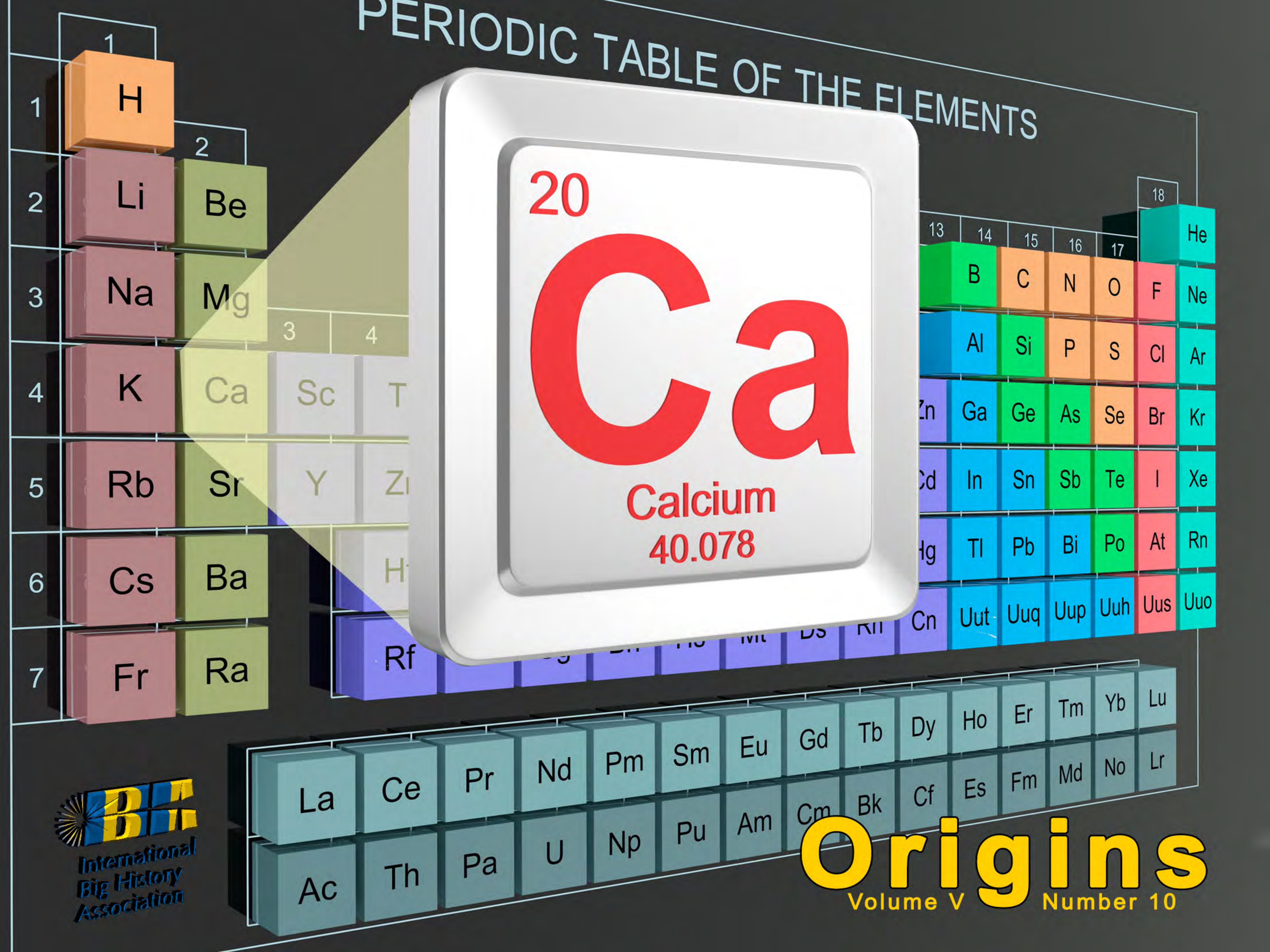

Origins

Volume V Number 10

International Big History Association

Table of Contents

Big History Research

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Big History of Calcium: Life's Actuating Element

Frans Verstappen

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Introduction

Calcium is the 12th most abundant element in the universe, the 5th most abundant on Earth, and the 5th most common element in the human body. Twenty-seven of the ninety-two chemical elements in nature are used by living organisms. The elements carbon, nitrogen, and oxygen play an essential role as building blocks of the molecules of life (proteins, fats and carbohydrates). In science the cycle of these elements on Earth has received extensive attention in the last decade. Hydrogen, the fourth most common and smallest element of life molecules, was created at the Big Bang. Hydrogen and helium are used for nuclear fusion in stars to create all heavier elements, including carbon, nitrogen and oxygen. Phosphorus, the fifth building block of life, is used for the molecules of genetic information (DNA and RNA) and for energy transfer (ATP and CP) and is therefore equally essential for life. Sulfur, finally, is a building block of several amino acids and thus of the proteins concerned. In addition to the primary role of certain elements as building blocks in molecules, another element actuates the processes in the cell, and that is calcium, the subject of this article. Calcium plays an important role in the geology on Earth, art and industry, and the conservation of our health. We will start by describing the creation of calcium in the universe and end with our modern understanding of the role of calcium in human health.

The creation of calcium

During a supernova explosion isotope ^{40}Ca is formed by the fusion of 10 helium nuclei. Calcium is very stable with 20 protons and 20 neutrons in its nucleus. All elements formed in the sheath of the heavy star are blown into the universe.

Those elements, because of their chemical properties (electromagnetic force), form molecules in the universe. In particular, crystals of H_2O (ice) and SiO_2 (rock) are present in the universe. Under the influence of gravity crystals clog together to form grit, grit to lumps and lumps to comets. Colliding comets create growing celestial bodies known as moons or planets. Our solar system is about 4.6 billion years old, with a number of planets are rotating around the sun. In the crust of planet Earth calcium is one of the elements available to use for life.

The cycle of calcium on planet Earth

The prevalence of calcium in the Earth's crust is 3.6 %, behind oxygen (46.6%), silicon (27.7%), aluminum (8.1 %), and iron (5.0 %). Rock consists mainly (60 %) of silicon oxide (SiO2) supplemented with all kinds of other crystal minerals. The Earth's crust consists of 6.4% of calcium oxide (CaO).

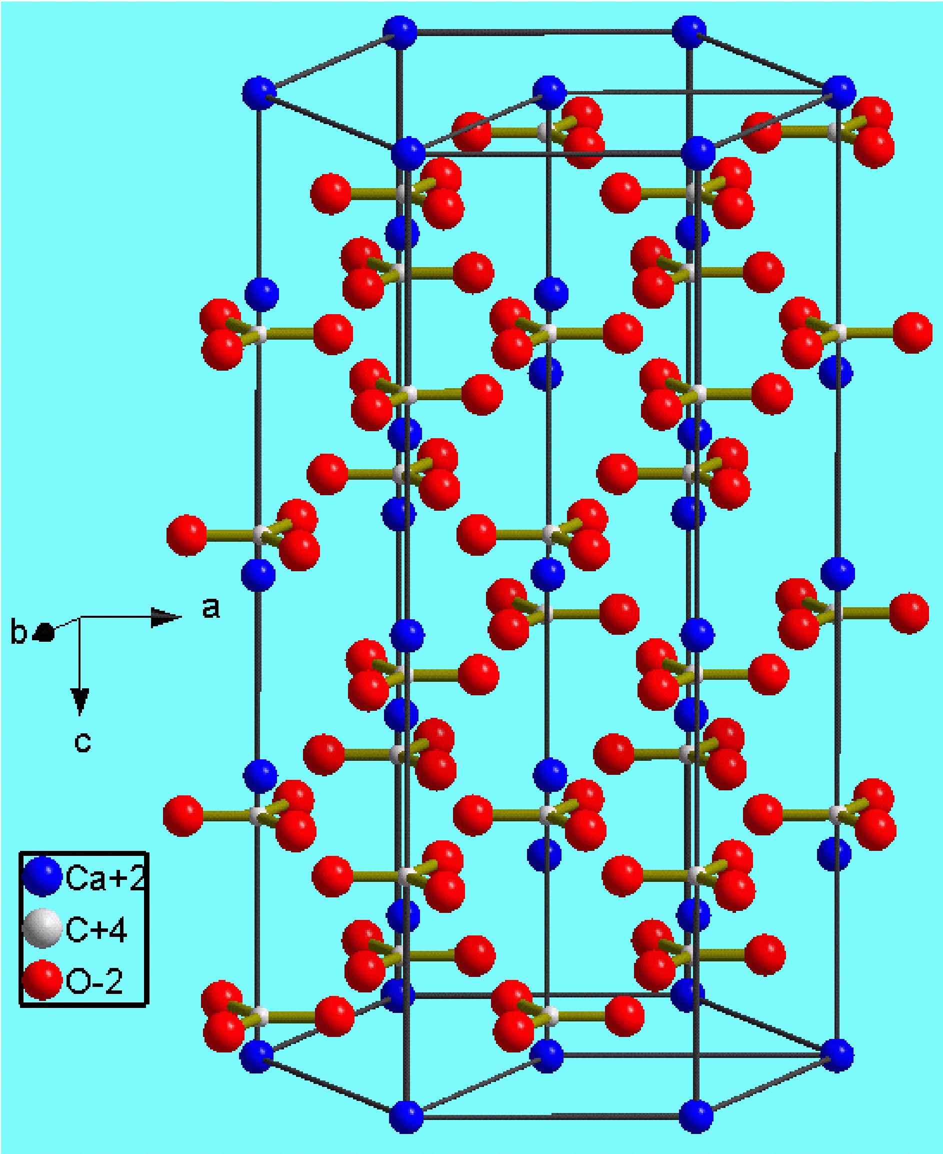

Figure 1: Hexagonal structure of calcite

Calcium carbonate (limestone) is one of most abundant compounds found on Earth. The massive amount of limestone (a sedimentary rock) on Earth was deposited by simple chemistry, by geochemistry, and by biogeochemistry in both fresh and salt water.

The chemical deposition of limestone in water is influenced by various conditions, such as concentration of calcium and carbonate ions, carbon dioxide content, acidity, temperature and hydrostatic pressure.

Limestone has three different crystal lattices: calcite, aragonite and vaterite. Vaterite is metastable and at exposure to water it is converted to calcite and aragonite. Calcite has a hexagonal structure in which the calcium atom is coordinated by 6 oxygen atoms (figure 1). In aragonite calcium is coordinated by 9 oxygen atoms and therefore is less stable than calcite. Limestone is also a huge source of carbon.

Figure 2: The White Cliffs of Dover, England

Natural sedimentary limestone that is deposited in shallow waters mostly contains impurities of sand, clay, mud (grain) but also iron oxide. When more than 80% of the rock composition is calcite, its history points to a long-term stable period of shallow waters, such as in the Cretaceous period of the Mesozoic era. A famous example is the White Cliffs of Dover (figure 2).

Marble and travertine are rocks of metamorphosed limestone. Marble is created by re-crystallization of limestone at great depth in the asthenosphere beneath the crust layer. Travertine is mostly formed in mineral springs when, in hot water, dissolved minerals precipitate as calcite or aragonite (figure 3). Thermophilic bacterial microbes may play a role in the process of deposition.

Beside calcium carbonate, other natural sources of calcium are minerals of sulphate ($CaSO_4$) and of phosphate $Ca_3(PO_4)_2$. In alabaster or selenite the building crystal of calcium sulfate has bound two water molecules ($CaSO_4.2H_2O$). In the history

Figure 3: Terraces of travertine in Mammoth Hot Springs Yellowstone Park, USA

of Western Europe the plaster of Paris mined from quarries in the Montmartre district of Paris is famous. When alabaster is heated, the water vaporizes from the crystal and leaves gypsum as a powder. Gypsum is extremely suitable as covering material for walls and ceilings. Whitlockite is a rock that mainly consists of calcium phosphate. It was discovered in 1941 by Herbert Whitlock. There are various crystal types of Whitlockite, including apatite, the building element of bone in animals. On Earth the mineral is relatively rare, but it appears to be more abundant in alien rocks from the moon, Mars, or meteorites.

The biological contribution to the deposition of limestone comes from the very first life forms. There are indications that early microorganisms already 3.5 billion years ago were involved in the calcium cycle on Earth. The fossil record of those early microorganisms was found in stromatolites. Stromatolites consist of layers of calcite produced by the chalk skeletons of microorganisms that live in shallow waters. Microbial mats may induce stratified precipitation of dissolved calcium carbonate salt to crystals near the water surface. Organic globule clusters and aragonite crystal structures in the fossils from the Archean Eon are indications of biological activity, but abiotic (geological) processes might support the accretion

Figure 4 : Stromatolites along the coast of Shark Bay, Australia

process. Microorganisms involved in stromatolite-formation are still present today. Contemporary stromatolites in the Shark Bay along the coast of northeast Australia are a tourist attraction (figure 4), but they are everywhere, also in fresh water (figure 4).

Stromatolites are visible constructions of limestone above the water level, but on the seabed coccolithofores (unicellular algae) are living in much larger numbers, and their chalk skeletons sink into deep water and form a growing layer of sediment. Thomas Aldous Huxley discovered the process in 1858 and gave the unicellular organisms their name. In 1861 Henry Clifton Sorby described the famous white chalk Cliffs of Dover. The deposition period was the Cretaceous era 145 to 65 million years ago when in northwestern Europe shallow seas were common. But from the Cambrian period, 545 to 480 million years ago, also multicellular organisms with an external chalk skeleton appeared in the water, like the extinct trilobites [well-known thanks to their chalk skeleton leaving many fossils, shellfish, and coral (figure 5). The formation of layers of calcareous skeletons on the seabed

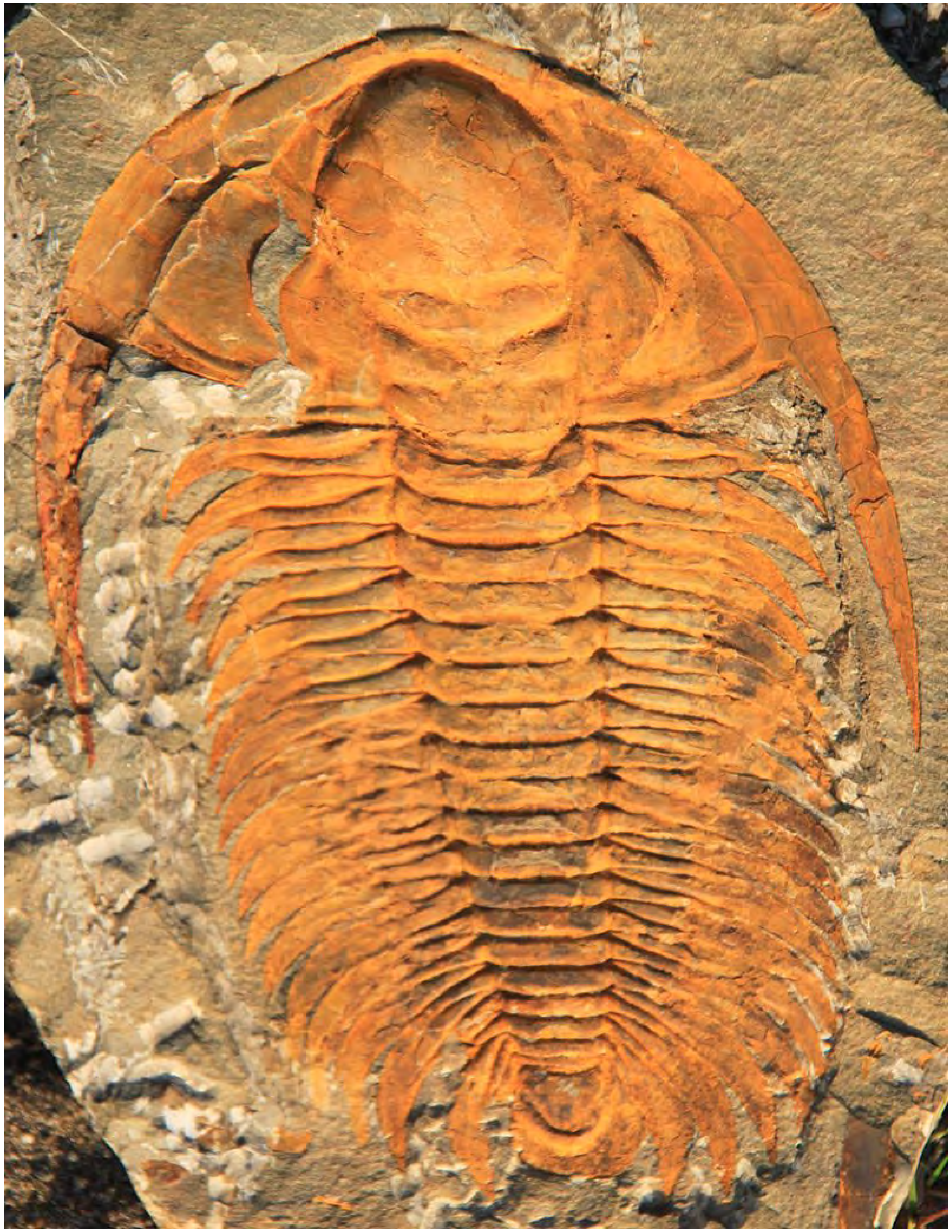

Figure 5: Fossil of a trilobite

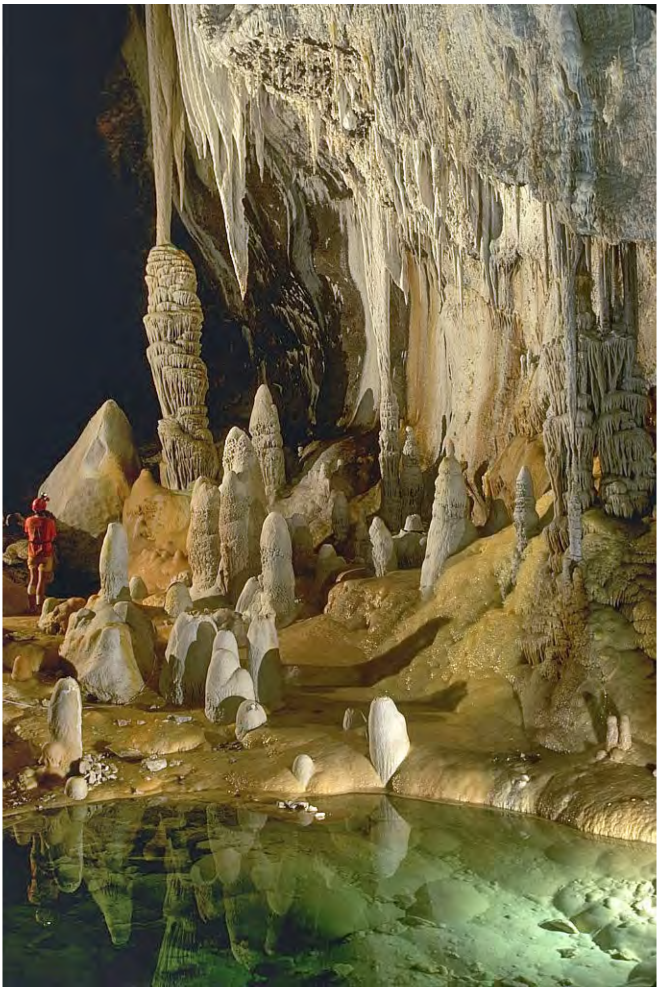

Figure 6:
Stalactites and stalagmites
in Lechuguilla Cave in New Mexico, USA

thus is a continuous process started 3.5 billion years ago.

Cretaceous, the last geological period in the Mesozoic, is derived from 'creta' meaning chalk in Latin. Limestone is porous, which means that water may seep through. The result is the creation of cavities, since limestone dissolves in carbonated water and is carried off. Caves with stalactites and stalagmites demonstrate the process of precipitation of calcium carbonate crystals again after dissolving in the water stream. At the surface a typical landscape of limestone is karst (figures 6 and 7). In conclusion, limestone disintegrates rather quickly, and calcium returns via rainwater in rivers to the sea. It is there again available for coccolithofores, shell fish, and coral organisms to build new skeletons for the next cycle.

