects.
Domination of foreign species in nature.
Water – contamination, preservation, desalination.
Nutrition – diversity and necessary food components.
Importance of statistical data.
Yeast in industry- wines, bear, cheese, penicillin.
Temperature and heart beat changes during the day.
Cooling down of a tea cup – measure dependence on initial temperature.
Common materials today and 100 years ago (e.g. Aluminum, plastics).
Plant growth rate – effect of light, water, temperature, fertilizers.
Human body as an engine – nutrition, energy, creativity.
Bees and insects – utilities and problems.
Recycling – needs and problems.

Ancient chemical models

3000BC in Egypt Ogdoad theory – primary forces that create everything. 8 elements of chaos that existed before the sun was created.
1900 BC The legendary Egyptian kink Hermes Trismegistus established the field of alchemistry.
624-546 BC Thales of Miletus – Everything emerges from water, including earth and air
610-546 BC Anaximander – The concept of infinite: no start and end (chaos). Also man is made of water. The universe is in a state of equilibrium between opposing forces.
585-525 BC Anaximenes – Air is an element and can be pushed in a blow like other materials. Air condenses into water, therefore is the source of everything, including life.

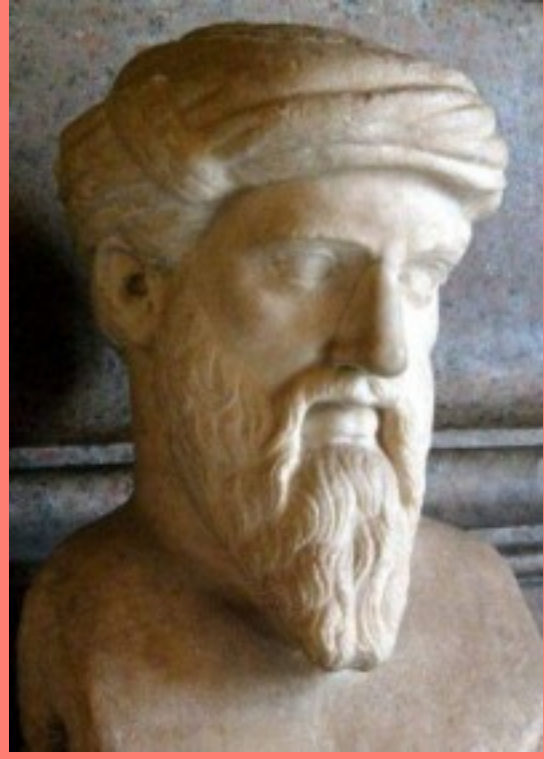
Thus, with some variations, the complexity of materials is explained by combinations of a small number of "sources" or "elements". Since earth is a source of different compounds, and water, can dissolve and when dried, precipitates various salts, they are commonly Named as "sources".



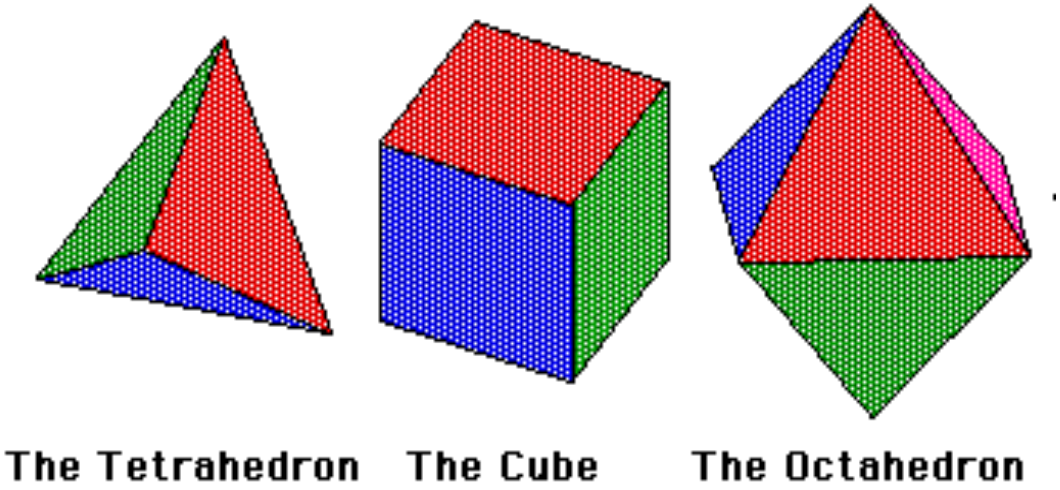
Thales

Anaximander

(570-495 BC) Pythagoras

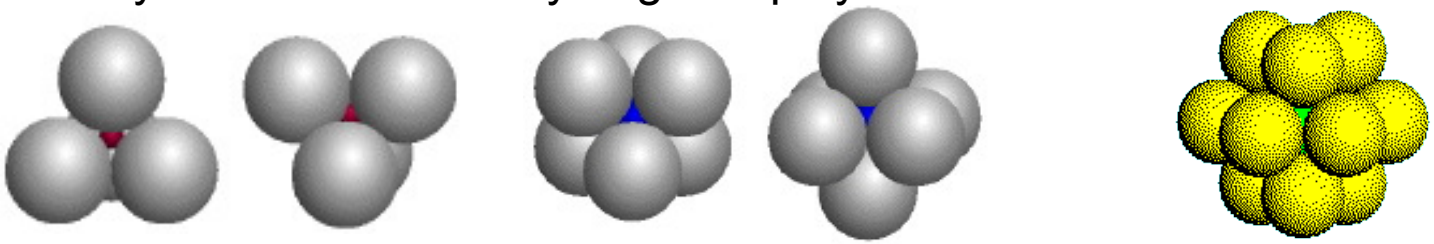


582-507 BC Pythagoras and his school in Croton- Numbers are the basis of the universe: Geometric arrangement of **atoms** creates different materials. (probably originated from shapes of crystals he found in nature). The atomistic theory reappeared Throughout history of science, but found experimental support only in the last 200 years.



Pythagorean regular polyhedrons.

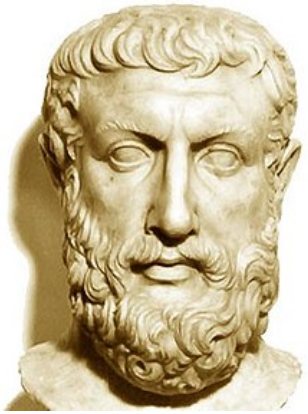
It is interesting that 2000 years later, x-ray crystallography was developed and demonstrated that crystals are packed arrays of atoms with distinct "coordination numbers" and symmetries of the Pythagoras polyhedrons.