The geological contribution to the deposition of limestone comes from plate tectonics. In the course of time the layers of calcium carbonate sediment grow, resulting in compression of the underlying layers. The calcium carbonate crystals are pressed together and will be transformed to limestone with the crystalline grid of calcite or aragonite (figure 8). Through tectonic movements of the Earth's crust, the ocean plate may slide under the neighboring continental plate and end up in the border area between crust and mantle, the asthenosphere (figure 9). The temperature in the asthenosphere is so high that solid rock becomes viscose. Due to the increased motion of molecules, the original crystal lattice will abrogated. Original limestone layers will re-crystallize when moving to the Earth surface. This process is the mechanism of metamorphosis in geology. The mantle material under the crust is rich in magnesium, aluminum, and silicon oxide. These elements or molecules may partly replace the calcium carbonate molecules in the original limestone. At the surface the original composition of rock is often difficult to establish. For instance,

Figure 8:
Cylindrical crystal of aragonite

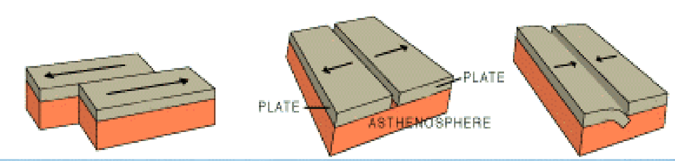

Figure 7:
Karst landscape in Minerve Hérault, France

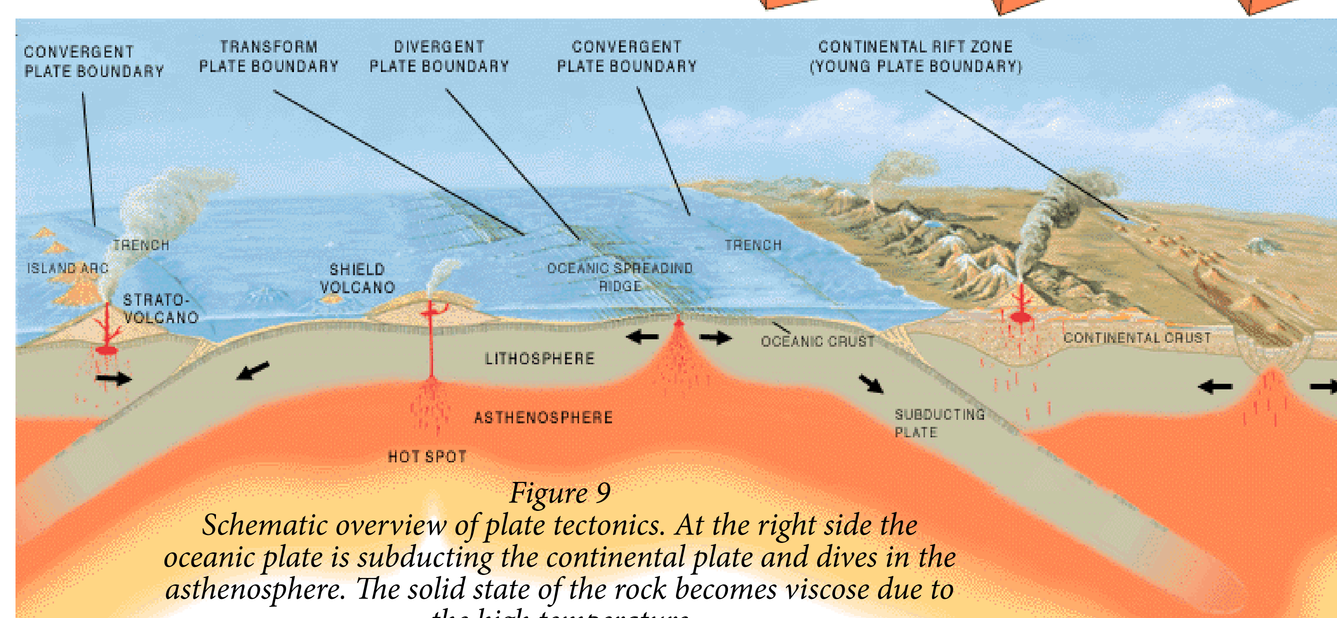

Figure 9
Schematic overview of plate tectonics. At the right side the oceanic plate is subducting the continental plate and dives in the asthenosphere. The solid state of the rock becomes viscose due to the high temperature

Figure 10: The Dolomite alps

The main application of calcium carbonate is in the construction industry: as building material, as aggregate in road construction, as an ingredient of cement, or as source material when heated in kilns for the production of calcium oxide (quicklime). The application of calcium carbonate goes back to the time of the first settlements at the beginning of the Neolithic approximately 10,000 years ago. The Sphinx and great pyramids in Egypt were built of limestone from chalk skeletons of foraminifera deposited during the Jurassic period of the Mesozoic era (figure 11).

A special application of limestone is its use as raw material for the production of cement. Cement was not the first binder used in the history of construction of buildings

Figure 11: Great Sphinx of Giza (Egypt) with the Pyramids (background)

dolomite, described in the 18th century by the Frenchman Déodat the Dolomieu, is built of crystals of combined calcium and magnesium carbonate. The Dolomite Alps in North Italy and Austria were formed in the Triassic period, 250 - 200 million years ago. (figure 10). Marble and travertine are also rocks of metamorphosed limestone.

Use of calcium in human history

* Use of calcium in industry

Figure 12: Old lime kiln Boscastle in Cornwall, England

or infrastructure. That was bitumen, which in nature is spontaneously formed from petroleum. In the Gilgamesh epic, over 4.000 years ago, bitumen was described as being used for making the Ark of Noah waterproof in preparation at the forthcoming deluge. Cuneiform tablets also record that bitumen was applied in the construction of temples, palaces, waterworks, and roads. The first use of cement and mortar is dated at 3000 years BCE in Babylon, Egypt, and the Indus Valley. Cement is made by heating limestone higher than 825 °C in kilns (figure 12). Carbon dioxide is then released from the calcium carbonate, so that calcium oxide (quicklime, burned lime) remains [$CaCO_3 \rightarrow CaO + CO_2$]. After mixing with water, calcium oxide is transformed to calcium hydroxide (slaked lime) [$CaO + H_2O \rightarrow Ca(OH)_2$]. When the water excess has evaporated, CO_2 gas in the air promotes the chemical reaction [$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$]. The precipitated calcium carbonate hardens and forms with molecular-size strong ties on the silicates of sand, baked clay, or rock.

For the production of hydraulic cement in a wet environment or on underwater constructions, a mixture of silicates and oxides of aluminum and iron (pozzolan) is added to the slaked lime. The Ancient Greeks applied this process first in the 5th century BCE, and it was further developed by the Romans. The name pozzolan refers to the area of Pozzuoli in the surroundings of Naples where volcanic pumice was found. The durability of the material is illustrated by the Pantheon in Rome (figure 13) and the Pont du Gard (figure 14) in Nimes (France). The oldest submerged construction of concrete is the City of Caesarea (figure 15) in the 1st century CE (Concrete Revolution). Since 1894, Portland cement is used as standard in the concrete industry.

Figure 13: Interior of the Pantheon in Rome, Italy

Figure 14 : Pont du Gard in Nimes, France

Marble and travertine were also widely used as a building material in ancient times. A splendid example of white marble is the Mausoleum Taj Mahal in Agra , India, built in 1653. Travertine was used for building the Colosseum in Rome, completed in 80 CE, without the use of cement. Apart from buildings, both metamorphosed limestone rocks are suitable as tiles for the construction of floors and paths.

* Use of calcium in art

The main application of limestone and gypsum in art is sculpture. Materials such as ceramics and terracotta are excluded in this paper because the raw material is not limestone but clay (silicates). Early in the development of cultural societies,

Figure 15: Caesarea Maritima in Israel

sculptures were created as expression in religion and politics. Sculpture of stone is better preserved than that of wood, which will rot, or metal, which can be melted down for another application. The oldest saved limestone sculptures are Venus figurines from Europe (figure 16) dated 35.000 years ago in the Aurignacian era (Paleolithic Age).

Figure 16: Venus figurine von Willendorf (Neolithic limestone)

The calcium-containing materials used in sculpture are marble, plaster, and concrete. Marble is the sort of hard stone that can be carved. A skilled sculptor can create out of marble a statue, a bust, or any depicting scene. Marble is also suitable for inscriptions or three-dimensional drawings in floors, walls, or ceilings. For reproductions of sculpture, gypsum is used as the material. Gypsum is also suited as construction material for making devices or molds to create art of other material, such as bronze or ceramic. Concrete in architecture is used to design art (figure 17).

The use of natural stone in sculpture, although started already 35,000 years ago, got hardly any further development until the middle of the Neolithic around 6000 years ago. The progression of civilization on the various continents, or between the different regions within a continent, did not take place simultaneously. The conversion of the nomadic hunter/gatherer lifestyle to that of agriculture and livestock farming within a settlement started first in the Fertile Crescent (figure 18). During the growth of a settlement to the size of a village and further to a town, the opportunity to specialize in various skills, including those within art professions, was rising. Hence, the oldest sculptures and monuments are found in cultures of the Fertile Crescent. The settlement cultures from the Fertile Crescent were adopted and further developed in Greece. In succession from the 3rd millennium BCE the cultures of the Ancient Greek, the Classical Greek, and the Hellenistic were ready to flower. The dominance of the Greek was taken over by the Romans. Since they got a later start, the oldest sculptures in other cultures in Eurasia and on the other continents are of a later date.

Figure 17: Concrete architecture in Montreal, Canada

The chemical properties of calcium

Modern science has given us the method and tools for discovering the inner workings of the element calcium. Calcium belongs to the alkaline earth metals. Calcium is positioned in group 2 of the 4th period of the periodic table of chemical elements. Calcium has atomic number 20 with 2 electrons in the outer shell (figure 19). On exposurure to air it violently

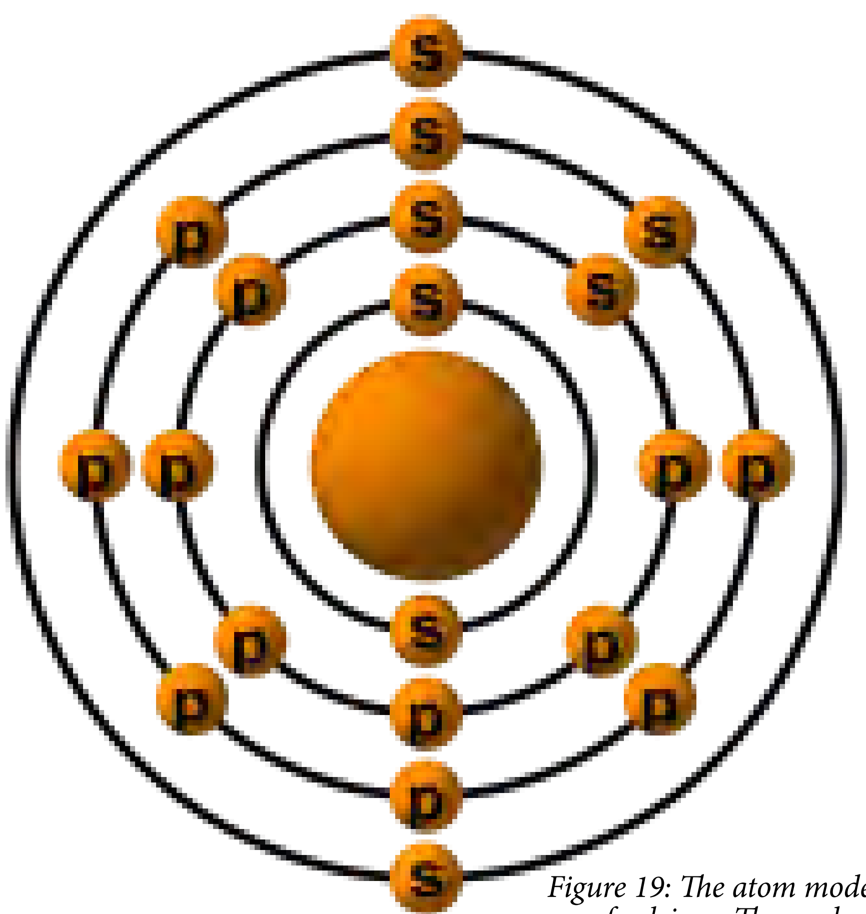

Figure 19: The atom model of calcium. The nucleus contains 20 protons and 20 neutrons. The 20 electrons are distributed over 4 orbits leaving 2 electrons in the outer orbit.

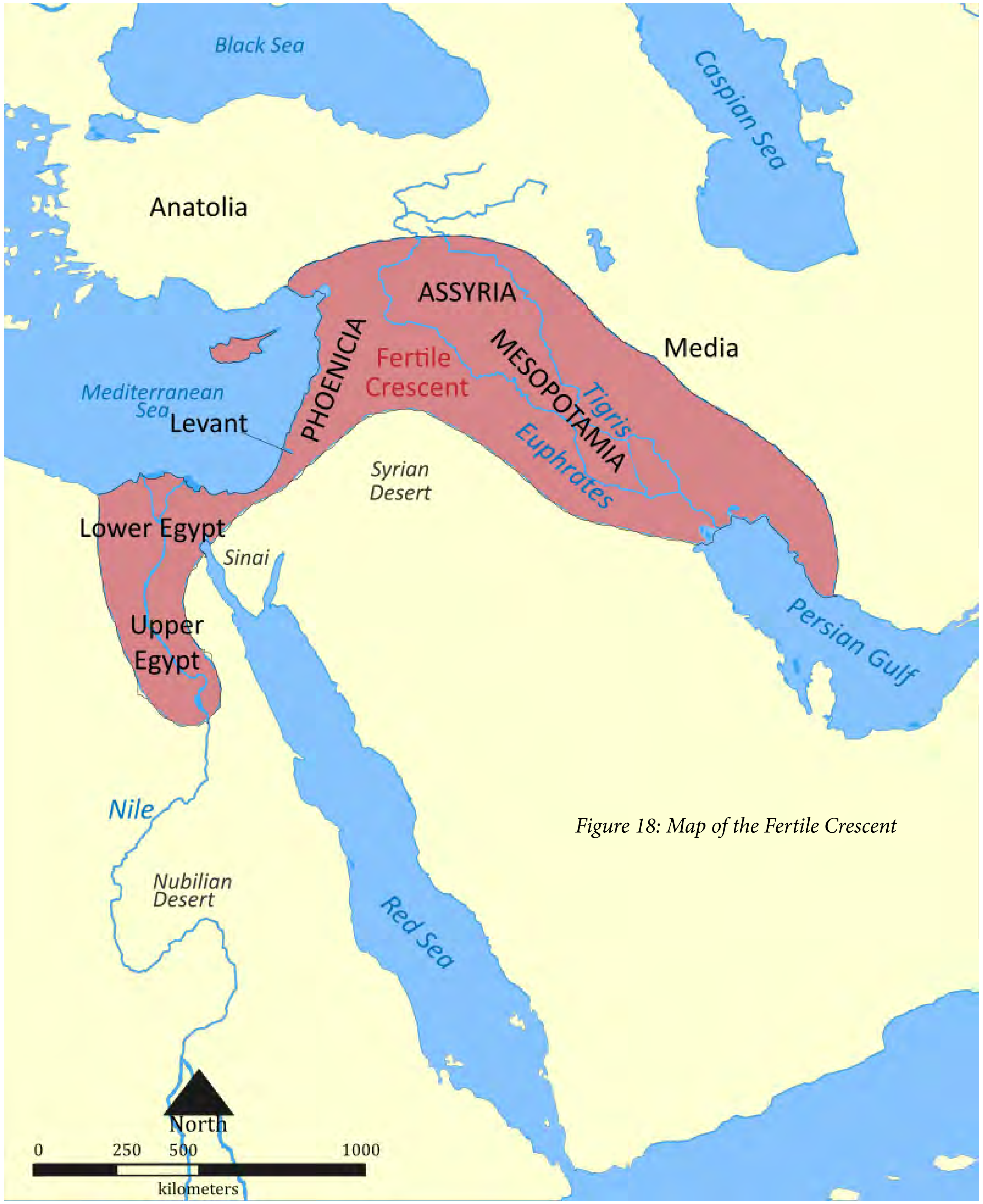

Figure 18: Map of the Fertile Crescent

with oxygen and forms calcium oxide (CaO). Calcium reacts in water to form calcium hydroxide $Ca(OH)_2$ and hydrogen (H_2). Calcium dissolves easily in water and forms salts with anions such as chloride, carbonate, sulphate, and phosphate.

Besides isotope ^{40}Ca there are 4 heavier stable isotopes of calcium in low concentrations. The ratio between light and heavy isotopes of calcium in a solution, such as blood plasma or seawater, can be used to examine the intake or release of calcium in tissue or coral, respectively.

Calcium in the human body

*An overview

Modern medicine has given us the method and tools for discovering the inner workings of calcium in the human body. In a human body of 70 kg, approximately 1 kg (1.5 %) is on account of calcium. Ninety-nine percent of this calcium is stored as crystals in the skeleton, not with carbonate but with phosphate as hydroxyapatite [$Ca_5(PO_4)_3OH$]. Vertebrates with an internal skeleton use hydroxyapatite as material for

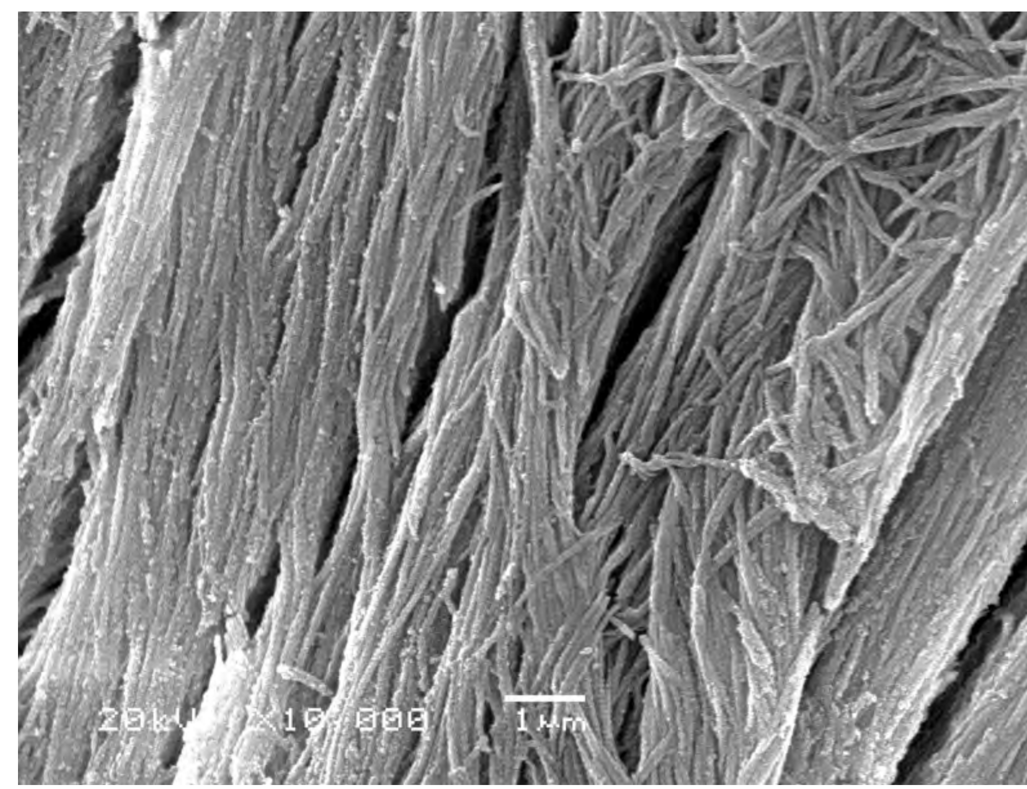

Figure 20:
Bundles of hydroxyapatite in the shaft of a pipe bone magnified under an electron microscope.

bone (figure 20).

The cells that build bone are named osteoblasts (figure 21). After completing their work, osteoblasts evolve to osteocytes. Osteoblasts and osteocytes construct tight junctions to form a barrier of contiguous cells. Tight junctions hinder the leakage of substances from one side of the cell layer to the other side. The barrier is impermeable for calcium and phosphate ions. For the mutual exchange of substances between the cells, gap junctions serve as channels . The structure of both tight and gap junctions indicate that the control of bone mineralization has been entirely in the hands of the osteoblasts.