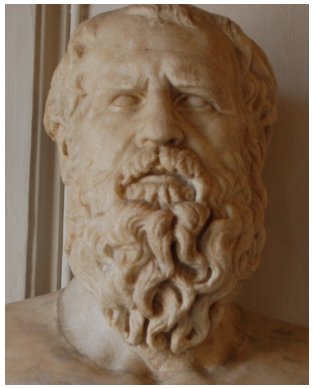


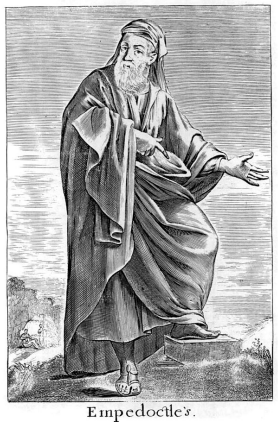
Coordination number: 4 6 12

540-515 BC Parmenides of Elea – denies possible existence of vacuum. Preservation rules implies that materials are only made from other materials (not from null).
535-475 BC Heraclitus of Ephesus – Introduces FIRE as material transformer entity. Ezz is the basic element. Opposing forces are necessary for existence of the universe.
490-430 BC Empedoceles of Acragas – Four elements (roots or sources) for all: Earth, Water, Air and Fire. Their mixtures and the love-hate relations between them form a variety of materials, (chemical affinity, a new concept)
late 400TH BC Democritus of Abdera and Leucippus – Atomism. Materials are not built of a continuum. Permit vacuum between atoms. Following Pythagoras: Shape of the atom determines the type of material. The idea was denied by Aristo.

Interestingly, with the development of inorganic chemistry, and the return of the atomic theory, Organic compounds were believed to contain a component special for life, in addition to atoms.


Parmenides


Heraclitus



Empedoceles

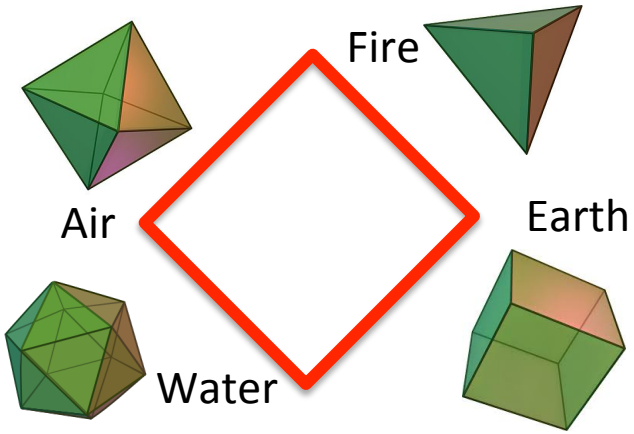

Democritus

Plato c. 427–347 BC

Aristotle 384–322 BC

Extract from Raphael's painting: Plato points up towards heavenly: (**philosophy)**, Aristo points down, towards earthy (**experimental**) scientific methodology.

427-347 BC Plato embedded the concept of “elements” or “roots” of all materials. Classified organic and inorganic materials. Followed Pythagoras believe in the geometrical shape of atoms, and created a correspondence between fire and tetrahedron, air and octahedron, water and icosahedron, and earth and a cubical shape. Based nature laws on mathematics, but claim that the physical world expresses these laws non-ideally, therefore experimental confirmation is difficult, and must rely on logical argumentation to reach the truth.
Founded the **ACADEMY**.



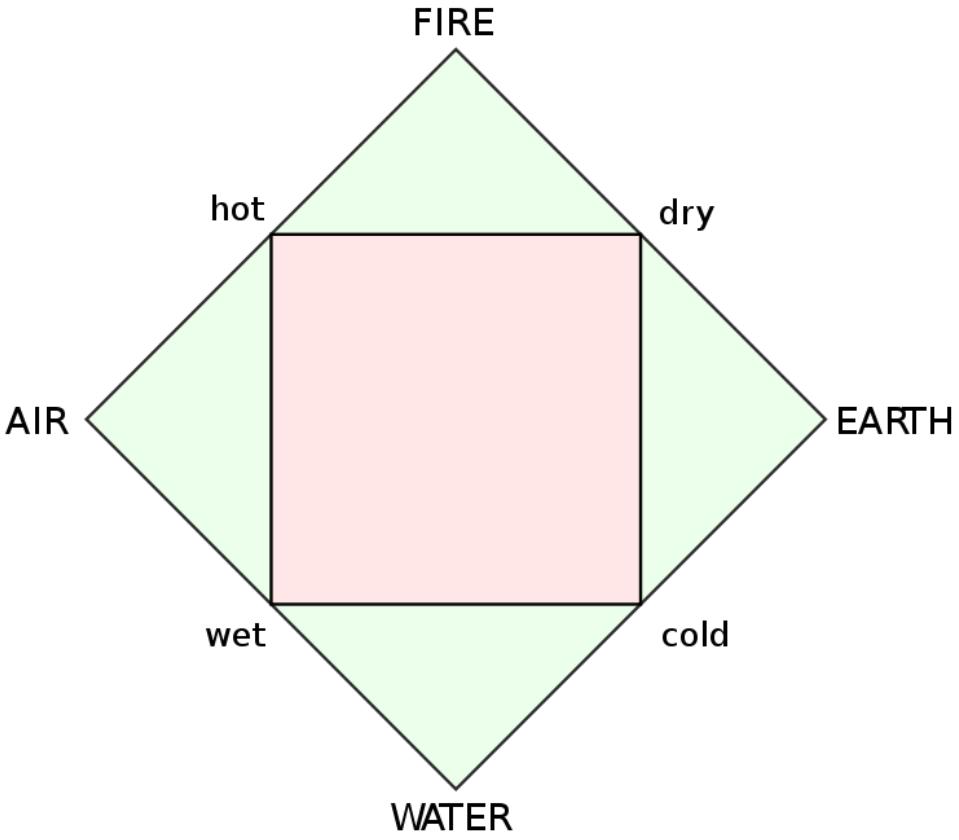
384-322 BC Aristotle – was a student of Plato, but diverted from his theory, believing in experimental science for testing the description of natural laws.
Following **Empedocles**, compounds are mixtures of elements and shapes. Air and fire flow away from the center, Earth and Water attracted to the center, added a fifth element: **Aether**, and denied vacuum: the world is totally filled by materials.
Started his own school, the **LYCEUM**

Interestingly, Aether was involved in modern electromagnetic theory at the 19th century.

46-120 AC Plutarch - was an historian who was a dedicated Platonist.
300 AC Zosimos of Panopolis - composes a book about alchemistry.

The Greek "chemistry book"

The element table includes Four "sources" or "roots": Water, Earth, Air and Fire
They are combined by four qualities or "affinity forces" : cold, heat, humidity and dryness and form all materials.

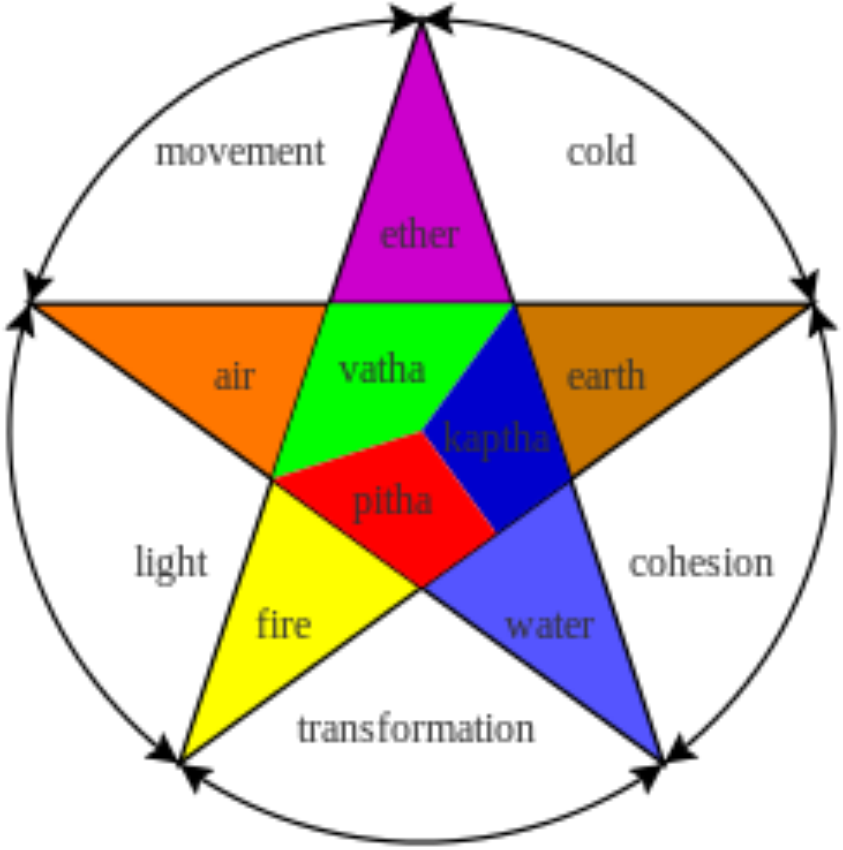


IN INDIA – Ayurveda, chemistry is linked to life sciences:

The Indian diagram of elements is more “abstract” than the Greek:

Five forces: Cold, Movement, Light, Transformation, Cohesion
Five elements: Aether, Air, Fire, Water and Earth
Three basic properties: Pitha (fire & water), Vatha(space & air), Kapha (water & earth)

They create 10 pairs of material properties:
Heavy/light, Cold/hot, Unctuous/dry, dull/sharp’ stable/mobile, soft/hard, non-slimy/slimy, smooth/course, minute/gross, vicious (solid)/liquid



Why were the ancient and classical scientists eager to explain the existence of a large diversity of materials they found in nature by a small number of elements?
What findings supported their theories?

i.e. Heating oars in fire extracted different metals
Heating metals in air created oxide salts
Pure minerals are often found in crystal forms in nature
Water evaporates and precipitates materials
But: Water evaporates to “air”, and air condensates to water: how can both be “sources” if they convert to each other?
Can you find more inconsistencies?

Yet, cultures that did not communicate accepted similar theories, all driven by the urge to put an order into the diversity of materials found in nature.

Fire created the earliest chemical processes serving humans.
Open fires allowed cooking foods and baking clays for pots and cups.
Stone-built ovens and furnaces better preserved the burning heat, maintained higher temperatures, and enabled separation of metals from oars or glass from sands.
Aeration of sealed furnaces burnt the wood faster and reached higher temperatures, not only high enough to melt gold, but also copper, and iron.

We next review the history of metal purification and their applications.

Gold [Au – Aurum]

Gold is the first metal isolated from gold-rich oars in Nubia by the Egyptians.

Why was Gold the first isolated metal?

First gold is inert – does not easily oxidize.

Secondly – its melting temperature is “low” : 1064^{o}C for pure Gold, and down to 700^{o}C for silver & copper alloys.

It was probably first found as grains mixed in sand, possibly In river beds, and later “industrially” purified in furnaces.

3500 BC Gold artifacts are buried in Egyptian graves

2600 BC Gold mines in Nubia (Sudan: Nub=Gold), using flint stones and clays for mining.

1600-1500BC – Mercury is found in graves – used to purify gold as an amalgam. Free Mercury droplets were probably trapped by flow of oar dusts over hairy skins.

Interesting: Mercury buckets were also found in Maya graves in central America.

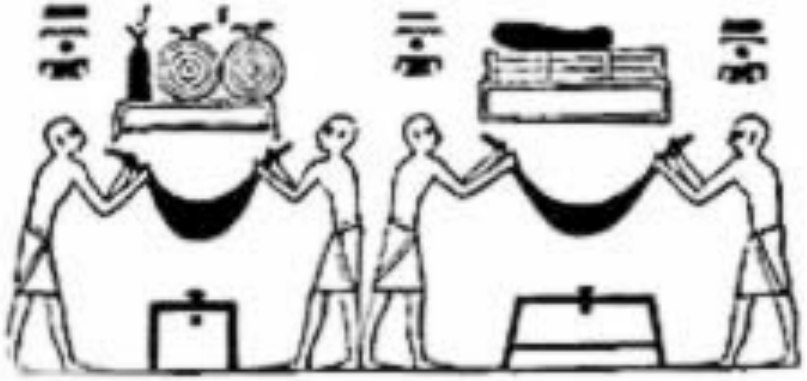
Gold oars, being heavier, were enriched by flowing sands in water over clays, that by friction held the heavier grains, and let the lighter ones flow away.

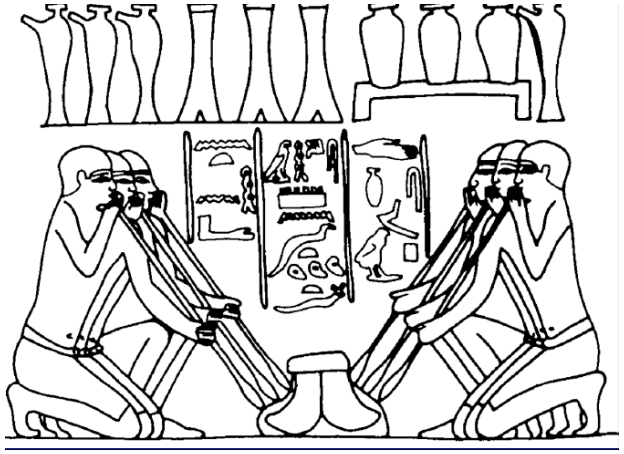
The Sign of gold:
The sun

The Hieroglyphs for gold:
Melt and mold

Gold plating of engravings and wooden statues from Ancient Egypt

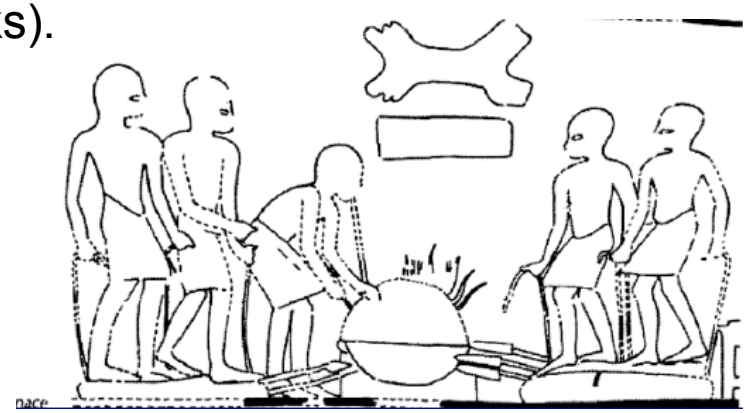
The paintings show gold purification workshop: Washing gold grains from sand, Blowing air into a melting furnace to kindle fire, gold plating, melting, casting and weighting.