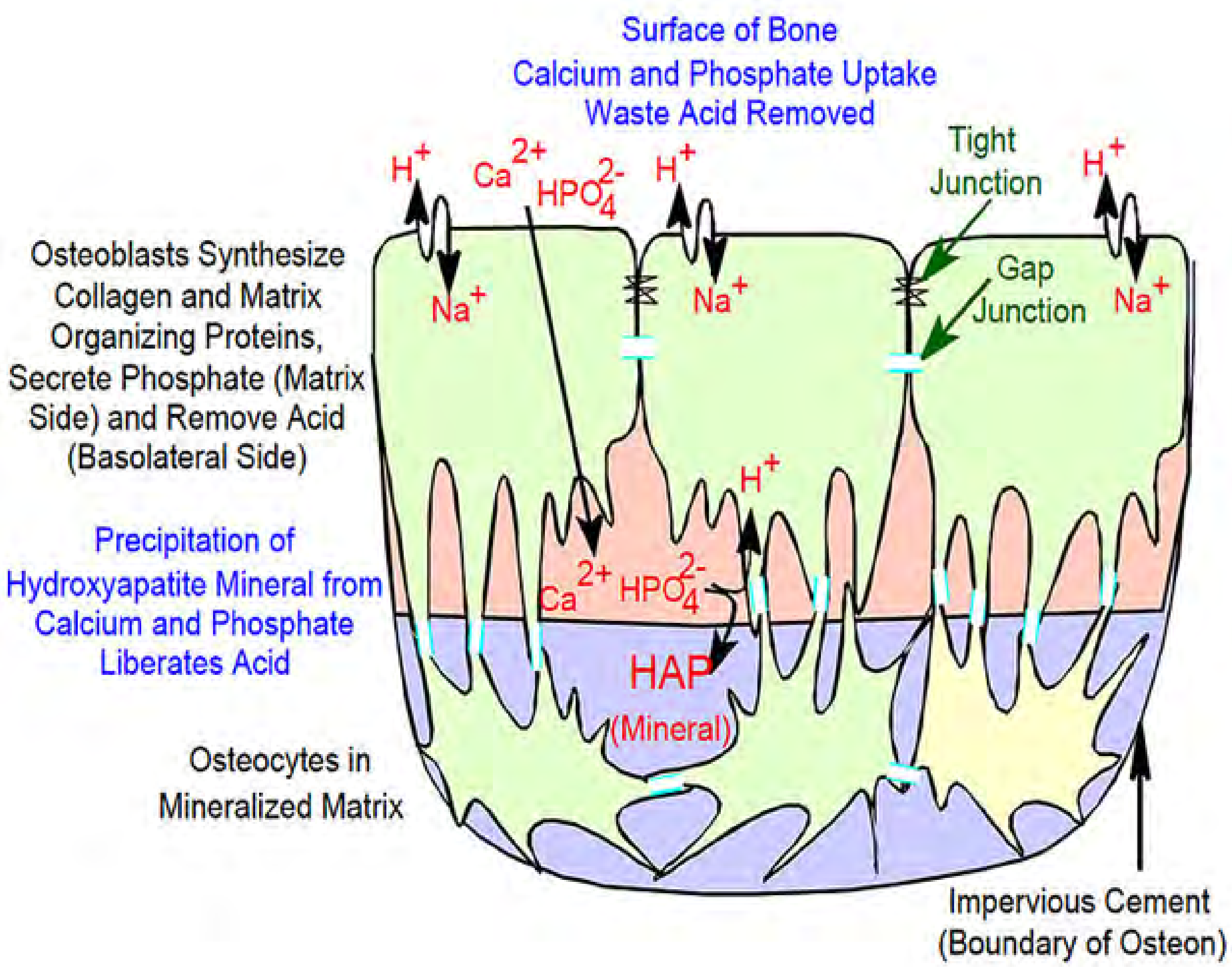

Figure 21: A schematic picture of a layer osteoblast cells. Hydroxyapatite (calcium phosphate bonds) are precipitated as crystals in the bone matrix. The releasing hydrogen ions in that process are removed by the cell through exchange with sodium ions. Osteoblasts have been mutually connected with tight junctions which prevent free transport of substances between extracellular space and bone material. Mutual gap junctions serve for transportation of substances between osteoblast cells. That transport is essential when osteoblasts have been developed to osteocytes which are surrounded by bone material.

In case of a fracture, damaged bone material needs to be removed before recovery construction by osteoblasts can be performed. Removal of damaged bone material is performed by osteoclasts, the demolition cells in bone. Osteoclasts are giant cells evolved by fusion of several macrophages (specialized cells in all tissues to clean-up any damage). Osteoclasts pump hydrogen ions (increase of acidity) in the space around the bone material to dissolve the crystals and secrete degrading enzymes to break down biological molecules. The waste products are resorbed by the cell, transported in vesicles to the other side and excreted. The blood drains all tissue fluids and carries the waste products to organs for recycling.

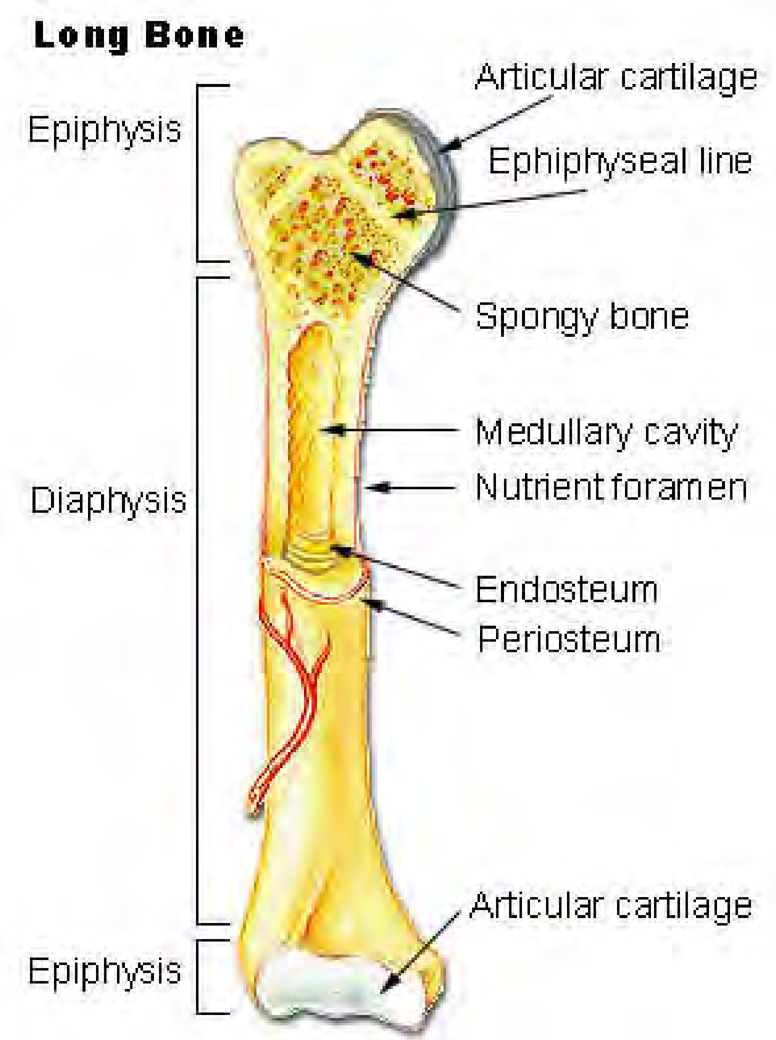

Figure 22:
The structure of a long pipe bone in arms and legs. The bone is hollow inside and filled with yellow fat. The strength of the shaft is appropriate to carry natural forces of bodily motions. At the endings of the bone (epiphysis) drag forces from attached muscles are led through lamellae. The cavities between the lamellae are filled with red marrow.

Bone is not just hard and stiff material of hydroxyapatite crystals, but it also contains collagen slender fibers that transfer the draft force of attached muscles. The fibers are produced by the osteoblasts and form a matrix for attaching hydroxyapatite crystals. This construction is very strong and permits cavities in the bone to save weight. The long bones in arms and legs are hollow inside. At their ends trabecular bone is constructed in thin layers (lamellae) directed according to the draft of the attached muscles (figure 22). The cavities in trabecular bone contain red bone marrow for the production of blood cells. Thanks to the light bone construction with cavities, the muscles will save strength and thus need less mass. The construction of the musculoskeletal system is an excellent example of efficiency in nature.

The body has, thanks to its skeleton, a huge stock of calcium and phosphate available. That is particularly welcome because the stock can be directly accessed in case of an imminent shortage of these substances in the soft tissues. Calcium and phosphate ions play a crucial role in the regulation of cell and organ functions. That is why the concentration of these ions in blood and extra-cellular space should be accurately set. The arrangement of the calcium balance is executed by hormones according to the same model as that of glucose, the energy-delivering substance of the cell. The concentration of calcium ions in blood varies within narrow limits between 2.2 and 2.6 mmol/L.

* The calcium balance of the human body

The hormone glands that regulate the calcium balance are the parathyroid (4 tiny glands) and the thyroid (figure 23). The produced substances are parathormone and calcitonin, respectively. A decline in calcium ion concentration may have serious consequences for many cell and organ functions. In severe cases, a rapid intervention to restore the decline is a matter of life or death. Cells of the parathyroid releasing parathormone use a short negative feedback system to enhance the concentration of calcium ions in blood and tissue fluids within a few minutes. Calcium-sensing receptors on the parathyroid cell membrane monitor the extra-cellular calcium concentration and transduce the signal to intra-cellular messengers. Preformed parathormone is stored in vesicles. The release from the vesicles is achieved through a rise in intracellular calcium concentration induced by the messengers. The liberation of the parathormone can thus be adjusted momentarily. The risk of an overshoot is prevented by a short half-life time (time needed to lower the concentration to the half of the original one) of the parathormone in blood of only 4 minutes.

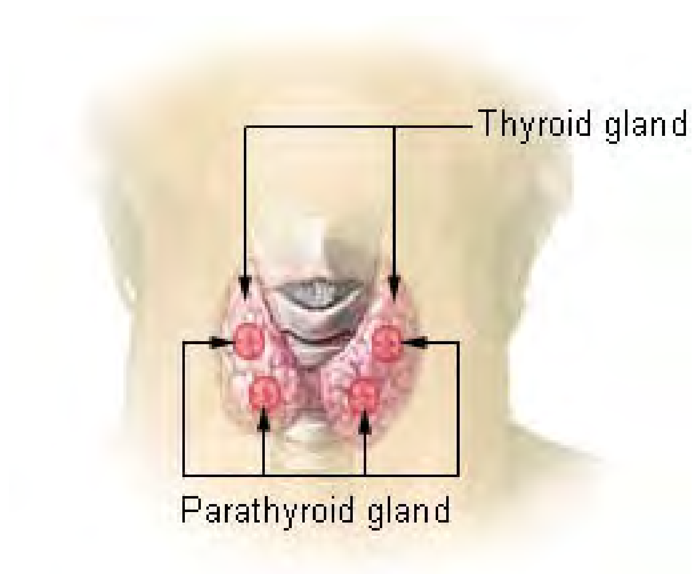

Figure 23: The location of the thyroid and parathyroid glands in front of Adam's apple.

The parathormone stimulates various processes in the body to restore the extra-cellular calcium ion concentration (figure 24). The release of calcium ions from bones is rapid and prevents acute disorders in many cell and organ functions. The parathormone stimulates the activity of the osteoclasts but not directly. The receptors for the parathormone in bone are located at the osteoblasts, and they transfer the activation signal to the osteoclasts. A second, slower effect of the parathormone is advancing the absorption of calcium in kidney and intestine. In the kidney less calcium is excreted via the urine, and in the intestine more calcium is resorbed from the food. An extra effect of the parathormone in the kidney is the activation of previtamin D3 (calcitriol). Vitamin D3 promotes the resorption of calcium from the intestine.

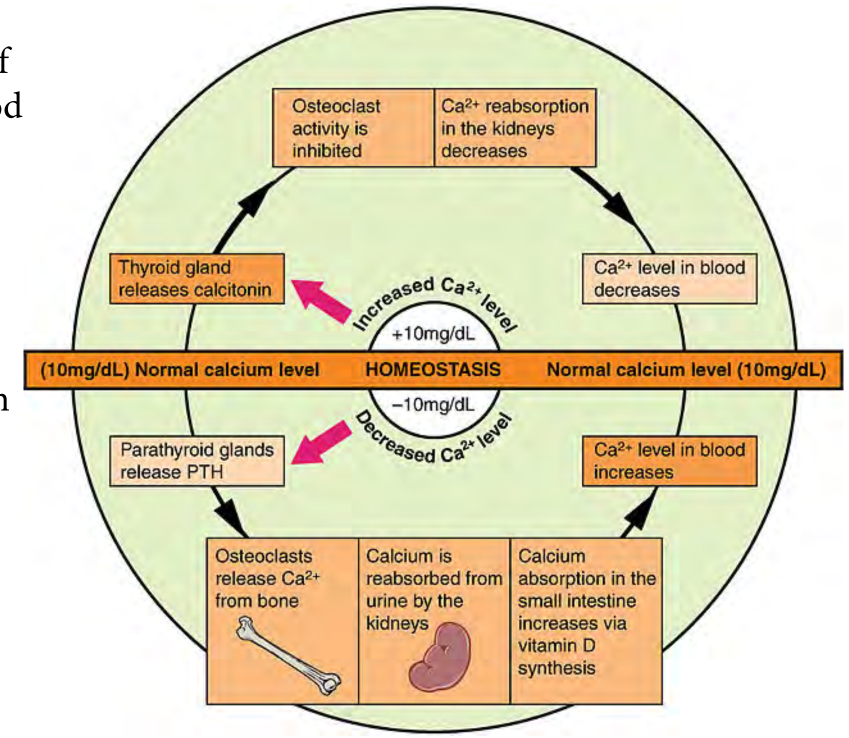

Figure 24
A schematic picture of the calcium balance in the human body. A decrease in calcium concentration in the blood is observed by receptors on cells of the parathyroid glands. The signal leads to a release of the parathormone. The parathormone promotes the acid producing function of osteoclast cells in bones. The acid does dissolve hydroxyapatite and the releasing calcium ions enhance the concentration in blood and tissue fluids. In the kidney parathormone enhances the calcium resorption from urine and the conversion of previtamin D to vitamin D3. Vitamin D3 promotes the calcium resorption from food in the intestine. An increase in calcium concentration is controlled by a similar feedback cycle in the thyroid gland producing the hormone calcitonin.

Calcitonin counteracts the effects of the parathormone. The controlling system of calcitonin production acts considerably slower than that of the parathormone. Disorders in the calcitonin release occur rather seldom.

*The role of calcium in cell processes and organ functions

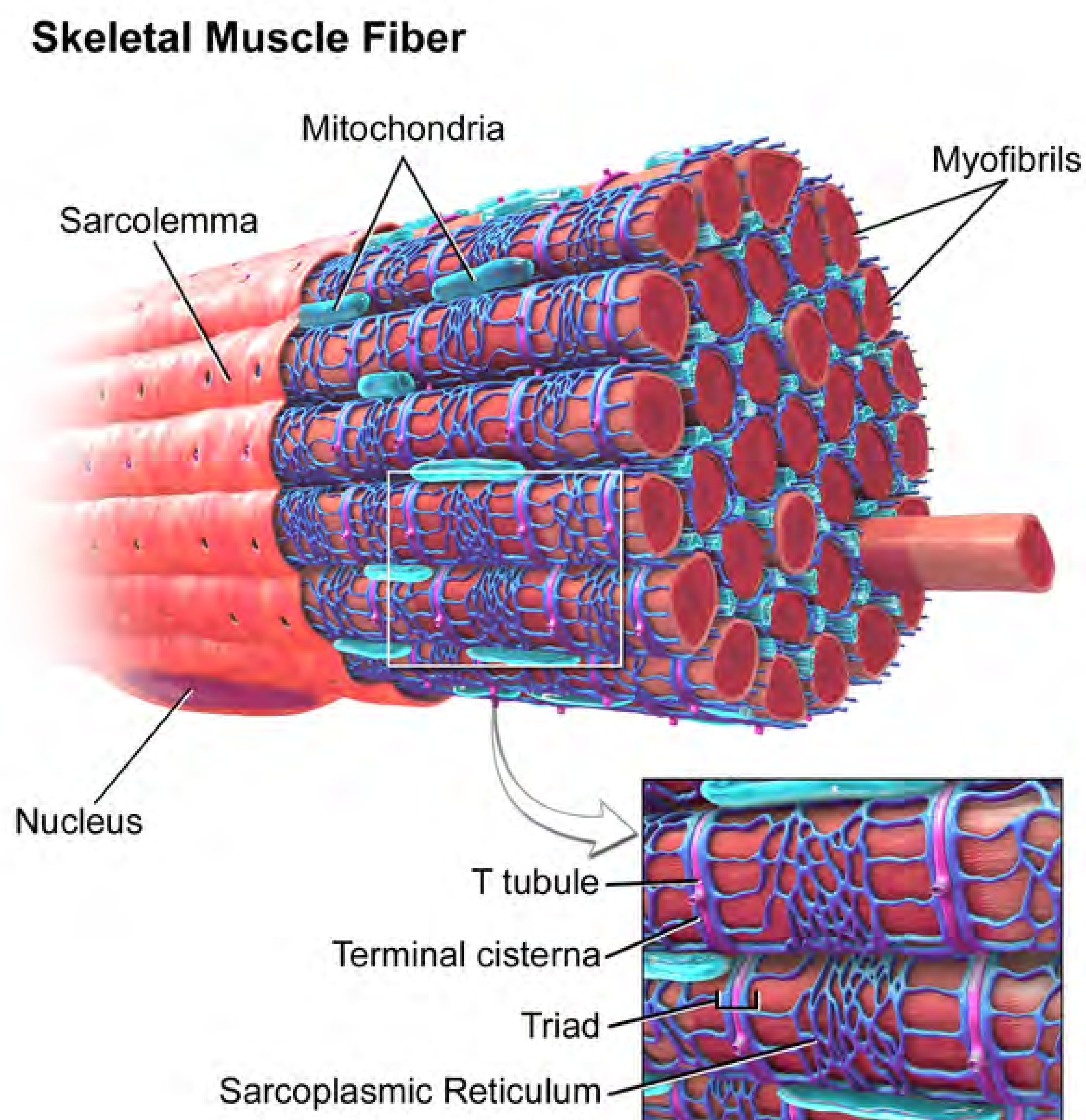

Figure 25
The sarcoplasmic reticulum is a network of tunnels surrounding the myofibrils of the muscle fiber. It does collect calcium ions through pumps in its membrane from the cell plasma. When activated by an electrical stimulus that is propagated along the sarcolemma, channels in the reticular membrane open very shortly to release calcium ions. Due to the high concentration gradient calcium ions diffuse rapidly inwards around the fibrils eliciting the mechanical action.

Calcium storage in the body is bound as crystals in the skeleton. Only 1% is dissolved as ions in the extra-cellular fluid (blood + tissue fluid) and in cells. The distribution of the calcium ions between the extra-cellular and intra-cellular fluid is remarkably uneven: the concentration gradient from outside to inside is about a factor 1000. So, it can be concluded that the cell membrane is impermeable for passive transport of calcium ions, and moreover that calcium ions inside the cell are actively pumped outwards.

It is beyond the aim of this paper to describe in detail the construction and function of calcium pumps in the membrane of cells. The following description is appropriate for understanding. Excitable cells of nervous system, muscles, and sense organs use electricity for their function. The transport of electrical charged particles is not via electrons but via positively charged ions, K^+ (potassium) and Na^+ (sodium). In muscles the transposition of the electrical signal along the membrane into mechanical action of the myofibrils is provided by calcium ions. Calcium ions are stored in vesicles of the sarcoplasmic reticulum (figure 25) near the power generating zones within the filaments of the muscle fiber. An electrical current elicits a very brief leakage of the vesicle membrane, resulting in a rapid effusion of calcium ions to the filaments. Calcium ions accomplish adhesion at special binding sites between the alternating filament chains myosin and actin. The binding is automatically followed by an articulation movement of a molecular bar in the myosin filament (figure 27). As a result of the power stroke, myosin and actin filaments are sliding into each other. That action synchronously occurs at thousands sites along the muscle fiber, providing a harmonious muscular contraction. Calcium is also involved in other muscular activities, like the pumping action of the heart, the peristaltic motions of the intestine, or the narrowing of blood vessels.

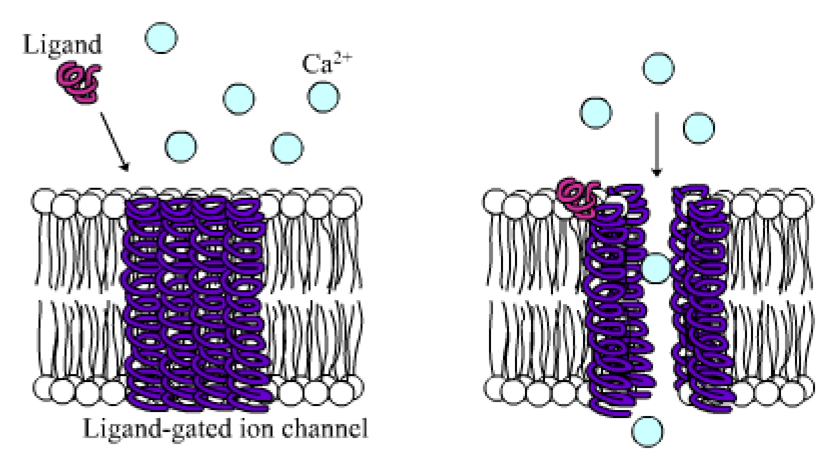

Figure 26
A schematic picture of a calcium channel in the cell membrane of nerve cells. The cell membrane consists of a double layer of fatty molecules that is impermeable for polarized water molecules, ions or electrically loaded molecules. Within the membrane selective passing of calcium ions is possible through channels. The channels can be opened very shortly by a fitting key molecule (ligand).