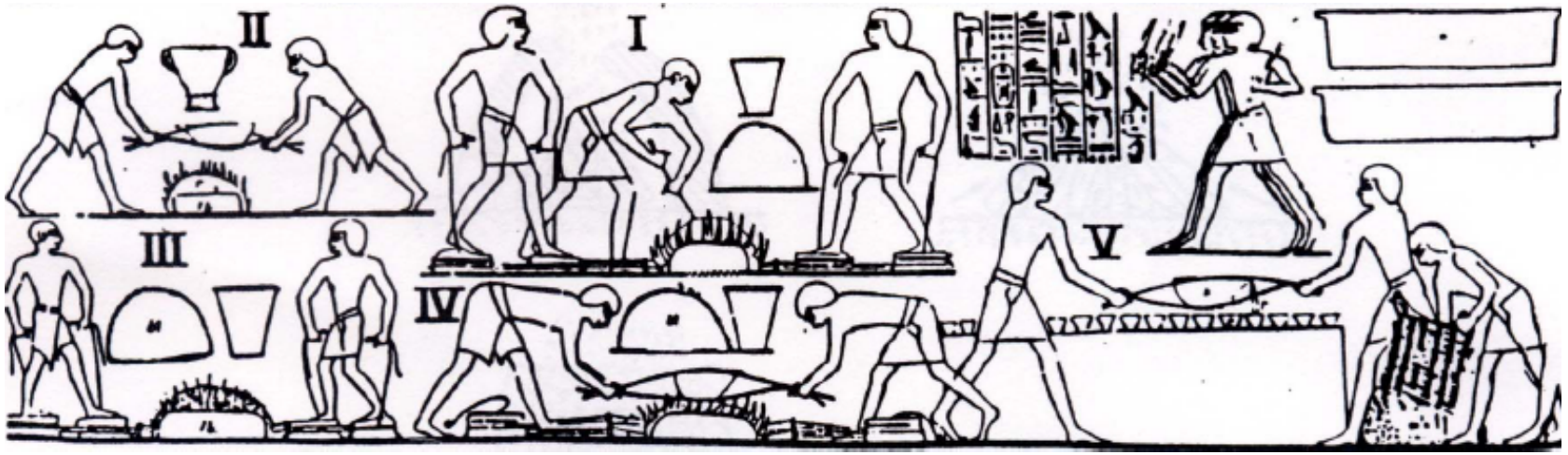




The melting pots were filled with gold oars and coal to reduce oxidized compounds.. Fire kindling was achieved first by fans, then by blowing into the sealed furnace for better isolation in order to reach higher temperatures.

The furnaces were first made of clay, with external fire underneath, and evolved into sealed furnaces containing coals and air blown into them, first through pipes blown by mouth, later by leg-operated pedal blowers made of skin and wood.
Molten gold was poured into lime-stone or clay molds. Early molds were “two dimensional” reliefs, but later two matching molds enabled casting three dimensional gold objects such as cups and jars.
The drawings show all stages of filling the clay furnace with coal and oar, covering, kindling fire, molding (clay furnace is held by two sticks).





Since metals are found in natural oars in mixture, various gold purity was produced, and characterized by color, and later by density. (Pure gold was the highest density material known at the ancient and classical world. Today Uranium and trans-Uranium metals have even higher density. Down the line we shall describe Archimedes floatation law and how he determined density of objects.)
Purification of gold was achieved by the inverse process: Since gold resist oxidation and stay molted even at high heat, while other metals mixed into the gold will oxidize and crystallize, pure liquid gold can be filtered through clay pores.
On the other hand, gold alloys with silver (Electrum) and copper created grades of colors from white to orange, and were used as thin foils for decoration and plating of statues and reliefs.

The importance of gold and silver coins in the economy of the Roman Empire motivated scientists to put tremendous efforts in “Alchemistry”, attempting to transform materials (typically with yellow colors) into gold using both chemical manipulations but mainly witchcraft…

290 AC Emperor Diocletian – destroy all books in alchemistry to prevent economic catastrophe by the chance of inflated gold production.

Copper [Cu – Cuprum]

Copper purification required higher temperature, as well as addition of alkali (from lime stone) for reducing copper oxides. Due to abundant oars of Copper and Tin mixtures, the lower melting temperature of the alloy (900^{o}C) , and the superior hardness, **Bronze**, an alloy of Copper and Tin, was the earlier and the main product of Copper mines.
(Tin melts at 232^{o}C and pure copper at 1084^{o}C)
Oars were identified by the green color. Miners used flint hammers with wooden handles, and aided by pouring water on heated rocks to crumble them. Oars rich in $CuFeS_2$ Cu_2S heated with silica become oxides, and at the presence of coal are reduced to metal.

3400BC Egyptian Copper mines in Sinai and Timna (Israel). King Solomon casted the temple service tools from copper.
3000 BC Indus valley – Produce Copper & Bronze, Gold & Tin.
666 BC Gabel (mount) Rasas in Iran – Tin & Copper mines.
400 BC India – advanced metallurgy, purification of minerals and alkaline.
300 BC Leyden & Stockholm Papyrus – probably buried with the alchemist who composed it, and contains instructions for purification of metals and alloys, imitation of silver and Electrum, Gold-Silver-Copper alloys, dyes for clothes, precious stones, and clearing mother of pearl for jewelry.

Large statues and tools were casted into sand or lime-stone molds, and could be repeatedly used. Inner cavities were created by bees wax that burnt away, and replaced by the molten metal. Sculptures had also cavities inside.
Softer copper could be heated and hammered for shaping jewelry, fine curving objects etc. Sand blasting and polishing by cloth or skins finished the process.

Bronze objects also allowed welding parts by alloys with lower melting temperature that bonded well to Bronze, such as pure Tin.
Metal wires were formed by rolling the melt, and used for ornaments, adding weight for arrow stability in flight, and tight bonding of parts.

Tin [Sn – Stannum]

Tin-rich oars were abundant in England (called land of Tin by the Romans) in France near the La-Mange channel, in Czech, Spain, Italy, Africa and some mines in Egypt, Iran and Syria.
Pure Tin is soft and melts at 262^{o}C, therefore used for soldering.
3000 BC certain Copper mines (with additional Arsenide and Tin content) were known to produce harder metal, that was easier to melt and cast – Bronze. The toxic effect of Arsenide-remnants in Bronze cups and eating utensils was soon discovered, but was used in small dozes (like most other toxic compounds) as curing medical drugs.

The spreading use of Tin, yet its dispersed abundance as Tin-rich rocks of Cassiterite SnO_2 found in riverbeds, created a world-wide trade contacts in the ancient and classical era.

Iron [Fe – Ferrum]

The external layer of earth crust contains 50,000 PPM of Iron, (as compared with 70 copper, 16 Tin, 5 Arsenide 2 Lead 0.1 Silver and 0.005 PPM Gold).

Why then Iron was not the first metal to be purified and applied?

The reasons are: The high melting temperature (1536^{o}C) and the high affinity of Iron to Oxygen (rust), making Iron oxides and salts intermixed in oars. While Gold and Copper were first identified in pure shiny pieces, motivating their purification, Iron blocks were purified only following the improvement in furnace heat isolation, fire kindling and creation of a reducing atmosphere by naturally occurring coal stones (coke, anthracite) and by silicates. Most compounds release oxygen upon heating. Presence of free carbon to bind the oxygen create a reducing atmosphere for pure metal condensation.

2900 BC Iron tools were found in graves inside pyramids.

1300 BC The Hittites king sends Ramses II of Egypt an iron sward. The iron was probably of meteoritic origin.

800 BC Iron mines in Egypt.

5th century BC in China – Casted iron utensils.

1000 BC in Persia, steel was produced by adding carbon under reducing atmosphere into molten iron. Became an expert industry for swards.

The biblical scripts list the known metals of the time: Gold, Silver, Iron, Copper, Tin, Lead, and Antimony (beauty powder). The profits often mention metal purification furnaces to illustrate spiritual purification. King Solomon's temple was built with stone that were not cut and shaped by iron tools (maybe reflecting their rarity)

Lead [Pb – Plumbum]

Lead is a soft and easy to hammer and shape to any desired form. Typically purified from black sulfide oars – PbS, by heating with coal. Its melting temperature is 327.5^{o}C.

Lead was used for fishermen net weights (quoted by the biblical profits). The Romans used lead pipes for water supply and sewage (therefore the profession name - Plumber)

Lead-derived chemical compounds have bright colors, and therefore used in paints.. Organo-metal lead compounds were used until recently to boost the octane of gasoline for cars. However, the toxic effect of lead on children brain development outlawed used of lead-based paints and other products.

Lead is used today in radiation-protective shields. (Why?)

Silver [Ag – Argentum]

Nobel metal, easy to hammer out and shape.
Produced from oars rich in sulfides (AgS) typically mixed with Lead, and therefore difficult to purify. Silver melting temperature is 961^{o}C.

Silver was more expensive than gold in the ancient world. The people of Greek and Crete learnt to produce silver in quantities, thus Silver coins became commonly used in the Roman empire. Silver is also used for jewelry, eating utensils (cups and plates), and ceremonial tools.

Due to the silvery color, the moon became a sign for silver (like the sun for gold).

Summary

Pure metal blocks were probably found in nature, originated from meteors or by lightening storms. Their shiny color and strength motivated man to produce them from heated oars. Gold was found as grains in Nubian sand beds, and melted to form solid gold and gold plates. The development of furnaces allowed to purify bronze, and later copper and iron.

Metals could be casted and shaped to produce fine tools such as needles, combs, eating utensils as well as arrow heads and shields.

Iron tools, such as hammers, plows and chariot axes and wheels, were advantageous over wooden and flint tool, and soon found uses in weapon production.

The development of metal products is undoubtedly a revolutionary step (maybe only second to the control of fire) in human history. Unlike fire, though, it required organized society and recruited efforts to build and operate metal purification plants.

Other Chemicals

Chemistry was experienced not only with heat.
Chemical reactions happen while mixing different naturally occurring compounds:

Grapes and other fruit fermentation produced vinegar, a mild acids

Bases were made by solutions of Caustic soda (NaOH and $NaHCO_3$) found in dried lake beds. Sodium carbonate (Na_2CO_3) was produced from the ashes of burnt seeds, and used to clear glasses.

Alcohols were products of fermentation of carbohydrates (wheat bear) and sugars (fruit wines). They were commonly produced for drinking, but found useful in extracting medications and drugs from plant leaves, roots, fruits and tree bark.

GLASS

1400 BC Phoenicians create glass bottles by blowing (Painting from upper Nile valley). Previous to blowing, small bottles were molded around sand, that was emptied after cooling. The story tells that camp fires on shore sands left behind glass clumps initiating glass industry development by the Phoenicians. Glass bottles spread all over the Mediterranean, and used to hold volatile perfumes.

The chemistry of glass production:

Burnt seed ashes are rich in Sodium Carbonate (Na_2CO_3). When combined with sand silica (SiO_2) they make glass: $Na_2CO_3 + 2SiO_2 + CaO \rightarrow Na_2SiO_3 + CaSiO_3 + CO_2$

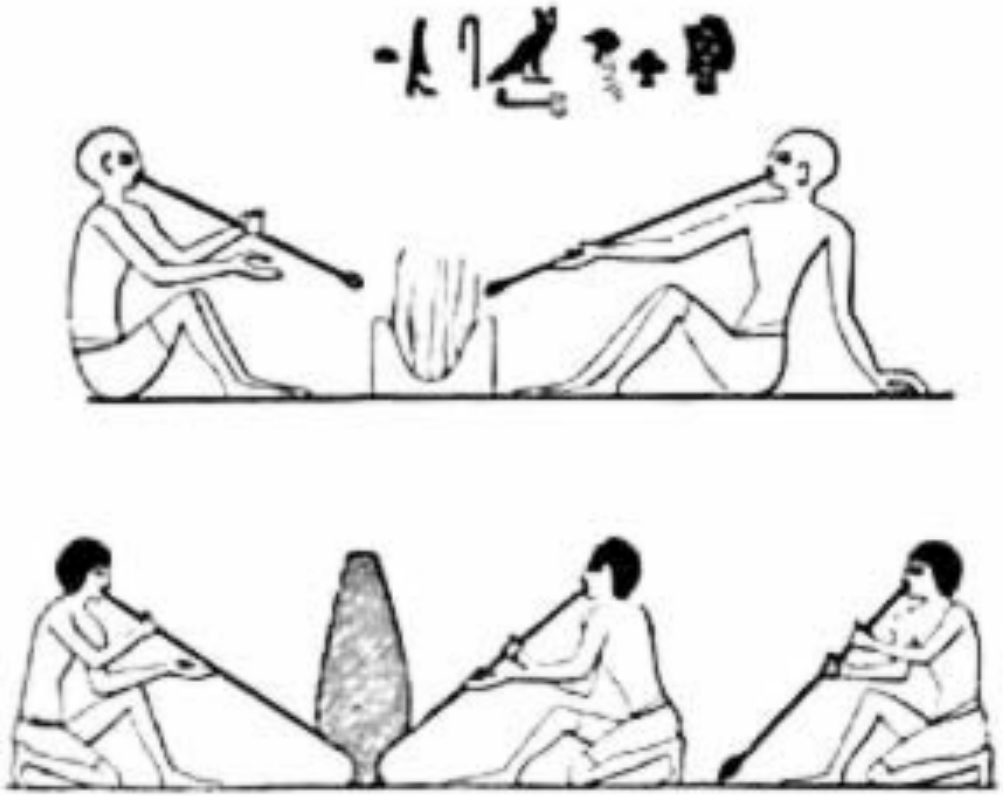
Pure silica melts at 2000°C, but with Sodium Carbonate the melting temperature is reduced to 1000°C.