In the nervous system the transmission of signals between nerve cells is executed in a similar way as at muscular

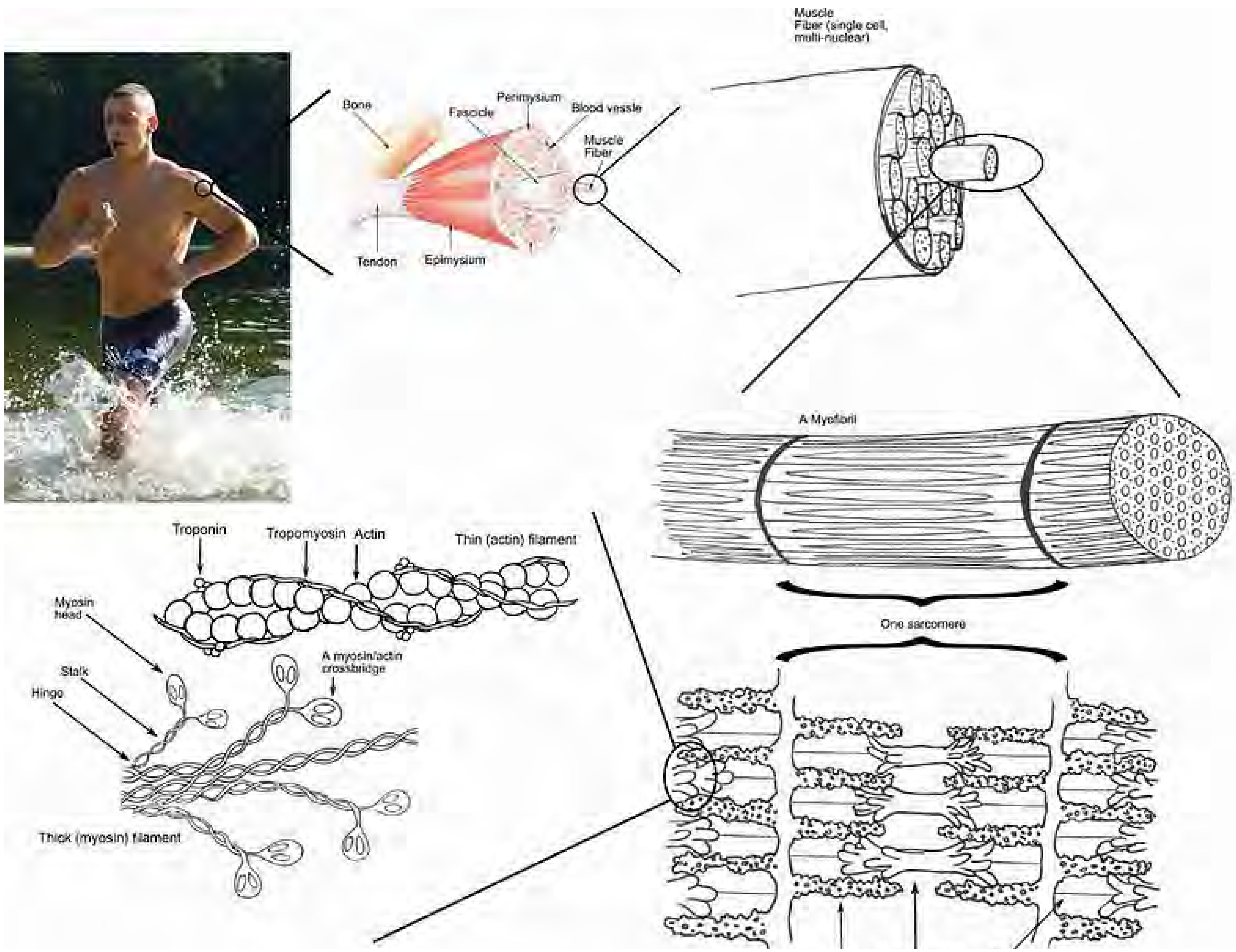

Figure 27
The skeletal muscle structure reduced in steps to molecules. The working unit of the myofibril is the sarcomere consisting of the filaments (fibrous proteins) myosin and actin. Change in length is possible through in- or outwards sliding of the filaments. Force is produced when the myosin head makes contact with the receptor of actin (troponin). The trigger of this contact is the calcium ion.

contraction. A diversity of calcium channels in the cell membrane (figure 26) is present for fine-tuning the transmission process. In conclusion, calcium ions are directly involved in the function of cells that use electricity. The maintenance of a stable concentration gradient across the cell membrane is therefore essential.

A second major essential function of calcium in all types of cells is that of second messenger. Second messenger in biology means that calcium is used as the signal transducer between the primary stimulus acting on the cell membrane and the target process in the cytoplasm. Examples of targets are metabolic processes, expression of genes, or cell division. Calcium affects the intended process as the ion (Ca^{2+}) tied to a specific protein, calmoduline (figure 28).

Some other essential tasks of calcium in the body include the process of blood coagulation (cofactor in a cascade of chemical reactions) and as the element of barrier material (tight junctions) between separated spaces in our body, as in bone (see figure 21) or neural tissue.

* Disorders in the calcium balance

In the previous paragraph the essential role of calcium for the anatomy and physiology of the human body is reviewed. In this paragraph, major disorders in the calcium balance and its consequences are discussed.

- Osteoporosis

The spontaneous decline in bone density starts around the 30th birthday and must be considered as a natural process. Bone, just as all internal organs or muscles, show a gradual decline in mass and thus functional capacity due to the process of aging. The variable used is Bone Mineralization Density (BMD) that can be measured via absorption of x-ray radiation (figure 29). The criterion for osteoporosis (figure 30) is a BMD less than 2.5 SD (Standard Deviation) of the average peak value for age and sex. Post-menopausal women, from 50 years of age (figure 31), belong to the main risk group. The inducement of the osteoporosis process is probably the cessation of the estrogen production by the ovaries. The balance of production and degradation, the turnover of bone material, is under control of both parathormone and calcitonin, but estrogen receptors at osteoblasts and osteoclasts apparently do affect the position of that balance. Actually, it is remarkable that estrogen is involved in the turnover of bone. Various types of estrogen receptors are present in cells of all tissues. From an evolutionary standpoint, one may argue that post-menopausal women have no further contribution to the reproduction and therefore to the conservation of the

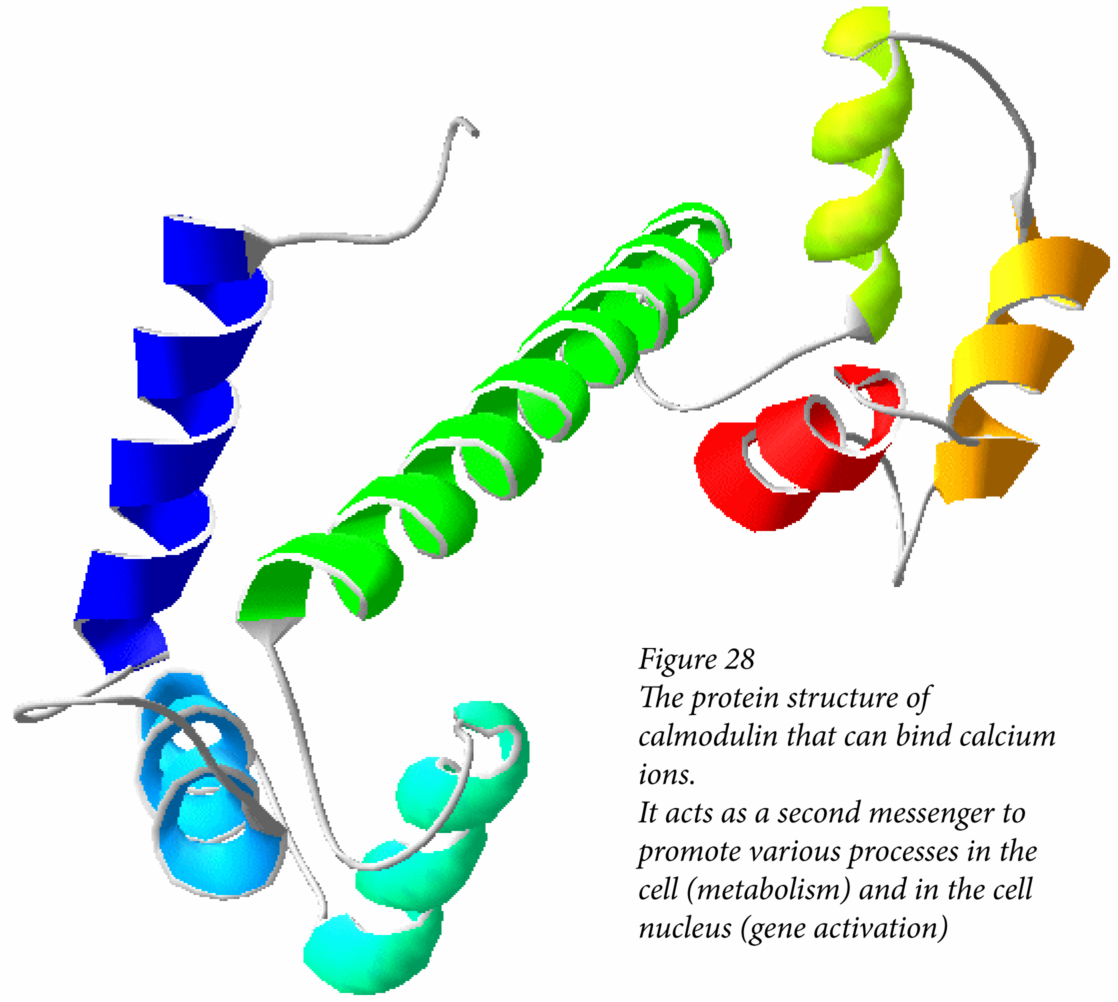

Figure 28
The protein structure of calmodulin that can bind calcium ions.
It acts as a second messenger to promote various processes in the cell (metabolism) and in the cell nucleus (gene activation)

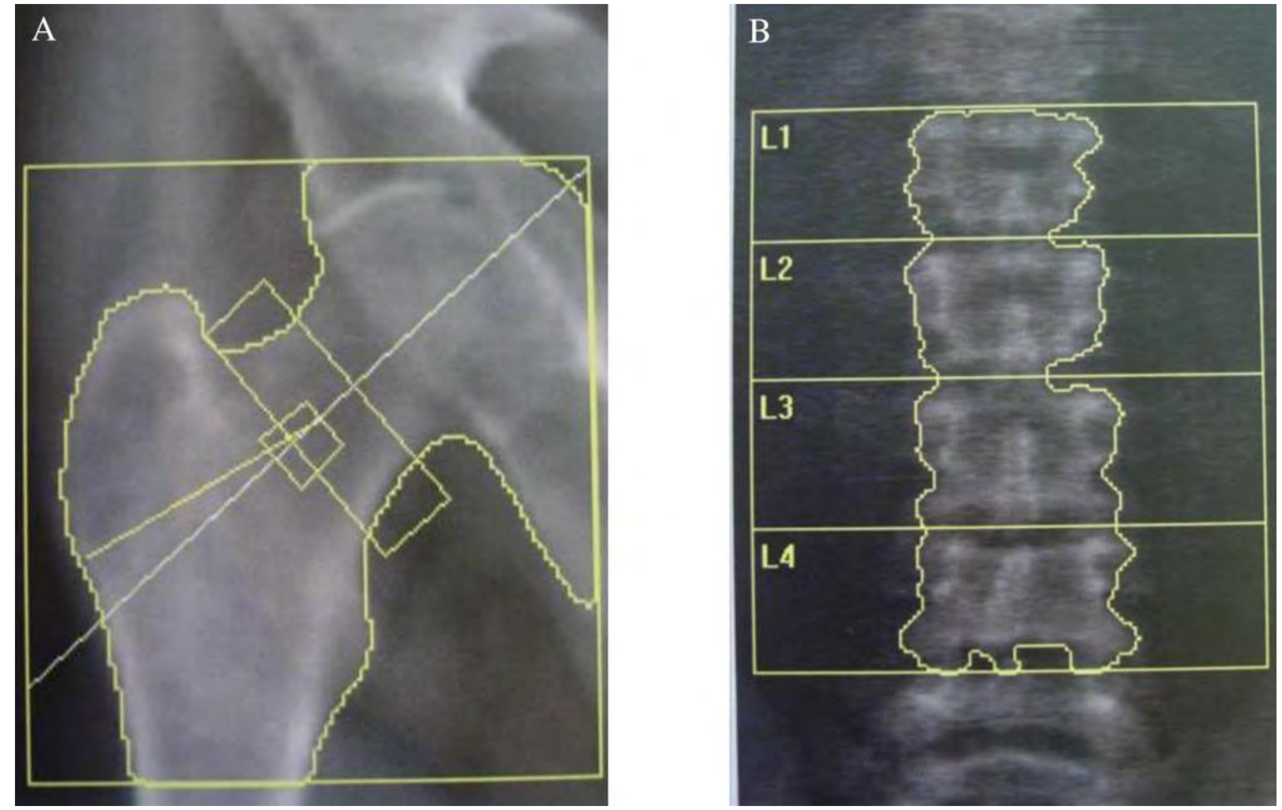

Figure 29
An X-ray photograph measuring the density of bones. At left the neck of a thigh bone and at right some vertebrae.

Figure 30
The typical posture of a woman suffering from osteoporosis compared to that of a woman with a normal bone density. The difference in thickness of the bone is magnified.

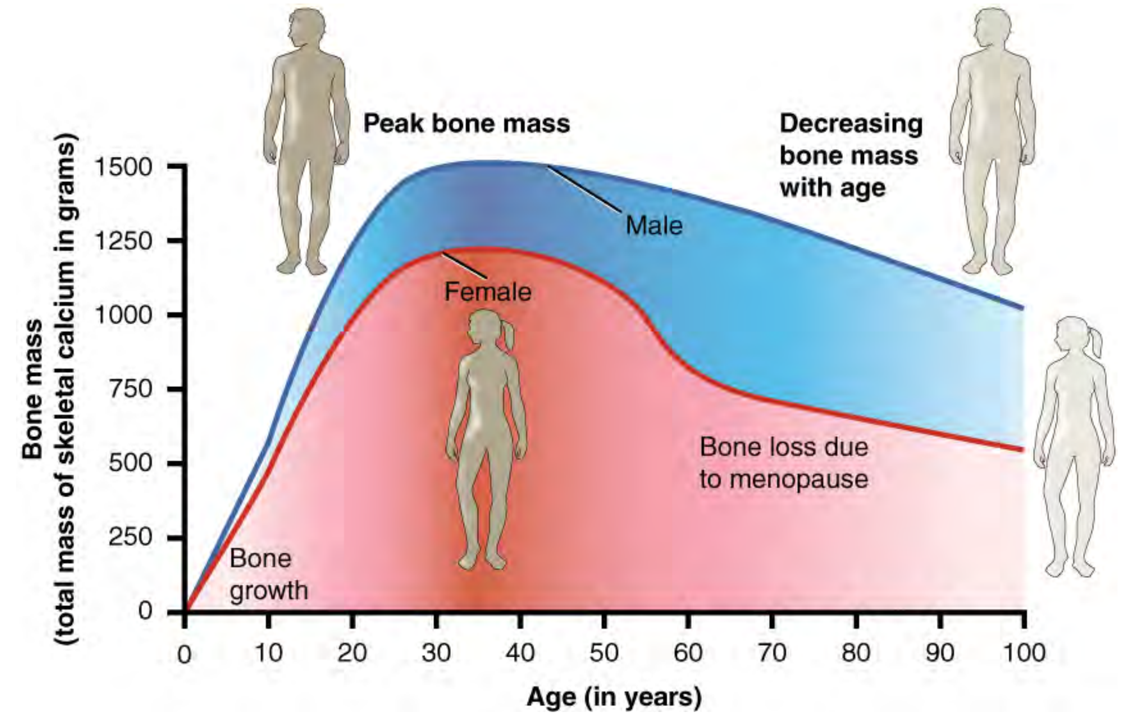

Figure 31
Bone mass expressed in weight of calcium as function of age. Bone mass increases in the first 20 years due to growth. The difference between men and women is due to the difference in length and body weight. After 30 years bone mass begins to decline. In men the declining line is rather linear but in women there is a sharp decrease around 50 years, the epoch of the menopause.

species. A strong skeleton is then no longer of interest. In wild life the time between menopause and death in primates is close. However, in humans life expectancy after the menopause is more than 50% longer than the age at menopause, due to the high prosperity. A similar effect is found in animals living under human care. In nature predation and struggle for food are the major factors for surviving to old age.

In men estrogen and testosterone also affect the calcium crystal turnover in bone, but from the much higher age of 75 years. Considering the fertility of men, at an age of 70 years of age 50 % are still fertile. At old age (above 80 years), in women 1 out of 2 suffers from osteoporosis and in men only 1 out of 5. The burden of osteoporosis is spontaneous bone pain due to micro-fractures. In case of complete bone fractures due to a fall, the frequently affected bones are thigh bone (neck), spine (collapse of vertebrae), ribs, and wrist. The consequences of a fracture at old age are loss of quality of life (physical limitations) and increased risk of premature death (complications). The treatment of osteoporosis in the elderly is not very successful. The drug of first choice is the group of bisphosphonates. Its action mechanism is inhibition of the osteoclast function.

-Hypocalcemia

Osteoporosis is in most cases a result of vitamin D deficiency, of a chronic disorder of the kidney, or of hypoparathyroidism. The emerging symptoms are related to the disturbance of the electrochemical processes in the neurological and muscular system. In electrically excitable cells the sodium channels in the membrane are controlled by calcium ions. When the calcium concentration has been reduced, the sodium channels open earlier. The cell membrane is therefore easier excitable (= generating an action potential) or, in other words, more sensitively adjusted. Patients experience the following symptoms: tachycardia and cardiac arrhythmia, convulsions, muscle twitches, and abnormal sensory receptions. Heart fibrillation and spasm of the larynx are potentially fatal complications.

-Hypercalcemia

Hypercalcemia is usually caused by hyperparathyroidism. The symptoms (kidney and gall stones and bone pain) are elicited by an enhanced production of calcium salts crystals and by a reduced excitability of nerve and muscle tissue (abdominal cramps and neuro-psychiatric disorders, such as depression, anxiety, cognitive disorders, insomnia, coma).

* Calcium in food and in medicine

In general, a varied diet with meat, fish, vegetables, and bread supplies a sufficient intake of calcium. Thinking about diet, we have to realize that all the animals and plants that we eat use calcium for their metabolism and organ functions and thus deliver a contribution to our intake. When the effective uptake of calcium in the bowel remains insufficient anyhow, abnormalities in bone structure will

Figure 32
A photograph of various gall stones.
Beside calcium carbonate gall stones may consist of cholesterol and other substances excreted by the liver.

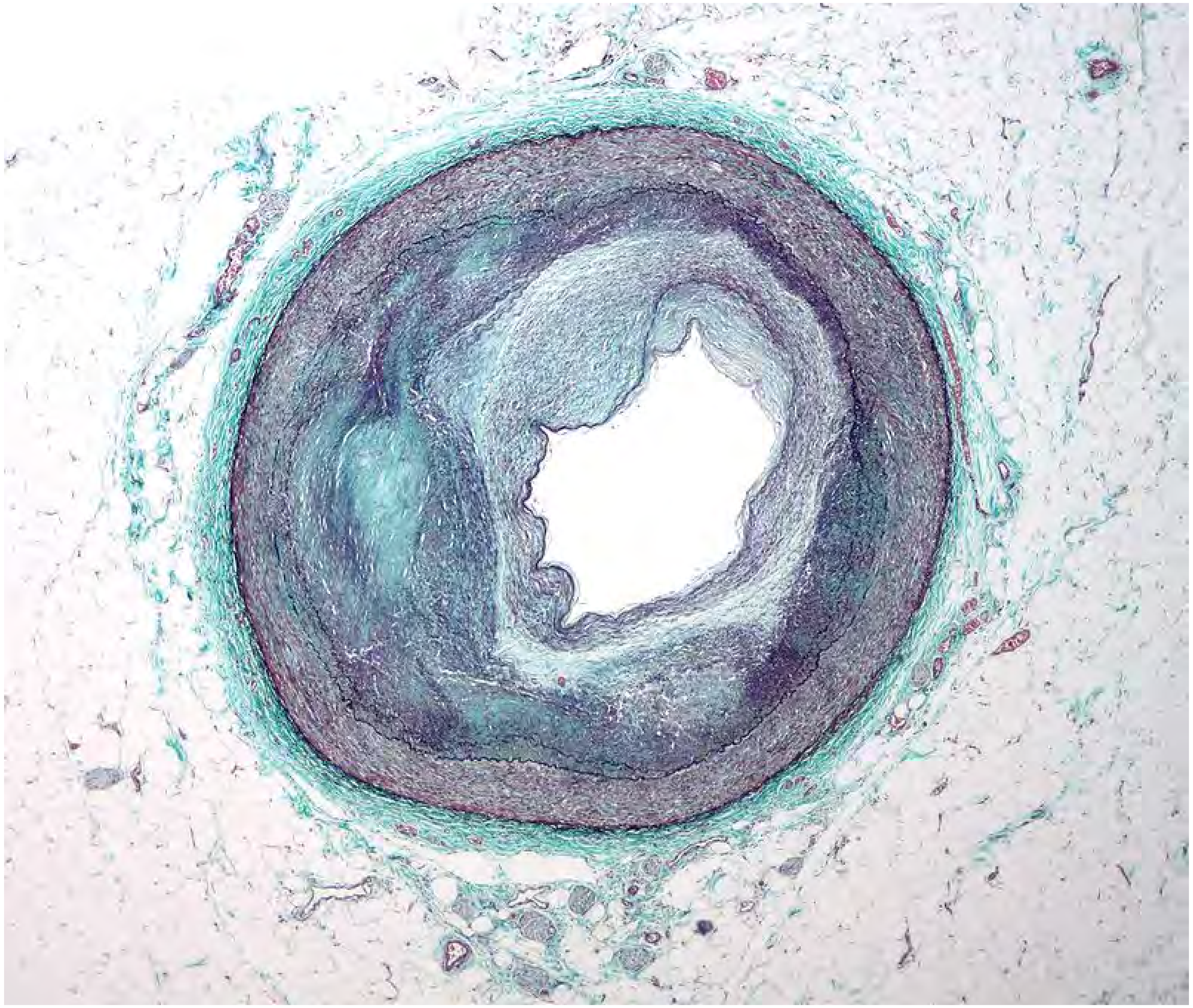

Figure 33
A microscopic cross section of a blood vessel with a narrowed passage due to precipitation of chalk and fatty substances in the wall.

be the result. At a young age this abnormality shows up as rickets, in adults as osteomalacia, and in old age as osteoporosis. In case of a shortage of calcium intake, calcium sulphate is recommended as an additional resource in the form of tablets or as an additive in various food products. The hardness of drink water (content of calcium and magnesium salts) has no special meaning for our health, but it does have a detrimental effect when used as heated water. Calcium salts precipitate in hot water and form a growing layer of chalk in pipes, boiler, and cooking pots. Clothes feel uncomfortable after washing in hard water due to hardening of the tissue fibers.