Na_2CO_3 was also collected from dried lake beds in Egypt, and used for preservation of Mummies.

Adding burnt lime (CaO) to the glass make it less soluble by water.

Due to various common minerals, glass is naturally deeply colored: Blue-copper oxide, Brown and Green-Iron, Deep Blue or Black-Nickel, Deep Green- Chromium. Colored glass beads were used for necklaces.

During Roman times: Addition of K_2O produces clearer glasses.



Phoenician glass bottles, commonly found in archeological sites all over the Mediterranean. Early glasses were colored-opaque and decorated. Later, in Roman times, clear glass became more prestigious…

The Chemistry of Dyes

Cave-wall paintings were drawn with soils mixed with animals fats, egg yolk etc.
2600 BC Wall paintings inside the Pyramids display a wide spectrum of colors probably collected at great efforts from far away mineral sites.
3000 BC Dying of textiles woven from wool, silk and linen was done by boiling clothes with plants, leaves, snails, roots and fruits. Colors were stabilized with various minerals and natural chemicals.

Trading of Indigo (blue extracted from plant leaves) and magenta (from see snails) spread all over the Mediterranean countries. Some rare colors marked aristocracy and exclusively used by emperors.
Cosmetics: was typically mineral powders, mixed with ointments that were absorbed by the skin.
Writing Ink and prints:
2300 BC in China– Ink from plant extracts with added graphite powder. Scripting with fine hair brushes.
400 BC in India– Ink from burnt bones with tar, writing with sharp tips.
Romans prepared ink from octopus “ink sac” mixed with powders from black minerals.
700 BC in China – Block printing (wood or stone).
Which properties are needed for writing inks? Viscosity (for continuous curve and preventing precipitation of the black powder), adherence to the skin/paper/papyrus, color stability: minerals and graphite are better than organic dyes (flowers) that fade in time.

COLORED MINERALS

Brown – Iron oxides

Blue – Copper carbonate $CuCO_3$

Blue-Green color of copper roof tiles
Eroded by acid rains

Yellow and Orange –Arsenide sulfates As_4S_4 , As_2S_3

Yellow - $PbCrO_4$

Green – Malachite $Cu_2CO_3(OH)_2$

Blue – Cobalt and Chrome compounds
the origin of blue glass
and of Blue painting on Chinese ceramic

White – $Zn(OH)_2$
widely used in Renaissance paintings.
Darkens upon oxidation and light, also PbS converts to dark $PbCO_3$
Recent reconstructions (e.g. the Sistine Chapel) by reducing agents and lasers

Greek pottery painting

Greek pottery is famous for its fine paintings in black-brown color grades.
The production includes three baking steps:
Iron rich clays become brown (Fe_2O_3) when burnt at 500^{o}C at the presence of oxygen in the air. When temperature is raised to 900^{o}C with no oxygen the clay becomes black (Fe_3O_4).
At the areas that the pot is painted with glaze it melts into the clay and creates oxygen-protected sites. When the temperature is reduced back to 500^{o}C the exposed areas become brown again, and the protected glazed areas are black.

Chinese ceramics

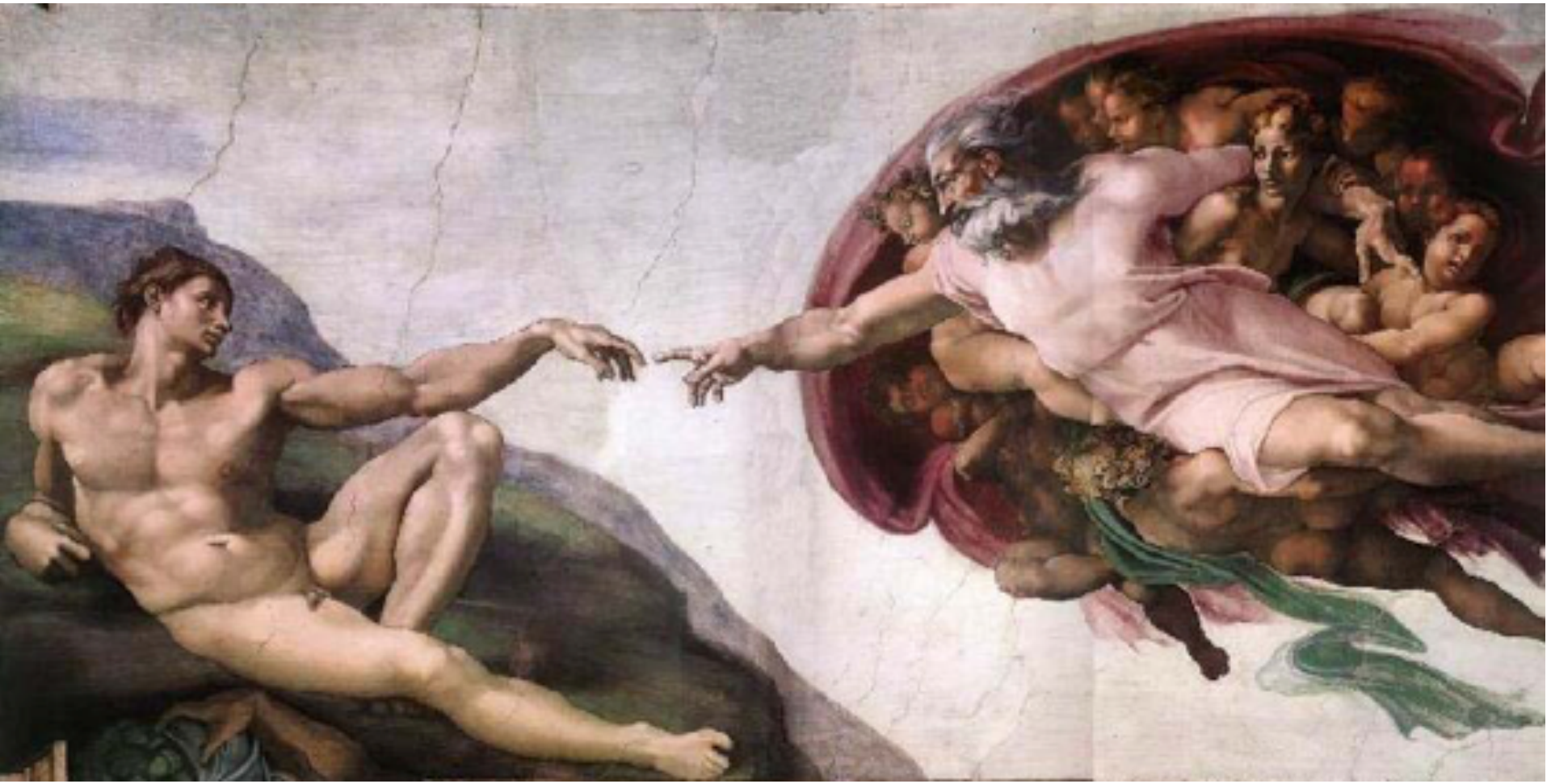
Chinese used Kaolin, a very fine grain white clay collected at the bottom of river beds.
Painting with glass colors and baking produced the famous Chinese ceramics.
It was imported to Europe by land convoys of traders (silk root) and was very expensive.