The most well-known application of calcium in medicine is probably the plaster cast to fix fractured bones or distorted joints. The Dutchman Anthony Mathijsen described this application in 1851. Gypsum is also used in orthopedics as replacement material of apatite when empty space in bone should be filled. Gypsum will gradually be absorbed and replaced by apatite. Addition of an antibiotic to the gypsum provides local protection against an eventual infection. In dentistry plaster is used to print the teeth for manufacturing a prothesis.

Within the body conditions may occur in which calcium salts crystallize and form stones in urine or bile. Stones of calcium oxalate are most common in urine (80%). A kidney stone larger than 3 mm and with sharp protrusions may become stuck in the tube of the ureter and damage the wall. The typical attacks of violent pain result from spastic peristaltic waves of the ureter. Similar pain may also occur in the bile ducts by stones containing calcium phosphate (figure 32).

A more gradual deposition of chalk salts takes place in all tissues of the body in the process of aging. The most notorious location is the wall of arteries, leading to the disorder arteriosclerosis. The hardening of the arterial wall causes a decrease in elasticity of the arterial tree, resulting in a rise of blood pressure. In some organs, in particular the heart and brain, a serious narrowing of an artery (figure 33) may lead to a complete obstruction, resulting in infarction.

**Epilogue*

The role of calcium in the evolution of life is based on its chemical properties.

It forms crystals with carbonate and phosphate and is therefore suitable for the construction of an external (shellfish, coral) or internal (vertebrates) skeleton. The internal skeleton of animals is, moreover, useful as stock for the release of calcium for its second role in ruling cell processes. A condition for executing that function is to maintain the intra-cellular concentration of calcium ions at rest very low. The cell membrane properties for achieving that condition are a barrier to hinder the passage of free calcium and a pump system to remove a surplus of calcium at a high rate. This membrane construction results in a huge concentration gradient from outside to inside the cell. The third property of the cell membrane is the presence of specific channels for calcium. These channels open and close again after electrical or chemical stimulation. The stimulus frequency may rise to 1000 per second. Thanks to this performance on a submicroscopic level in our cells, our body is able to function on a macroscopic level in daily life.

A fundamental condition for operation of the calcium regulation system in cells is a nearly constant calcium gradient across the cell membrane. The extra-cellular calcium concentration is very precisely controlled by 4 small parathyroid glands (parathormone) and the thyroid gland (calcitonin). In the system vitamin D is a crucial element for taking up calcium from food. A lack of vitamin D causes rickets in children (figure 34) and osteoporosis in the elderly.

The storage of calcium on Earth is substantial. Its availability for organisms is indeed a prerequisite for its role in the evolution of life. The supply to organisms is guaranteed by the dissolving of calcium crystals from limestone or rock in rain water due to erosion and their transportation via soil (plants, bacteria) or rivers (animals). Rivers finally drain in the sea, where shellfish and coral use calcium for their skeleton. After millions of years a sediment layer of shells has been sunk in the ocean crest and compressed to limestone. When exposed to the high temperature and pressure conditions in the asthenosphere, sedimentary limestone becomes metamorphosed to marble. In hot springs calcite of limestone may deposited as travertine.

Since the transition of life style from hunter/gatherer in small groups to farming in settlements and a growing society limestone is used as material for construction works, for sculpture in art, and for health care.

In conclusion, calcium plays a fundamental role in life, in biology as well as in culture. Calcium's role in life is based on its abundant prevalence as a chemical element in the Earth's crust. The cycle process of calcium is the necessary condition for its continuous availability in favor of organisms. In that perspective, calcium belongs to the Goldilocks conditions in the concept of Big History.

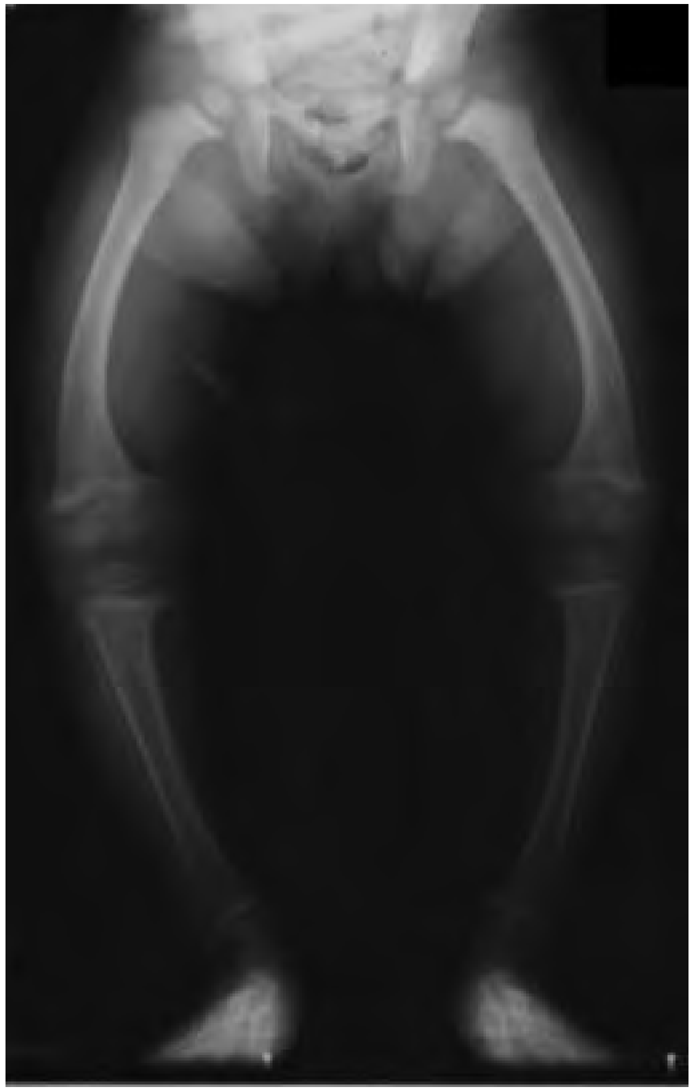

Figure 34
X-ray photograph of malformed leg bones due to rickets

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Curriculum Vitae

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Specialty: (exercise) physiology

Work: University Maastricht, Netherlands (1975 – 2005)

Author: *Medische Basiskennis (medical basic knowledge), Boom/ Lemma Amsterdam (2004)

*De evolutie naar gezondheid; van oerknal tot obesitas (The evolution to health; from big bang to obesitas), Lias Utrecht (2014)

What I Learned on My Summer Vacation:

Flying through Big History in One Week

By Lucy B. Laffitte, Ph.D.
Science Educator for PBS affiliate UNCTV

In the May edition of *Origins*, I wrote enthusiastically about the journey that led me to a summer gig teaching Big History at the North Carolina School of Science and Math (NCSSM). In June, I found out that my two-week gig was to be one-week, populated with middle schoolers, and mostly boys. The class was to be 9-5 Monday through Friday, ending with a parent presentation on the last day. Gulp.

I quickly sketched up a mind map of teaching methods for a day that might prevent adolescent boys from mutinying. Lectures would be minimal. Videos would be mind blowing. And the rest would be a mix of hands-on materials and activities.

Figure 1: Mental map of course elements.

I started by taking stock of what the school might have in the way of resources, and the answer did not disappoint. I was like a kid in a candy shop!

I'd taught big history in typical college classrooms equipped with little more than AV. Now I had a state- of-the-art repository of everything science can bring into the classroom. A spectroscope, diffraction gratings, and vacuum discharge tubes. Booyah! Microscopes for observing living protists? Check. A complete collection of hominin skulls? Yup. A large model of DNA. Of course. Walking around the building giddily picking and choosing equipment, I didn't know how I was going to fit it all into one week, but I wanted it all!

The next task was to inventory my mini museum of natural history artifacts and teaching aids stuffed in closets and bookshelves around my house: bismuth, zinc, iron, copper, nickel. Two meteorites. Sacks full of igneous, metamorphic, and sedimentary rocks. A diverse collection of sea shells. Dried lichen, moss, and lycopods; tree fern fossils, a sugar pine cone, and a lotus seed pod. A cecropia cocoon, paper wasp nest, and a collection of benthic macro-invertebrates in vials. A fish skull and a shark's tooth. No artifacts of amphibians, but I did have dried turtle eggs, a carapace, and snake and lizard skins. Bird materials are easy to collect. I had gobs of feathers—primaries and tail feathers, and 15 bird nests, from a hummer to a Cooper's hawk. My mammal collection was fair: a beaver stick, a fox pelt (from a road kill I skinned and tanned myself), and a deer skull. To this, I added a woodland Indian tool kit and broken pottery, a basket of wheat berries, a model schooner with 3 masts and 16 sails, and the guts of an old Mac G4. I packed all this up with the *Wall Chart of World History* and the *Illustrated History of Battle*. Can you tell my background is science and not history?

Preparation for the *synthesis activity* required a lot of time —the activity where each student gets to reflect personally on the lesson and recapitulate it privately. Pulling on summer camp counselor experience of calming hooligans, I came up with a craft. Enchanted by the big history necklace I heard about from the Montessorians, I decided to have students make a necklace. But instead of choosing a single bead to represent an event, students would make a complicated charm to represent each milestone.

Thus began the quest for supplies with which to make the milestone charms. I spent hours at high-end bead boutiques, sewing shops, scrap exchanges, and big box craft stores, combing through racks and aisles looking for inspiration and cheap metaphors. I spent about $150 for the representations and the same amount on findings, wire, glues, and tools. Then I poured the contents of the shopping bag onto the dining room table of a friend with three girls, ages 17, 15, and 12. By the end of the evening, the five of us had a rough prototype for each charm. The Scrap Exchange provided me with a lucky find—15 identical foam-lined card board boxes that made perfect containers for the delicate and roly poly beads, findings, and tools that each student would need to make each charm.

I was given access to the giant classroom on Thursday before the class started on Monday. So I spent the next four days in there, letting the equipment and artifacts help me organize the story. By Sunday evening, five big tables were crowded with stuff but covered in sheets, so as not to let the artifacts steal the thunder of the story that was about to unfold. My mental map of the course was still fluid, but the mind map now looked like this.

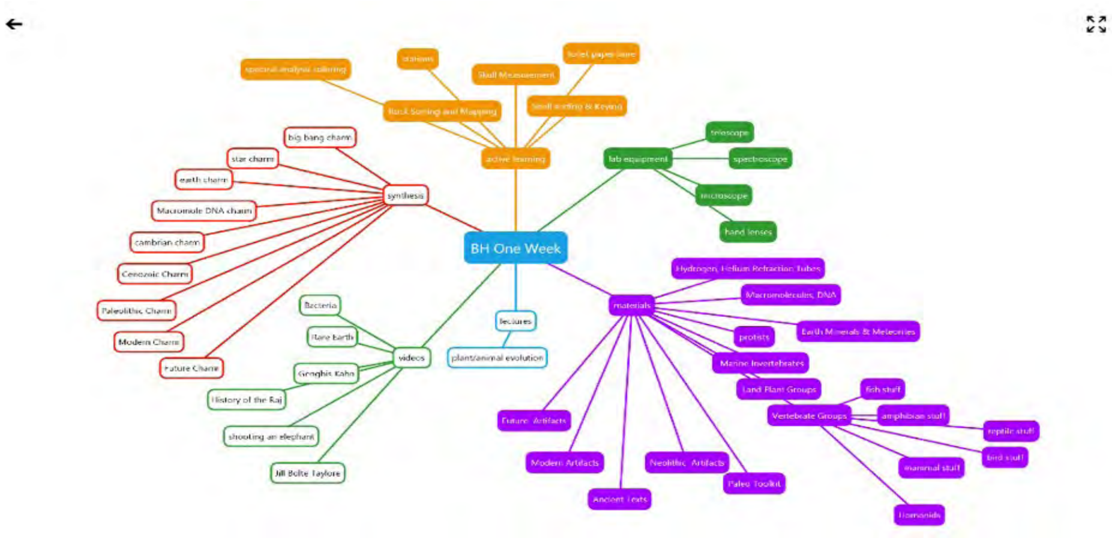


Figure 2: The mental map fleshed out.

Day 1

MORNING. Monday began with an icebreaker of 'Talking-stick-20-questions' (with 13 questions, one per student). Tell us the age of the "artifact" and everything you know about:

hydrogen(interlude 1)

supernova (interlude 1)

iron (interlude 1)

tides (interlude 2)

prokaryotes (interlude 2)

mollusks (interlude 3)

primates (interlude 4)

"Lucy" (interlude 5)

Homo sapiens (interlude 6)

agriculture (interlude 7)

hieroglyphics (interlude 8)

Genghis Khan (interlude 9)

Gandhi (interlude 10)

Not everyone could speak to their artifact, but there was always someone in the group who could get a conversation about each topic started.

Then I played the video Our Story in A Minute and asked how we could wrap our heads around a time span of 13.8 billion years. The response was blank stares. "How about with toilet paper?" I said. I leaned down and lifted up three rolls of Scott's 1000-sheet toilet paper, one three quarters full, and put them on the table. This time, I got guffaws and giggles.

"Each sheet is five million years. So if we start with the big bang, let's see how long it takes to unroll to the emergence of each "artifact" we just discussed." Then I asked them to stand up and spread out around the walls of the room.

We started with the bang, of course, using the partial roll. By the end of that roll, we were up to 10 billion years ago, and we'd covered only the creation of stars, galaxies, supernovae and elements. Then it got really boring during the second roll. By the middle of the third roll, we'd lapped the room in toilet paper 4 times, the strand had several patches, spats had broken out, and the attention of even the most focused students had flown out the window. I cut to the chase and held up one sheet of toilet paper, pointing out that the emergence of "Lucy," *Homo sapiens*, the Fertile Crescent, hieroglyphics, Genghis Khan, and Gandhi were all crowded on the very last sheet.

It was a daring exercise to initiate frustration and futility at the start of a class, but just before break I rolled up the giant screen in front of the white board to dramatically reveal ten laminated placards of numbers.

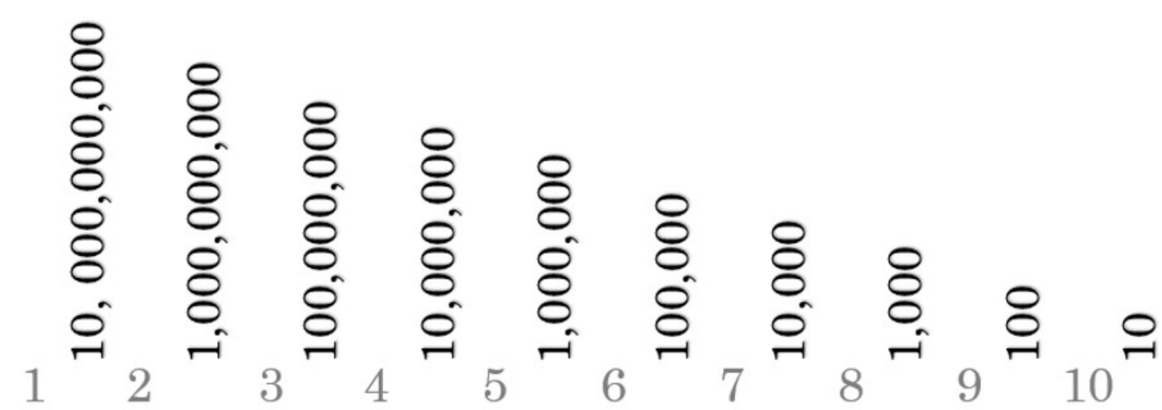


Figure 3: The logrithmic numbered placards with ten interludes.

After a quick overview of the logarithmic scale, I introduced the plan for the week: we would fly through deep time by focusing on one concept per logarithmic interlude, and we would do this at the rate of two stops per day: one in the morning and one in the afternoon (except Friday afternoon, when they were to present to their parents). Time for charm-making would be provided in the last half hour of each session.

My hope for this introductory activity was for the fog of deep time to clear and the road map of the 9-stop journey to be clearly laid out. I couldn’t quite tell if the cheer that went up when I announced break meant that they fully grasped that a logarithmic scale can make deep time manageable, but I hoped so.

Following the break, we jumped right into the big story.

Hands-on teaching tools for the beginning of time are hard to come by, but Neil deGrasse Tyson, PBS, and National Geographic are good at making mind blowing visualizations of the big bang, stellar evolution, and the creation of the elements. And YouTube has bite-sized snippets of them all. I supplemented these with the spectroscope, an H-R diagram, and some goofy metaphors in the hopes of making the big bang, stars, and elements tangible.

Students got to “touch” the big bang using the spectrometer equipment. The diffraction grating acts like a super prism, splitting out the different frequencies of the excited emissions of each gas tube in the spectroscope. Students were to match the spectral “fingerprints” of what they saw with a printed list of spectral lines, unwittingly claims testing the evidence used by astrophysicists.

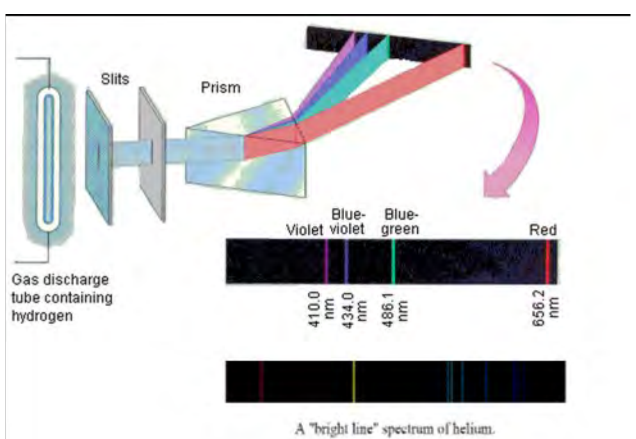


Figure 4: A diagram of how a prism splits the light into the unique spectral lines of an energized element (Purdue University).

Students got to “touch” stars with the H-R diagram—a plot of luminosity versus temperature of 22,000 stars. The “hands-on” part came when they locate some of the brightest or well-known stars on the graph: Rigel, Sirius A, Procyon, Sun, Pollux, Aldebaran, Betelgeuse. (This is great activity to do in January in the northern hemisphere when all these stars are visible!). Then I asked them: Why are the stars clumped on the graph like this?

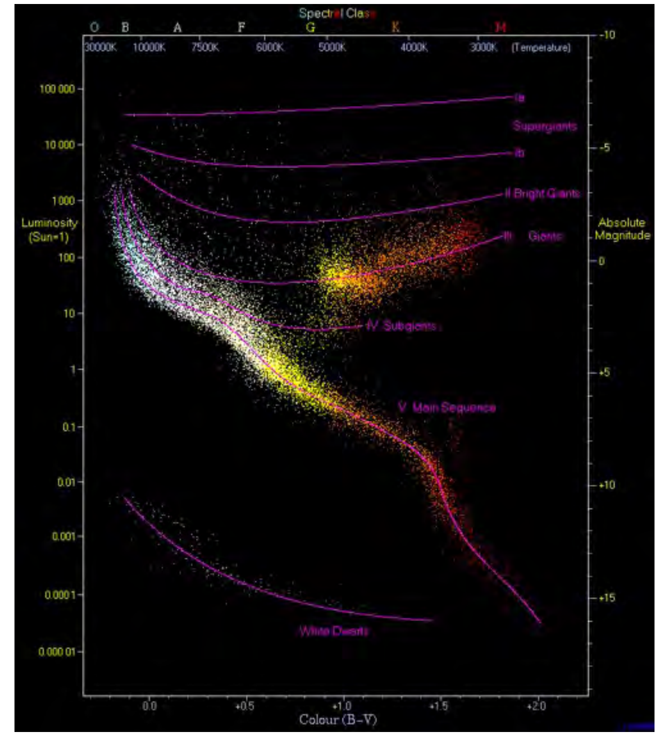


Figure 5: Hertzsprung–Russell diagram with 22,000 stars plotted from the Hipparcos Catalogue and 1,000 from the Gliese Catalogue of nearby stars (Wikimedia).

“That’s because white dwarfs are cool and dim and the red giants are bright and hot.”

“But that’s not what I’m asking. I’m asking why, when you map 22,000 stars, do they clump like this? Why the big slash from upper left to lower right? And why the two side clumps?” I let them wrestle with this for an uncomfortable amount of time.

Then this pair of images was flashed on the screen: a family portrait and another version of the H-R diagram. “Why am I showing you this?” I asked.

The eventual “aha” that came was a blend of satisfaction and astonishment. The sudden kinship among the young earthlings around the table with the family portrait of the stars was almost palpable as the story that stars are born, mature, and die was revealed.

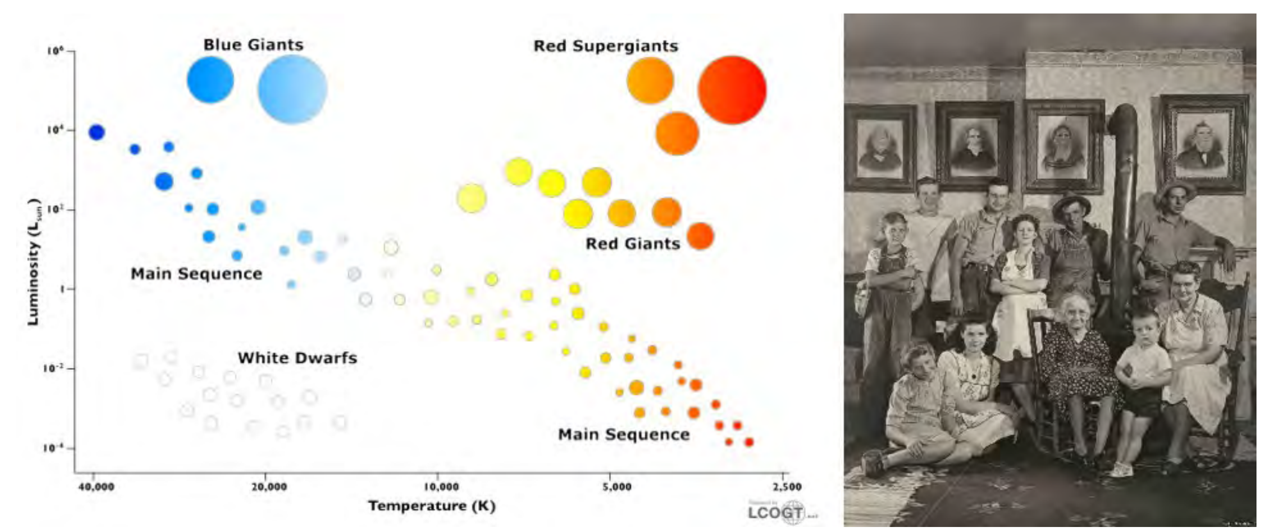


Figure 6: Comparing a pictorial H-R diagram (Los Cumbres Observatory) to a multigenerational family portrait (Nina Leen, Family of Man).

Students got to know the elements more directly. Objects made of pure titanium, nickel, copper, iron, bismuth, aluminum and zinc were on the table for holding. But in order for students to grasp the magic of the elements, I gave a little lecture about reactivity using a silly roleplay depicting the nature of the groups in the periodic table—the satiated noble gases, the hungry halogens and chalcogens, and the overstuffed alkali metals and alkaline earth metals. This flowed into getting the students involved by having them link up with each other in different bonding methods. Covalent bonds had a student running a figure eight around two students. Ionic bonds had one student grasp the hands (the positive end) and the feet (the negative end) of another. A hydrogen bond was personified by two students stretching silly putty until it broke. Then we all figured out how to make NACL, H_{20}, CO_2, O_2, and CH_4. Goofy metaphors tend toward entropy fast. At the end of this chaos, there was a two-hour (thank goodness) break for lunch.

AFTERNOON. We finally got to get our hands dusty in the real stuff after lunch. The afternoon plan included a quick look at, and discussion of, the early solar system (with meteorites) and the bombardment of the early Earth, a classification and mapping of rocks and minerals from North Carolina, and an awesome video that elegantly summarized the lesson.

I was premiering the rock and mineral activity for the first time. The materials for this were a lucky find at a spring teacher's conference where I picked up a ridiculously heavy bag of rocks, compiled and given away free by the North Carolina geological society. Inside were 13 small bags of rocks numbered one to 13 and a cheat sheet with the mineral type and name of the mine and company that supplied it. In preparation for the activity, I googled the location of all 13 mines and then bought a large laminated geologic map of NC. I hid the locations from the students by pricking a tiny hole in the map at each mine location.

The activity was divided into two stations, one to categorize the rocks and the other to locate them on the map. For mapping, each student was given one of the 13 rocks to locate on the map using latitude and longitude. (The raised pin pricks in the map were my cheat sheet to check whether the students had found the correct location.)

For categorizing, I gave students an egg carton and a bag of 52 rocks, four of each of the 13 types. They were to sort them into piles using the "alike and different" methodology. The first student looked at me perplexed.

"This is just gravel." He said standing up looking down at the table.

Figure 7: Students try to find the degrees and minutes of latitude and longitude to find the mine location of their rocks.

"Look closely." I said.

He looked again and separated the four smooth white river quartz and put them in an egg cup. Then he picked out eight of the jagged speckled granites. He looked at me.

"Go on. There are only four of each type." Then he saw it—the slight variation between a late Proterozoic gneiss and a middle Paleozoic granite. He couldn't discern that history, but his visual sensitivity to texture, grain, weight, shape and color deepened. He sat down and pulled his chair closer and promptly and correctly sorted the rest of the gravel into 13 categories of rock in a matter of minutes.

In the table talk at the conclusion of the activity, we talked about the difference between the tools, methods, and types of evidence of astronomers and geologists: telescopes versus pick axes, spectrometry versus rock property tests, ephemeral spectral lines versus tangible material.

We wrapped up the day with geologist Iain Stewart's epic "Power of the Planet: Rare Earth" video. This is a beautiful telling of the Goldilocks conditions for life on Earth, with the music, sweeping camera angles, and Stewart himself pummeling the viewer with awe.

Day 2

MORNING. We began with a bit of reflection and charm-making. My teaching assistant, the wonderful Aliza, had stocked their boxes with the makings for three charms. I had wanted to limit the craft to two charms a day, but how can you cover 9.1 billion years of a 13.8 billion year story with only 2 charms? Charm 1 was to represent the creation of hydrogen, helium, electromagnetism, and gravity by the big bang. Charm 2 was to represent stellar nucleosynthesis with 6 types of stars. Charm 3 was to represent the rocky planets in the solar system. Charm 4 represented plate tectonics and the water cycle. Charm-making and reviewing took us until the morning break.

After break, I posed a question: Is life on Earth inevitable? I let the question hang in the air before going to the white board to unpack it, reviewing the doctrinal definition of life. We discussed what types of structures life might need to carry out the functions of living. I suggested we might need four crucial types of molecules. I drew color-coded cartoons of archaea and bacteria. I used blue for cell walls, pili, and flagella; yellow for permeable cell membranes; red for instructions in the cytoplasm and orange for instruction-readers in the cytoplasm. Then I answered the question that every kid reading the back of the cereal box wonders. Why do I care how many grams of carbohydrates, fat, and protein my Captain Crunch has? "Because those big molecules (plus nucleic acids) are the building blocks of all life. Meet your new best friends, the macromolecules." And now, take a look at how ubiquitous and ingenious a very simple collection of these macromolecules can be in one of the earliest and most primitive life forms on the planet. Take a look at this Ted Talk by Bonnie Bassler on How Bacteria Communicate.

While the video played, Aliza set up the microscopes for viewing of the living protists, pre-ordered to arrive so that Tuesday would hit during the 2-day guarantee.

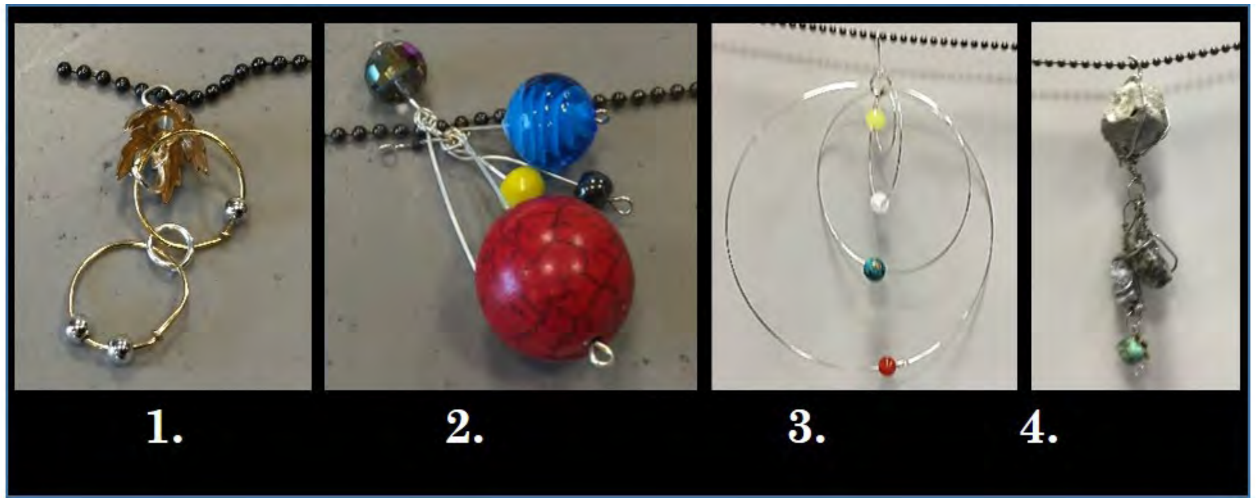


Figure 8: Charm 1) An incomplete big bang with hydrogen and helium atoms, a piece of diffraction grating (representing electromagnetism) and a large "G" (for gravity) were added. Charm 2) Six types of stars. Charm 3) The rocky planets around the Sun. Charm 4) Earth's plate tectonics with an igneous, metamorphic, and sedimentary rock and snowflake to represent water in all forms

She ingeniously used fibers from lens paper to trap at least one of each of the singled-celled paramecium, volvox, and amoeba floating around the slides. When the video concluded, student were to *meet the eukaryotes* by sketching all three species in their journals, taking notes on behaviors. Then we concluded the morning with the fantastic Inner Life of a Cell video. I showed it twice. The first time I was silent. The second time, I did my best to explain how each scene in this incredibly complex visualization was a just a short phase of a very simple operation: triggering a white blood cell to leave the blood stream and slide in between the throat cells to bring help to the site of an inflammation.

AFTERNOON. The goal for the afternoon was to marvel at the diversity of body types that exploded in the ocean during the Cambrian period from sponges to octopi, to see a video on the rugged persistence of the horseshoe crab, and then to talk in depth about the life cycle of a sea squirt. The activity part of the session was another classification. I asked the students to take a handful of shells and sort them into piles. There were at least 15 different species represented in multiple sizes, so it was challenging. When it came to sorting the bivalves, I focused their attention on the hinges. The activity culminated by playing a segment from my well-worn VHS (!) of David Attenborough's Building Bodies segment in Life on Earth. He is standing at the edge of the sea at night under a full moon showing us the *Limulus* mating frenzy, an activity that has been occurring for 500 million years.

Figure 9: A collection of mollusks, coral, echinoderms, and sponges for categorizing.

After break, I explain that we were now going to fast forward through time with two videos. One was five minutes and spans 3.5 billion years and the other was an hour and spans 530 million years. I brought popcorn and the students got comfortable on the floor for an afternoon at the movies. We watched Carl Sagan's brilliant (slowed down from the original) animation of animal evolution a couple of times and then settled into From Fish to Man.

Figure 10: Charm 5) representing the macromolecules, was a tiny glass bottle filled with four different colored and sized beads and a spiral of DNA, using the alleged recipe for LUCA, the last universal common ancestor. Charm 6) represented the Cambrian marine explosion with a diverse group of tiny shells glued into a large bivalve shell.

Day 3

MORNING. I started Day 3 with a little time for journal reflection. They were to describe what they learned about macromolecules, bacteria, and marine body-making during the Cambrian. When they looked ready to move on, I explained that the goal for the morning was to look for examples of parallel evolution between plants and vertebrate animals as they solved the problems of moving from the comfort of the water to the harshness of dry land. I handed out a rubric for the students to fill out as I gave a walking lecture presentation called *Crawling Out on Land.* Artifacts from my extensive collection of plant and animal parts were passed around to illustrate my talk.

Rubric for Crawling Out on Land

Need	Ocean Solution	Land Animal Solution	Land Plant Solution
support	buoyancy	backbone	sporophyte
hydration	diffusion	rain, streams and lakes	soil moisture
dehydration	not a problem	skin	epidermis
oxygen	diffusion	lungs	roots
sperm to egg	floating, swimming	wetlands, internal semination	pollen
shelter of the young	rock nests	egg shell, den, woven nest, lodges	seed coat
feeding the young	filter feeding	egg yolk, regurgitation, mammary glands	cotyledons
dispersal of young	floating, swimming	arms and legs	fruits
ongoing support of the young	none	childhood, grandparents	mychorrizae, nurse logs

At the conclusion of this, again the students felt kinship with early parts of the big story. They see the prototype behaviors of their species emerging way before humans were a gleam in any eye. Holding a beaver stick and knowing a parent beaver used it to create a nursery for its young elicits an "Aww." They also perceive the parity between animals and plants in how they care for their young. Seeing a picture of a fallen western hemlock tree covered with seedlings extends their empathy to the mute members of an old growth forest community. Okay, there is the botanical analog of Mr. Rogers!

Figure 11: A Western Hemlock tree supporting the next of generation of forest trees (Jonathan Ley).

AFTERNOON. The plan for the afternoon of day three was to look at the evolution of hominins by comparing the brain sizes of skulls of *Australopithicus aferensis, Australopithicus boisei, Homo erectus, Homo neanderthalensis Homo sapiens*, chimpanzees, and gorillas.

I'd participated in this activity at the Dominican University Big History Summer Institute, and I loved it. The NCSSM had a set that would be delivered to my class on Wednesday afternoon. In the haste and complexity of preparing the content and classroom for the morning talk, it wasn't until lunch time that I was confronted with the fact that this would be the second time in my life I had ever seen this set of skulls. My adrenal cortex flooded my bloodstream with the wonder drug, and I began to Google. Then a guy wheeled in the skulls. They were gorgeous—full size and way more than the seven I had requested. And he was in a chatty mood. My panic made me it hard for me to focus on what he was saying, but gradually it dawned on me that he wasn't just a guy, he was *the* biology professor who used them every year in class. And he was very astute. Realizing that I desperately needed rescuing but would never ask, he generously and delicately said "I can stay and help if you would like." Was that a Goldilocks condition or a miracle?

After break, we watched the Ted Talk by Susan Savage-Rumbaugh, the Gentle Genius of Bonobos. The kids were mesmerized. They watched with smiles on their faces the whole time. Then we watched a video of Kanzi using his lexigram, followed by a slide of the lexigram beside the hieroglyphic alphabet. The implication was self-evident. If the kids felt kinship with stars, and more related to plants, they wanted to adopt Kanzi. Their joy was overflowing as they left that day. Mine was too. Hump day was over. I heard later that the Wednesday emails that the kids sent home to their parents depicted kids red-lining the fun meter.

Figure 12: Kanzi, the Bonobo who "speaks" with a Lexigram (The Des Moines Register). What is the difference between a Lexigram (near left) and Egyptian hieroglpphics (far left)?

Day 4

MORNING. The plan for the morning was to consider the difference between Paleolithic and Neolithic humans. I passed around a Woodland Indian tool kit, bought from a Tennessee farm, and a hand ax I'd found in the Uwharrie National Forest. I encouraged each student to pantomime the use of each tool, so as to get a muscle memory from the experience. Then I asked a student to help me get two items from the tables. I gave her a sweet grass basket filled with wheat berries, while I picked up a Mac G4 and flipped open the hinge, revealing the guts of this heavy hard drive. We placed these items on the corner of the big table so that all could see the guts of the machine. I then asked a question: How did the invention of this, pointing to the basket, lead to this, pointing the Mac G4? I answered it with a proposed hypothesis by Matt Ridley in a Ted Talk called When Ideas Have Sex. When the video ended, I asked a student with an Iphone if he would trade me for the hand ax and the basket of wheat berries. They groaned at the weak joke as they filed out for lunch, but I did it to emphasize Ridley's point—that societies benefit when trade between cultures with different types of intellectual capital occurs.

Figure 13: Charm 7, representing the modern forms of plants and animals, was an eclectic assortment containing a stamped brass bird's nest, a woodpecker tail feather, a mint flower, a swatch of rabbit fur, and a red oak acorn. Charm 8, representing Paleolithic humans, was actually a bit early. It was made of a raw hide loop (tied with an Indian binding knot), a bone button, a brass arrow, a dog bone, and a tuft of fox fur.

AFTERNOON. As I mentioned in the preamble, I come to Big History from science, with just a dash of environmental history. In my opinion, this stop in my telling of Big History was the weakest of the week. Four stations were set up around the room. One was the *Wall Chart of History* spread out on the floor, where I asked them to trace a single culture from one end of the 15 ft chart to the other. Another was the *Illustrated History of Battle,* where they were to flip through the evolution of warfare. A third was a computer, where they were to watch the Imperial History of the Middle East and list the name of every empire that could lay a legitimate claim to Jerusalem. The fourth station was a simple question, which they could answer with their phones: What was the name of the largest empire in history, and why did it get so big? After they had all cycled through these, we convened at the table for a short video clip. I asked them again: What was the biggest empire? And why? Then I clicked a four-minute clip from Ten Things You May Not Know About Genghis Khan to answer that question.

Following the afternoon break, students played catch up, finishing up incomplete charms and preparing their presentations for the show and tell the next day.

Day 5

Figure 18: Charm 9) A modern collection consisting of a cross, a spoon, a sheep, a revolver, and faceted beads. (I can hear the historian’s harrumph!) *Charm 10) The prototype for the charm called Homo-connected-us, without a photo.*

MORNING. I opened the last day of the course with a little political theory from a book that describes *who gets what, how* called Preview of the Policy Sciences. I like to think of this view of policy science as functional ecology—what do humans want and how do they get it? According to this doctrine, all humans are motivated to do things that they perceive will leave them better off. “Better off” is boiled down to a short list of seven values: respect, power, wealth, skill, enlightenment, affection, well-being, and rectitude. The only way humans can motivate others to give them what they want is a short list of four strategies: coercion, payment, inspiration, or reciprocity. I like this framework because of its simplicity. Like Big History, its critics argue that it over simplifies, so I suspect I don’t need to present the counter argument to this audience.

To demonstrate the value of the functional ecology framework, I led the students through a quick history of the British Empire in three parts: a video; a short story, read aloud; and a question. The video was live footage and actual letters and headlines from a YouYube video called The British Raj in Colour. It depicts a flabbergastingly un-self-aware Britain when it ruled over one third of the population on Earth. The tiger hunt is appalling, and it sickened the students. The story I read aloud was George Orwell’s *Shooting an Elephant* about a British civil servant doing his duty. The question I asked was: how did Gandhi get the British to politely pack up their Raj? We used the framework to analyze the human actors in each part of this history. The video depicted a society where the power, wealth, respect, and well-being were dangerously lopsided and made possible by coercion. The short story depicted a bereft man whose quest for respect and rectitude was denied him by his duty to his culture. The question led students to conclude that the lust for rectitude was the most powerful motivator of the British government’s decision to give up *the* jewel in the imperial crown. I love the edification that comes from this story. The mood as the students dispersed for lunch told me they got it. They were somber but not pessimistic, more contemplative.

When the students were gone, Aliza turned to me and said “Wow. I thought you were going to read them “The Lorax.” That’s the story everybody always reads aloud.”

“I love that book as a morality tale. But to cultivate discernment, I like to prepare the soil so that the seeds of understanding can germinate on their own time.”