Roman wall painting on plaster (Stucco) was a common replacement to marble tiles and Mosaics. Paints immersed into the plaster created a robust decoration, and elaborate patterns.

Fresco painting

Paints, mixed with egg yolk, were embedded into fresh plaster and dried.
Michel Angelo perfected Fresco painting, giving an impression of three-dimensional sculptures.

The darkening of such paintings with time motivated restoration by various methods.



Restoration of oxidized and faded paintings

Painting of one of the profits at the Sistine Chapel ceiling before and after restoration.

OIL PAINTING

Color is mixed with solvent (turpentine) that evaporates leaving solidified layers.
Old oil paintings (e.g. by Rembrandt) are dark since white based $PbCO_3$ used to create light colors, degraded into black PbS. Restoration is achieved by H_2O_2 that turns PbS into $PbSO_4$

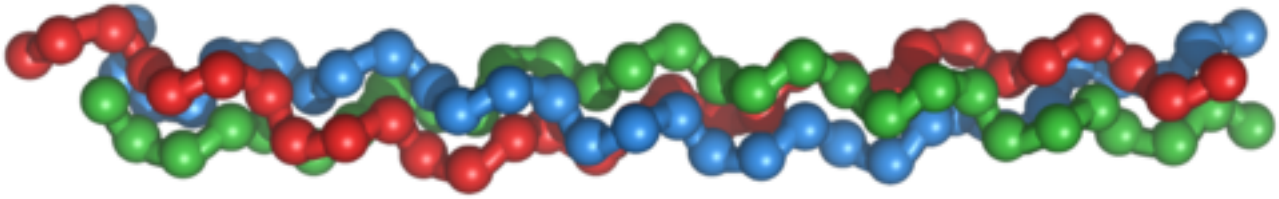
Vincent van Gogh –
The cedar tree at moonlight

Some claim the painter madness is due to the use of toxic Arsenide yellow colors.

Leather processing

Animal skins become brittle without processing. The reason is long collagen fiber aggregates. Leather processing involve breaking of these fibers by extraction of proteins by salts, softening by chromium salts (that break collagen fibers) and soaking in oak bark containing high concentration of tannin (with typical heavy smells of leather workshops). Leather has been used in clothing, horse harness, belts and straps for packing, skins for writing and more. It was widely available as a “side product” of the meat supplies from caws (stronger leathers) and sheep (soft skins and furs), as did the wool industry.

Atomic model of collagen triple-fiber



EXPLOSIVES

The chemistry of explosives may have started by the “fire balls” shot using catapults by the **Romans**. The supply of oxygen from tar or Quicklime to the flaming straw and wood prevented extinguishing the fire during flight of the torches.

673 AC The Turks conquer Constantinople using “Greek fire”:
fire bombs containing quicklime, crude oil, tar and Sulfur.
The fire bomb was thrown by catapults.

During medieval age, commercial convoys to China brought fireworks, and motivating the development of gun powder. See below.

Perfumes, Cosmetics, Drugs and medications

1200 BC Tapputi-Belatikallim is a world-recognized perfume maker from Mesopotamia, mentioned on clay scripts. His preparations were extractions from smelly parts of plants. First attempts of extraction probably meshed and boiled the mixtures, but the resulted preparations destroyed the flavors and smells, since the aromatic compounds disintegrated in heat, and crashing plant cells expose organic compounds to oxidation and loss of their medical efficiency (e.g. antioxidants such as garlic, onion and pepper). Purification without heating was therefore found effective using alcohols and oils. Perfumes as well as drugs and poisons were extracted from leaves, fruits (typically bitter and uneatable), roots, mushrooms, snake venoms (Cleopatra), snails, lizards and other "disgusting" animal fluids. Alcohols and oils differentially extract aromatic compounds. Alcohol was known in Mesopotamia from bear and later wine fermentation, and oils were prepared from olives as well as animal fats.

Extract from leaves and bark of the willow tree was known **2600 BC in Babylon**, and used to bring down high fever and ease pains and treat inflammation. It is now called Aspirin (acetylsalicylic acid).
2000 BC Stone scripted medical text from **Ur of the Chaldeans** mention Aspirin.
1543 BC Egyptian Ebers papyrus lists Aspirin.
460-377 BC Hippocrates knows Aspirin

Inorganic drugs were prepared from minerals –
e.g. Arsenic compounds – as poison, or mineral powders to clear the digestive tracts..

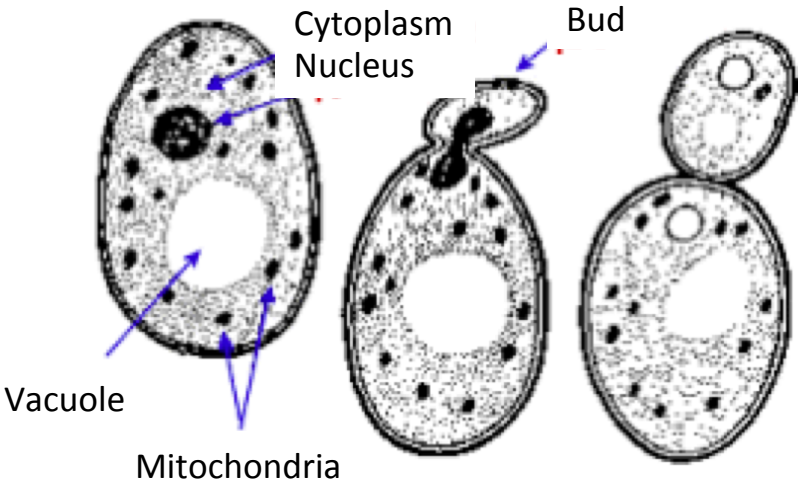
FOOD CHEMISTRY

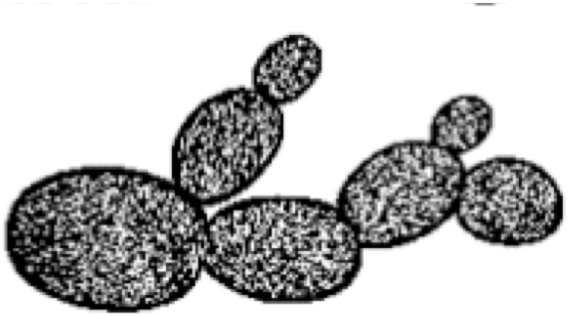
BREAD

3000 BC Egyptians used yeast in bread and wine preparations.
Dough, from ground grains and water, was left out in the air for spores in the air to fall on it and multiply in the rich nutritional substance. Samples that fermented well were used for next time yeast seeding, sometimes cultured with added sugars.
The yeast fermentation inside the dough emits small air pockets, that make the bread light and soft.