While the students were at lunch, the fantastic Aliza put the materials to make their last charm in their bead box. This one was to represent the future. Inside was a clear cabochon, a small color picture of themselves, a broken chunk of a motherboard, and some hat pins. The name of this charm was *Homo-connected-us*. I carried on a Socratic conversation as they worked. Is the universe alive? Do you think it was an accident there was a goldilocks zone for the Earth? How should we greet extraterrestrial life? Did the universe that made the pillars of creation, the rings around Saturn, the sapphire earth, giant red woods, blue whales, spider webs, beaver lodges, and bonobos all of a sudden make a mistake when it made humans? I concluded our conversation with my answer to that question, a quote from “Desiderata” (Ehrmann, 1927). It’s the only preaching I allow myself to do: *The universe is unfolding as*

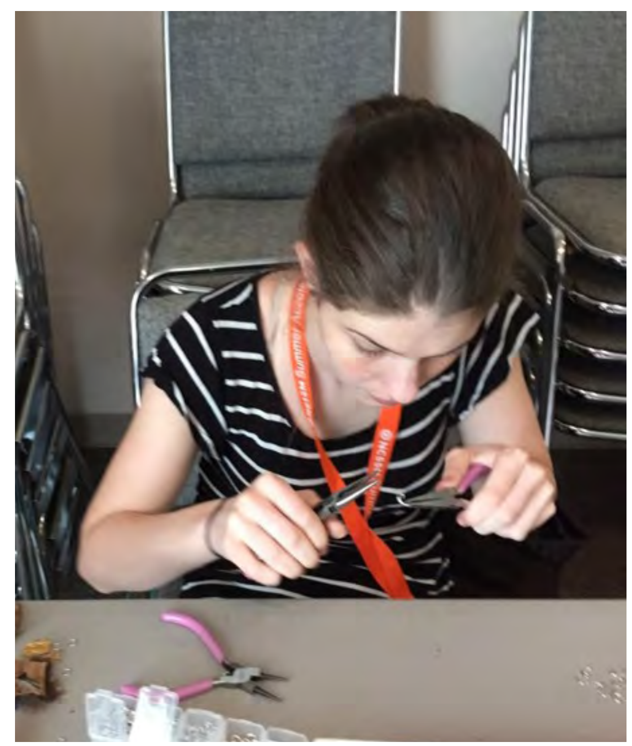


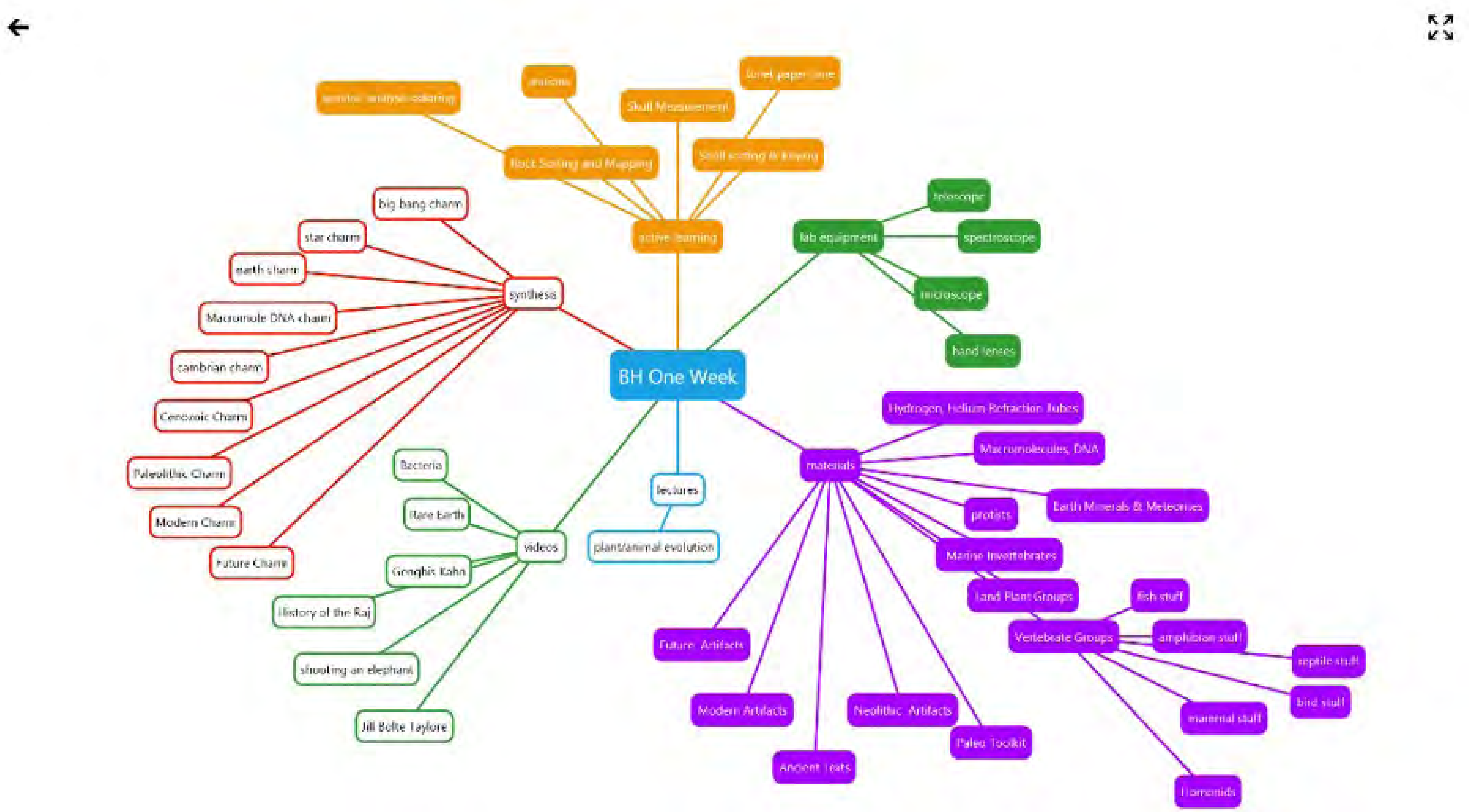
Figure 19: Godsend Aliza preparing the materials to be loaded into each foam box before each charm-making session.

Figure 20: Parents and friends visiting the tables at the end of the class

it should.

As the students were finishing up their charms and setting up their presentations at the 10 stations around the room, I played the Ted Talk by Jill Bolte Taylor—My Stroke of Insight. I introduced it by saying that our understanding of consciousness is still pretty much a mystery. When the video ended, I turned on the light and greeted a room full of parents, visitors, and students. I recapped the movie:

"This woman was a neuroanatomist working at Harvard when she had a stroke on the left side of her brain. When she recovered her speech, eight years later, she wrote a book about it. She brings us tidings from the right side of our brains. And this place is a yet uncharted frontier. Based on her experience, I think it bodes well for our future. Now, if you will tour the tables, you will get to hear from your children the greatest story ever told. They will be the ones writing the next chapter…"



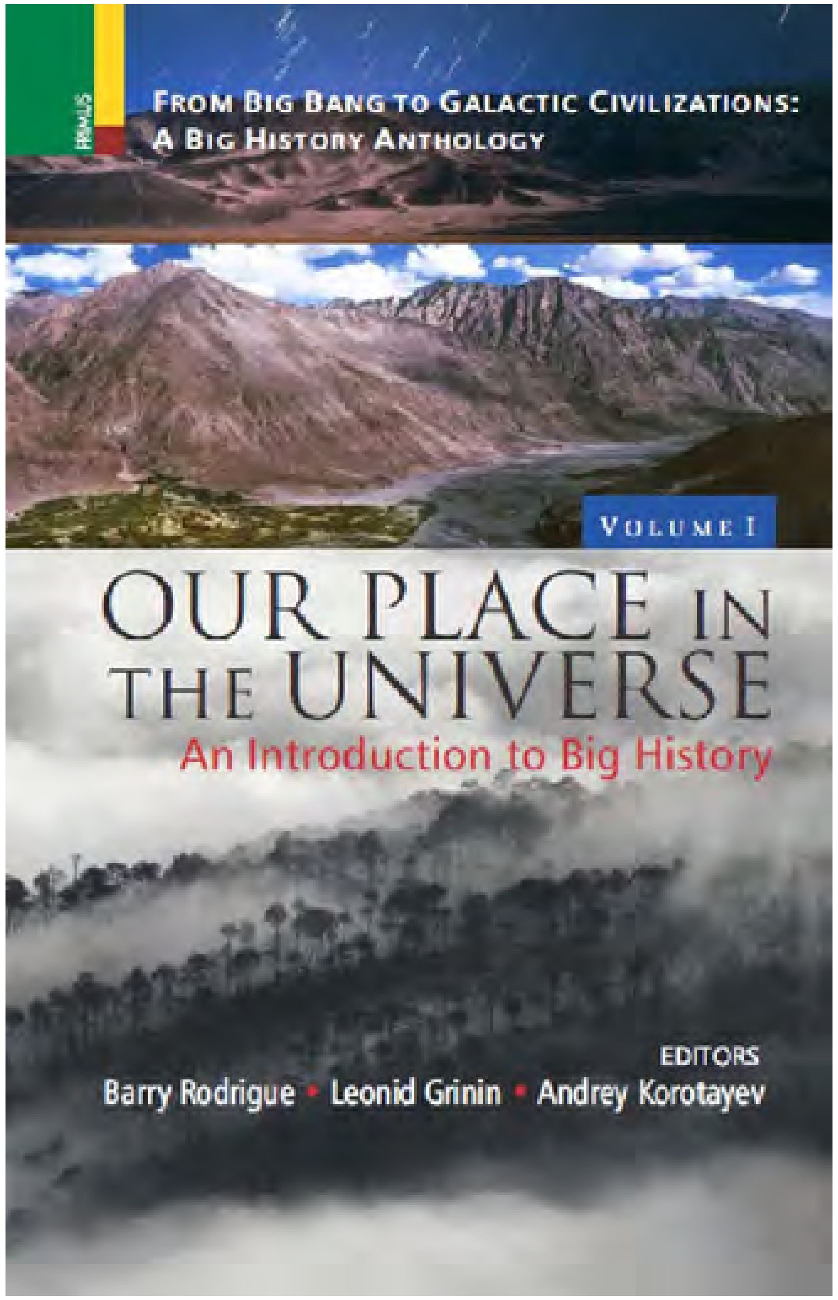
From Big Bang to Galactic Civilizations: A Big History Anthology, Volume I

Our Place in the Universe

An Introduction to Big History

Edited by Barry Rodrigue, Leonid Grinin and Andrey Korotayev

2015, xii + 370 pp, hardcover, $56.00 plus shipping. Paperback and Kindle edition will be issued later.
Series ISBN: 978-93-84082-45-1
Primus



The Book

Big History is a new field that has been developing rapidly around the world. It seeks to understand the cosmos, Earth, life and humanity by bringing together the latest empirical evidence and scholarly methods. *Our Place in the Universe: An Introduction to Big History* considers our existence from different points of view: as a history, philosophy and factor in the lives of ordinary people. It provides a lively connection between our past, present and future. This edition will prompt readers to question their existence and offers insights into the latest discoveries, from the history of ancient cities like Jericho to the history of information technology. Together with the authors, who come from all the world's continents, readers will embark upon an amazing journey into time and space.

This collection will appeal to readers interested in large and small questions, as well as in our existence as evolving life forms on this planet and in the universe. It engages scholars, faculty and students from departments of history, astronomy, sociology and all other programs. These materials are used in schools around the world, including Harvard University, the Russian Academy of Sciences, the American Museum of Natural History, the University of London, and NASA. It is a collection for everyone, presented in clear English with images, photos and many other fascinating illustrations.

Contents

The Editors

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Leonid Grinin is a historian and sociologist as well as Senior Research Professor and Deputy Director at the Eurasian Center for Megahistory and System Forecasting, Institute of Oriental Studies, Russian Academy of Sciences.
Andrey Korotayev is an anthropologist and mathematician who is Senior Research Professor at the Eurasian Center for Megahistory and System Forecasting, Institute of Oriental Studies, Russian Academy of Sciences.

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New and Returning

IBHA Members

One of the key purposes of the IBHA is for those of us who are interested in Big History to have a place to associate. It is a place to learn of other members' Big History activities and thoughts. So we are delighted to welcome new members to the IBHA – and by the vote of confidence and recognition of the value of our association by those who have renewed their membership. It is a pleasure to have each of you with us.

Lori Brakhage

Jean Bronzwaer

Steve Curtis

Cecilia Dockendorff

Eleanor Fein

John Griffin

Bruce Howlett

John Maunu

Clare Patterson

Steve Sisney

Frans Verstappen

Marcia White

Barbara Winkler


Third IBHA Conference
July 14 - 17, 2016
Amsterdam

Call for Papers

INTERNATIONAL BIG HISTORY ASSOCIATION CONFERENCE

July 14-17, 2016

The University of Amsterdam

The Netherlands

Building Big History: Research and Teaching

DEADLINE FOR PAPER / PANEL SUBMISSIONS IS FEBRUARY 12th, 2016

> The International Big History Association (IBHA) defines its purpose as "to promote, support and sponsor the diffusion and improvement of the academic and scholarly knowledge of the scientific field of endeavor commonly known as "Big History" by means of teaching and research and to engage in activities related thereto."
>
> Article 2 of the IBHA Articles of Incorporation.

The theme for the 2016 conference is "Building Big History: Research and Teaching." The conference seeks to present the latest and the best in Big History research and teaching, while creating a forum for the articulation and discussion of questions that are central to Big History. Among the topics that are to be addressed at the conference through a series of panels, roundtables, and discussions, are:

Approaches to Big History; Big History research agenda; Scholarship contributing to Big History; Big History teaching at universities, secondary, and primary schools: achievements and challenges; Little Big Histories; Reactions to Big History. We encourage proposals along these lines on any topic related to Big History.

To allow the Program Committee to effectively group individual participants into panels, we request that you format your proposals as follows:

- Individual paper proposals must include two separate paragraphs of no more than 150 words each.
  - Paragraph one should contain the title of your proposed paper, and provide a summary of its specific content.
  - Paragraph two should carry the title "Methodology, and Relevance to Big History", in which you address the underlying methodology of your paper, your approach to Big History, and in which you explain how your specific paper

(as described in paragraph one) relates to the broader field of Big History.

- Your proposal must include your name, institutional affiliation (if you have any), e-mail address, phone and/or fax numbers, and a brief curriculum vitae.
- All of this must be provided as one single file, preferably in MS-Word.
- Proposals for entire sessions or panels must contain all this information for each participant, as well as contact information and a brief C.V. for the moderator, if you suggest one. (The program committee can help find moderators, if necessary.)

Please submit your paper or panel proposal by clicking on one of these links, which allow for submission of information. The deadline for paper and panel submissions is February 12th, 2016. The time limit at the conference for presenting papers will be 20 minutes, and the deadline for submitting papers to the session moderator is three weeks in advance of the conference.

All presenters at the conference must be members of IBHA. Presenters may become members at www.ibhanet.org and will need to do so prior to registration for the conference.

The IBHA Conference will convene on premises of the University of Amsterdam, The Netherlands, located in the center of this beautiful European city. Attendees will have the option of selecting from one of several hotels in Amsterdam and the surrounding area with whom special conference arrangements have been made.

The Conference Planning Committee is already hard at work investigating walking and other pre-conference tours of the city, and a post-conference tour that will visit many of the leading scientific, geological, and cultural sites in Europe. We will keep all members fully informed as plans for the third IBHA conference evolve. (See the IBHA website www.ibhanet.org)

For all things Amsterdam, you can go to http://www.iamsterdam.com/en/. For a complete guide to the Netherlands and its many attractions, you can visit http://www.holland.com/us/tourism.htm. If you have more time to explore the larger area, similar websites exist for nearby Belgium, France, Germany, and Great Britain.

Please find more details on the conference at www.ibhanet.org. We very much hope that you can join us at the 3rd IBHA conference.

Program Committee: Jonathan Markley (chair), Cynthia Brown, David Christian, Lowell Gustafson, Andrey Korotayev, Esther Quaedackers, Fred Spier, Sun Yue.

The conference will take place at the Oudemanhuispoort (Old Man's Home Gate). Part of it was built, as the name implies, as a home for poor old people in the early 17th century. In the late 19th century the University of Amsterdam started to use the building. Around that the same time book traders also moved into the little shops that line the main hallway of the building. The book traders are still there. Fred Spier started teaching a Big History course in Oudemanhuispoort 20 years ago. It ran there for 10 years.


Oudemanhuispoort (Old Man's Home Gate)

We have retained two hotels – IBIS Amsterdam Centre Stopera (http://www.ibis.com/en/hotel-3044-ibis-amsterdam-centre-stopera/index.shtml) within a 15 minute walk to the University of Amsterdam, and the Volkshotel (https://www.volkshotel.nl/) within a 15 minute metro ride to the University. The two hotels are totally different types of hotels; check the great reviews of these hotels on tripadvisor (http://www.tripadvisor.com/) . Please mark the dates of July 15 - 17 on your calendars, and start planning to join us in Amsterdam in July of 2016!

If you have any questions – just email Donna Tew, IBHA Office Coordinator @ tewd@gvsu.edu

Big History (and the IBHA Conference) at the University of Amsterdam

The next and third **IBHA conference will be held from July 14th to July 17th 2016 at the University of Amsterdam**.

The University of Amsterdam has a long history. It was founded as the Atheneum Illustre in 1632, during the Dutch Golden Age. The prosperous city of Amsterdam wanted and needed a university to educate its citizens about the riches of the world. Yet the central government did not allow it to have one, since a university had already been established in nearby Leiden in 1575, possibly as a reward for that city's successful resistance against the Spanish. Amsterdam, however, was not discouraged and simply established an educational institution under a different name. It subsequently hired a number of internationally renowned scientists and scholars and started teaching from the Agnietenkapel, a former nunnery. This chapel, which currently houses the university museum, is right around the corner from the IBHA conference location.

The university's slightly anarchistic nature never quite disappeared. After almost 400 years and numerous upheavals, some of which led to major university reforms, the institution still identifies with its somewhat rebellious roots. Even today, one of its three core values is a form of determination, described on the university's website as "inherent to any Amsterdam citizen who looks at the world from an independent, critical and self conscious perspective. University of Amsterdam researchers, teachers and students are competent rebels who, boldly yet responsibly, choose their own paths and set trends."

Partly because of its history and identity, the University of Amsterdam was one of the first in the world to adopt the groundbreaking and unconventional approach to history that was being pioneered by David Christian at Macquarie University in Sydney in the early 1990s. After visiting David in 1992, University of Amsterdam professor Johan Goudsblom brought the syllabus of the big history course that was being taught in Sydney home and decided to set up a similar course at his own university. He did so together with his former Ph.D. student Fred Spier, who after Goudsblom's retirement in 1997 became the course's main organizer.

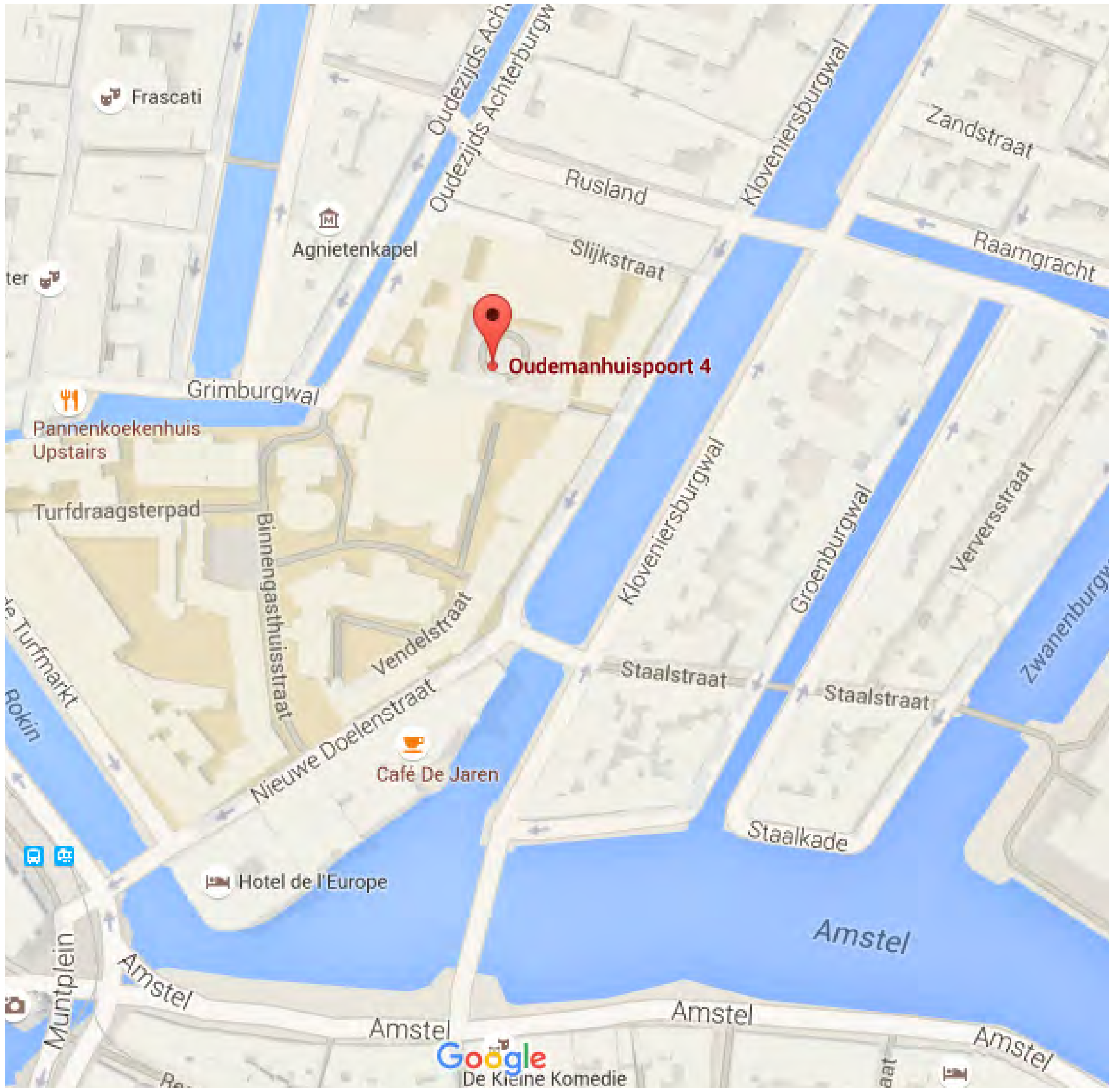
The new course proved to be a big success. About 200 students attended its first run and hundreds of students have registered for the course each year ever since. Within the university, the course's success occasionally led to some resistance, mainly from faculty members who deemed the big history approach to be too broad. But thanks to student engagement and the strong support of a number of the university's most prominent scientists a semi-permanent position in big history was created for Fred Spier in 1997 and was turned into a permanent position in 2006.

Meanwhile, new big history courses, aimed at slightly different student populations, were established both within the University of Amsterdam and outside the university. The university started to function as a kind of big history course contractor, which in turn made it possible for the university to develop into a regional big history hub. The university's latest efforts to create a big history MOOC that will be published on Coursera in early 2016 (alongside Macquarie's big history MOOC that will be published on the same platform in the upcoming months) neatly fits into this pattern.