YEAST

Although yeast was used by humans for thousands of years, budding yeast cells were seen in microscopes only at **1680 AC by Leeuwenhoek**. 200 years later **Miler** describe yeast proliferation by budding, and **Pasteur** studies wine yeast metabolism, synthesizing alcohol from sugars, and bread yeast digesting carbohydrates and emitting CO_2.





Yeast budding

BEER

6000 BC Babylonians fermented beer from sprouting cereal grains (malted barley, wheat, maize (corn), and rice) that are rich in enzymes that digest carbohydrate. the Code of Hammurabi included laws regulating beer sales. "The Hymn to Ninkasi" is a recipe for beer making.

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Recipe for beer preparation

Meshing baked grains with water (Mash), heating to extract sugars, and filtering (Wort). Boiling Wort for sterilization and concentration by evaporating water. Hop is then added as antibacterial agent and for bitter taste, and the mixture is transferred into closed containers to minimize oxygenation, and yeast is added to break sugars into alcohol and CO_2 . Various yeast types determines the beer taste. Lower temperatures are used to prepare lager beers prolongs the fermentation process. The final drink contains 4-6% alcohol.

Hop fruit

WINE

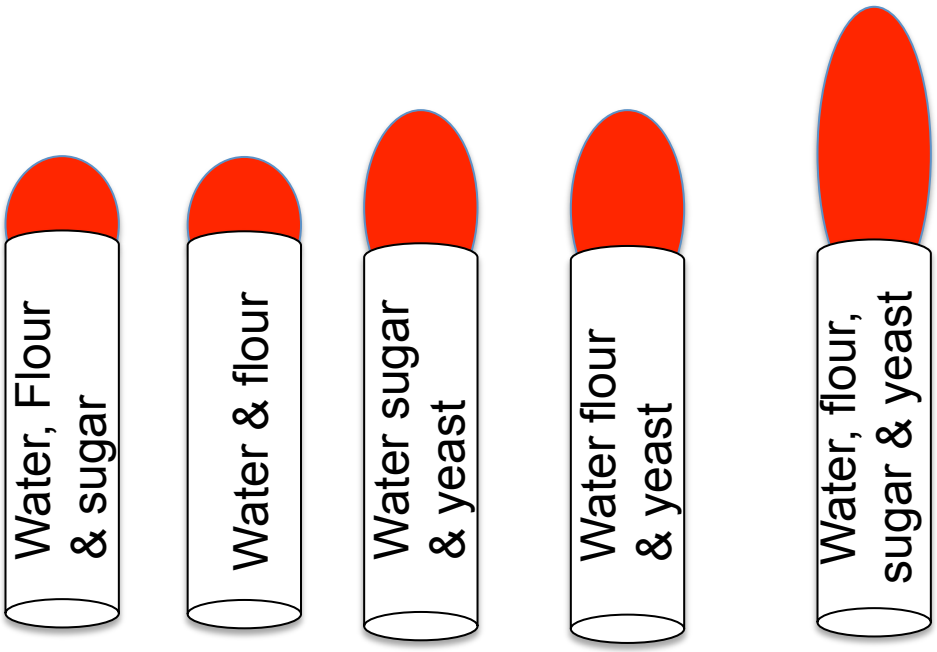
Wine was probably first used for sacramental purposes, but spread fast due to the ease of preparation and the effect on the brain.

Wine is prepared from grapes (or other sugar-rich fruits). Yeast is added to break the sugars into alcohol. Fermentation in barrels helped keep the same type of yeast that got stuck into the wood from year to year. Obviously the ancient world did not know yeast cells, but learnt to “seed” new preparations from last years samples.

Wine fermentation reach up to 14% alcohol content (why?). Higher alcoholic drinks are prepared by distillation: Alcohol evaporated at lower temperature than water, thus its vapor is led to a new, colder container, were it condenses into concentrated alcohol (liquor, brandy etc.)

EXPERIMENT

Simply add mixtures to a test tube and seal with a balloon.



OLIVE OIL

Olives are harvested manually or by shaking or hitting the tree and collecting the olives from the ground. They are brought to the press, crashed between two stones, inserted in sacks, and the mash is pressed to separate the liquid from the solids. When the liquid is left alone to stand oil floats over the water, and collected (today this is performed faster by centrifuges). Olive remnants are filtered to prevent acidification.

Olive oil is used for cooking, lightening, soaps, curing and cosmetic ointments and creams, and as solvents for extracting medications.

Olive oil is used by all cultures to crown kings and priests.

Soap

Soaps are used for laundry. Their uses for hygiene became common only during the last 150 years, before it was proven to exterminate bacteria that existed on our hands even if they look clean…

Soaps are produced by adding ashes and fats to boiling water and oil. The ashes contain Potassium salts that convert fats into fatty acids.

Dried fruits

This was probably the first method to preserve foods available in large quantities for a short season of the year, for later times when they are absent. Fruits dehydrate fast in the sun, but need protection from mold, insects and maggots, as well as night mildew. For efficient drying fruits were dissected open, and dried in mildly heated stoves.

Yogurt and cheese

3000 BC domestication of sheep and goats. Cheese is made from sour milk. The story tells about a nomad who carried his milk in goat's gut bottle, and got yogurt due to the remaining gut enzymes.

Cheese bacteria, when added to milk, reduce acidity when heating to ~40^{o}C. The casein from the milk precipitates and is separated from the water by filtration with cloth. Hard cheeses are prepared by further squeezing and evaporating out water.

Drying and smoking fish and meat

Salting and drying in the sun or on fire deters bacteria and mold from flourishing in the rich medium. Preserving meat in cold started only less than 200 years ago.

SUMMARY

Fire and heat accelerates and induces chemical changes. Therefore fire was considered itself a material “root” (element), that can create with earth, air and water all materials found in nature.

Metals (gold, copper, iron) were purified at high temperatures in reducing atmosphere to avoid oxidation.

Glass originated from sands.

Colors found in nature were extracted and used for dying cloths, painting, cosmetics and inks.

Processed foods such as beer, wine, bread and cheese, dried fruits and preserved fish and meat diversified human nutrition and provided means for food storage.

Oil supplied fats in nutrition, as well as media for extracting perfumes and medications from plants.

Soap was used for laundry 3-4000 years ago, but only recently appreciated as a sterilizer killing “unseen” bacteria.

Alcohols were available from the beer and wine productions, and was distilled for drinking, for medical applications and for extraction of drugs from plants and animals.

Humans of the ancient world accumulated a lot of experience in applications of complex chemical processes , although they did not understand them (at all, or at least as we understand chemical reactions today).