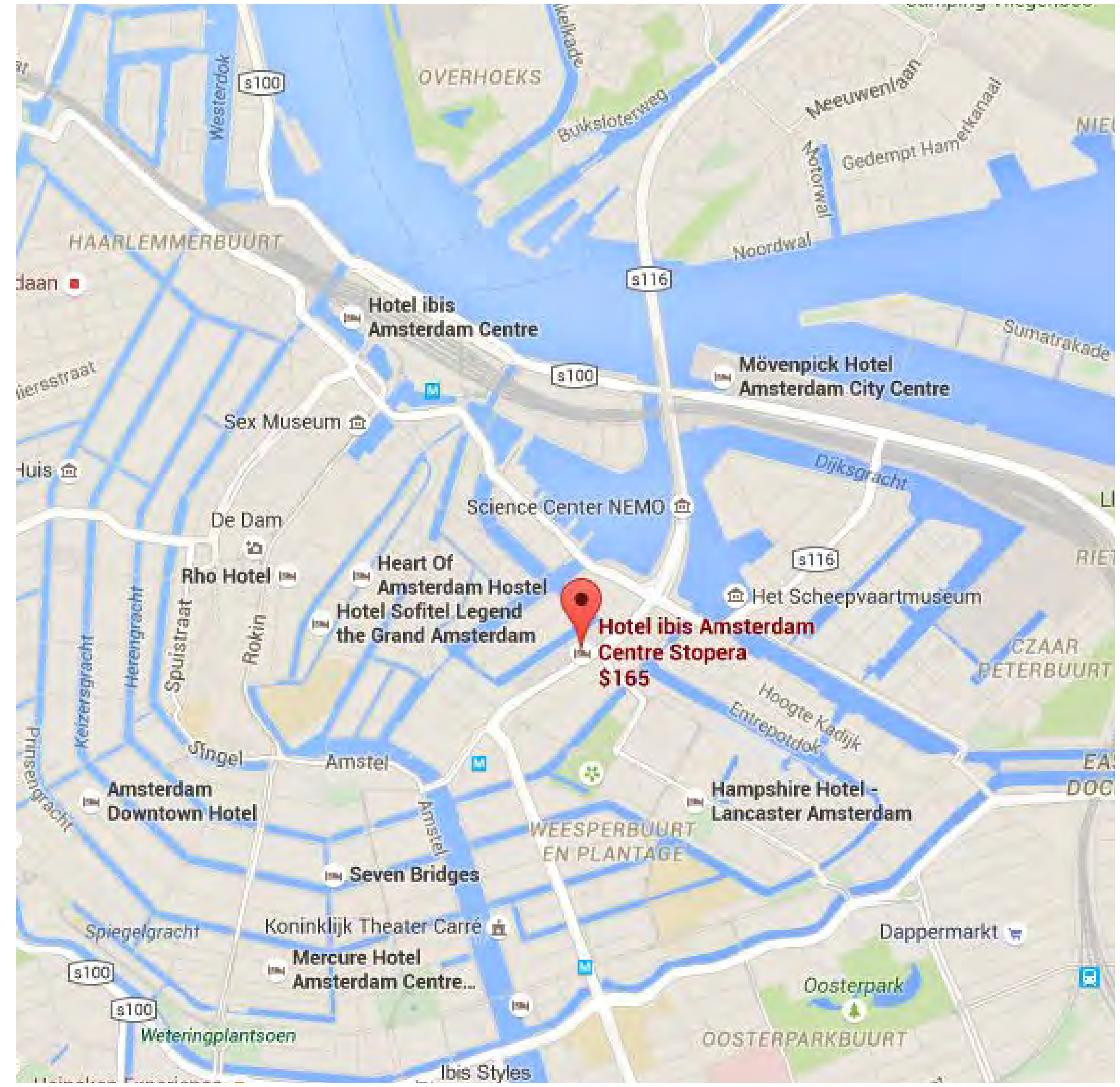
All of these developments have led to the creation of another permanent position in big history in August 2015, which will be filled by Esther Quaedackers. These developments have also enabled the University of Amsterdam offer to host the 2016 IBHA conference. This offer has been accepted by the IBHA, which, given the university's dedication to big history, deemed it to be a suitable place to hold its first conference outside of the US.

The Agnietenkapel
(source: Wikimedia Commons)

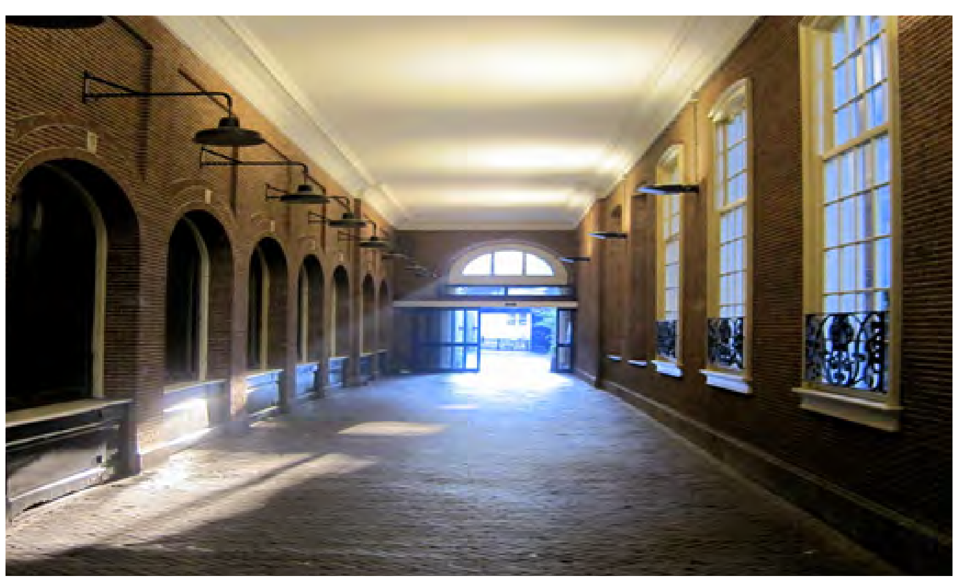
For more information on the history of big history at the UvA, you can also read Fred Spier's The Small History of the Big History Course at the University of Amsterdam that appeared in World History Connected in May 2005.



Location of Conference: Oudemanhuispoort 4-6, 1012 EZ Amsterdam



Hotel ibis Amsterdam Centre Stopera, Valkenburgerstraat



Volkshotel, Wibautstraat 150, 1091 GR Amsterdam

New Big History Program in India

In late August, Craig Benjamin (IBHA Treasurer 2011-present) was invited to the Indian state of Kerala to participate in the Third Annual Colloquium at the Sri Atmananda School in rural Kerala, about four hours drive southeast of Cochin. Sri Atmananda is an 'alternative' K-12 school that focuses on student-oriented education. Classes are small (with a teacher-student ration of around 1:10) and children learn through pursuing their individual interests in a series of focused projects. The school only has some 200 students, but its alternative approach has attracted interest from educationalists all over India. The school has also adopted the Big History Project course, which is being taught to 8th and 9th Grade students.

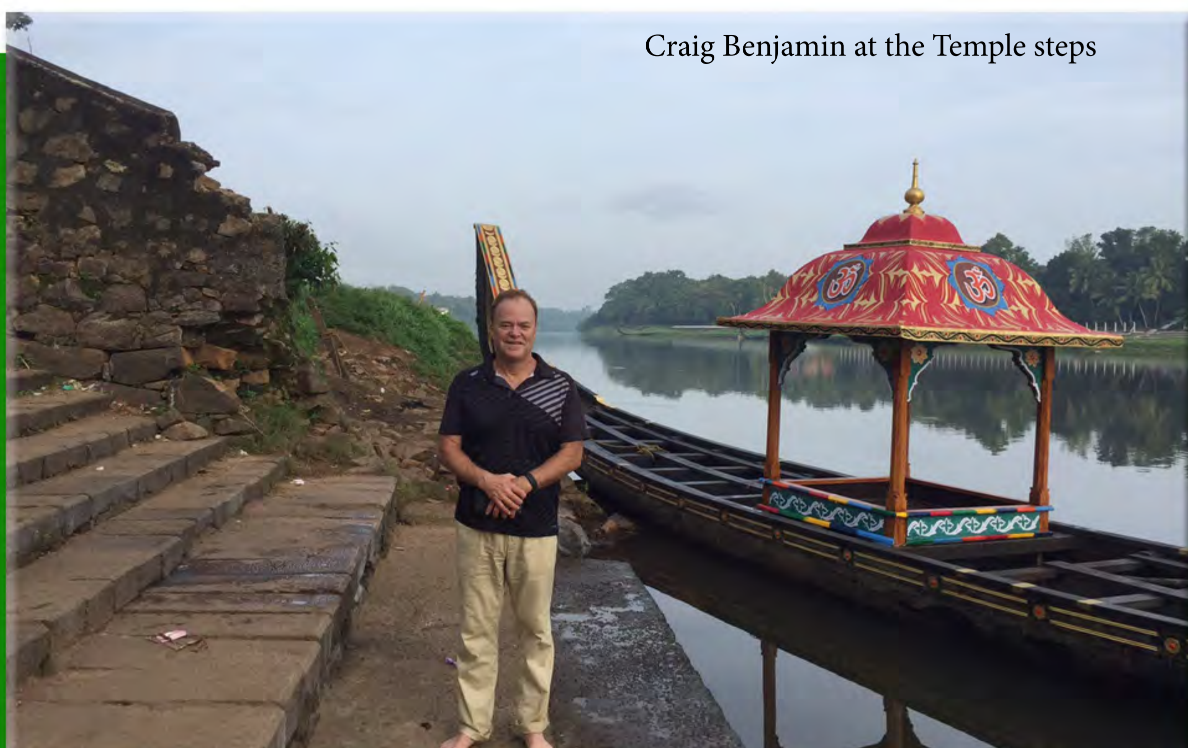
The theme of the Colloquium was the 'Teacher Student Relationship in the Digital Age', and Craig was invited to participate in his role as big history pioneer, and also as an educator who uses technology extensively in the classroom. Other invited guests at the colloquium included several leading corporate representatives (from Intel and De Beers Diamonds, for example), and also may leading educators and leaders in non-profits associated with education.

The school is located in a superb 'Big History' environment. It sits on top of a granite dome surrounded by lush vegetation and extraordinary wildlife. In the village of Aranmulla below there are two superb temples – one dedicated to Krishna that is almost 2000 years old, and the other to Ganesh. The Parabaya River runs through the region, and is the location for famous snake boat races that take place during the Onam Harvest Festival in September.

Craig had the opportunity to meet students, teachers, alumni and parents, and was deeply impressed with how excited everyone was to be associated with this school, and also to be studying Big History, which has made a much wider impression than just the current class. Indeed, since returning to India he has been engaged in e-correspondence with several other colloquium invited guests about the prospects for introducing Big History more widely into the Indian K-12 education system.


Snake Boat with rowers


Arunmulla Temple front


Craig Benjamin at the Temple steps


Students from Sri Atmananda School with Craig Benjamin

Big History Panel at 22nd International Congress of Historical Sciences (ICHS) in Jinan China

IBHA Cooperates with the Network of Global and World History Organizations (NOGWHISTO)

The IBHA was represented in Jinan, China at the 22nd International Congress for the Historical Sciences. There were 2600 delegates from 90 countries presenting in a week-long series of panels, roundtables, plenary sessions and business meetings 12 hours a day. The ICHS meets every five years; their first meeting was in 1900. This was their first meeting in Asia. Big History had been represented at teh 2000 ICHS in Amsterdam, with a panel including David Christian and Fred Spier.

Our Big History panel this year opened with Barry Rodrigue giving a background of big history, Sun Yue explained the Chinese tradition of big history, Seohyung Kim shared the development of convergence education in Korea and how it successfully includes big history, Lowell Gustafson presented about how big history can provide unified concepts to frame a variety of contemporary political issues, such as racism, nationalism, gender relations, and globalization. Liu Shanshan gave a powerpoint about her poster on the little big history of Amsterdam, and Sun gave Qi Tao's powerpoint on the natural science behnd the origin myths of the Chinese people.

Qi Tao is now deputy governor of Shandong province, and was called out of town at the last minute, so he could not make his presentation in person. Nonetheless, Sun and Barry had dinner with him and his director of education just before he left. They had a productive discussion about big history and its potential for inclusion in primary and secondary education, as well as at the univerity level.

As a wonderful end to the event, Shanshan was awarded the Prize for Best Poster at the closing cermonies of the conference!

Our ICHS participation was conceived at the 2011 WHA conference in Beijing, when we felt that it would be a great opportunity to more widely introduce the ideas of big history among another venue of traditional historians. Barry's sabbatical in 2013, which was mediated by Sun and facilitated by Qi, was the second step in the process. This led to Barry teaching Big History in Shandong University.

Under the ICHS protocols, we came to the ICHS as a member of the Network of Global & World History Organizations. The IBHA panel was sponsored by NOGWHISTO; Lowell and Barry have been named to its bureau as IBHA representatives.

The next ICHS conference will be in Posnan, Poland in 2020. IBHA memebrs are encouraged to also make productive outreach at ICHS and NOGWHISTO affiliated professional associations and conferences, from architecture to political science.

More pictures of the conference are here.

Jennifer Joy is an artist who presents various types of performances about science and Big History. She performed at the 2014 IBHA (International Big History Association) Conference.

Her collaborator, beatbox/hip hop artist Benu Muhammad and she are putting together a podcast/audio series about evolution - for junior high/high school students.

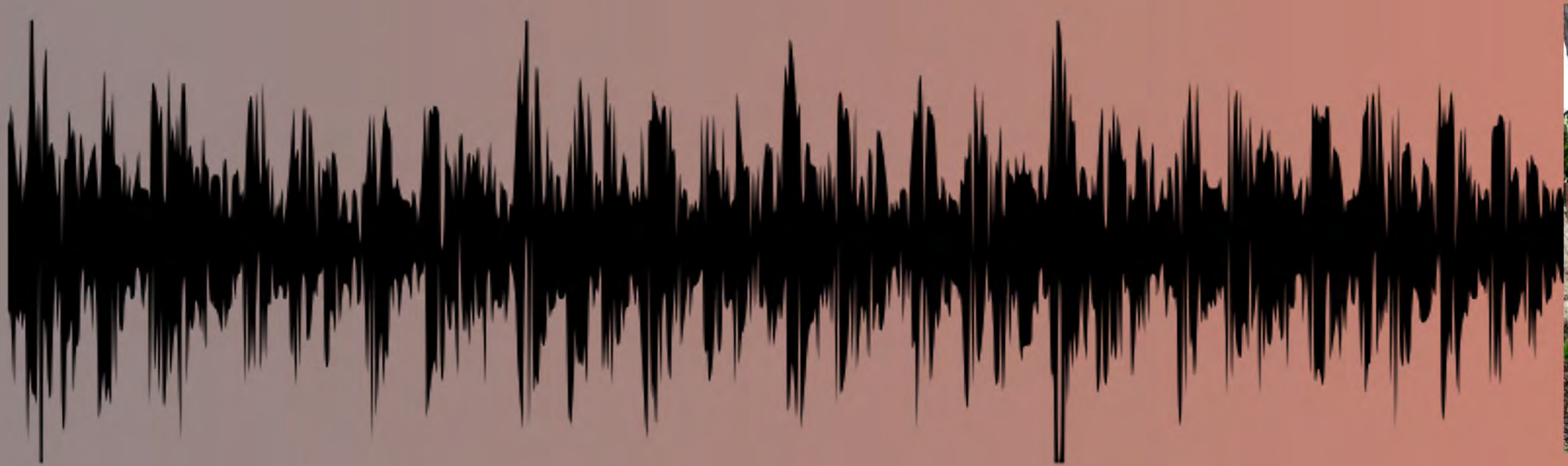
They will combine storytelling, humor, characters and vocal sound effects to tell evolution's stories. Their first one is here:

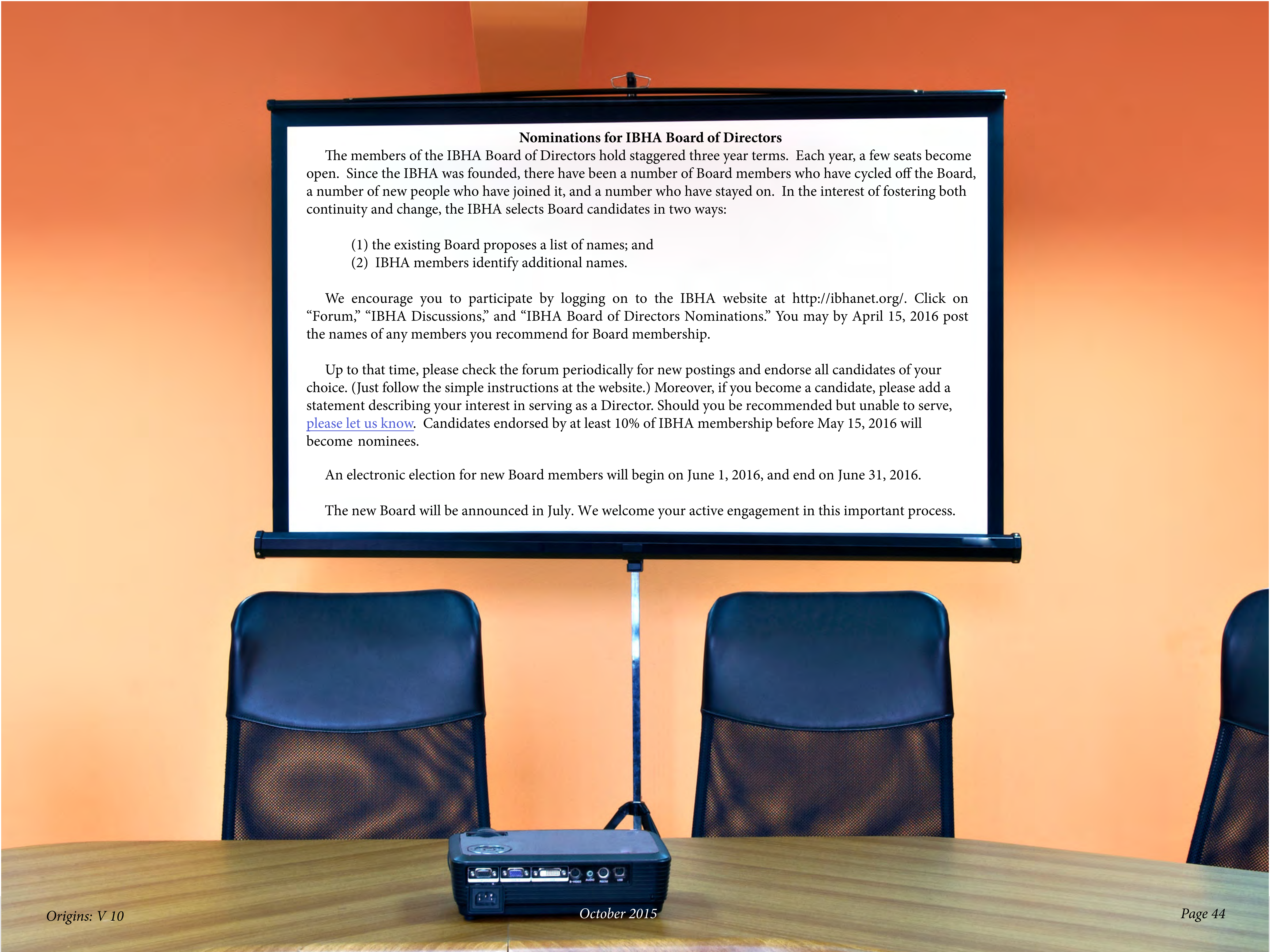
https://soundcloud.com/user-625378467/i-am-life

They are looking for support. To get the attention of students, educators, and the media, they're using a professional sound studio, which is a bit expensive. We're looking at doing 5-10 right now, maybe more. And of course it takes real time to do the necessary research and development for the project.

They are hoping for support in getting kids excited about science. To help fund them, please go to:

http://igg.me/at/evolutionpodcast/x/11656877





Nominations for IBHA Board of Directors

The members of the IBHA Board of Directors hold staggered three year terms. Each year, a few seats become open. Since the IBHA was founded, there have been a number of Board members who have cycled off the Board, a number of new people who have joined it, and a number who have stayed on. In the interest of fostering both continuity and change, the IBHA selects Board candidates in two ways:

(1) the existing Board proposes a list of names; and
(2) IBHA members identify additional names.

We encourage you to participate by logging on to the IBHA website at http://ibhanet.org/. Click on "Forum," "IBHA Discussions," and "IBHA Board of Directors Nominations." You may by April 15, 2016 post the names of any members you recommend for Board membership.

Up to that time, please check the forum periodically for new postings and endorse all candidates of your choice. (Just follow the simple instructions at the website.) Moreover, if you become a candidate, please add a statement describing your interest in serving as a Director. Should you be recommended but unable to serve, please let us know. Candidates endorsed by at least 10% of IBHA membership before May 15, 2016 will become nominees.

An electronic election for new Board members will begin on June 1, 2016, and end on June 31, 2016.

The new Board will be announced in July. We welcome your active engagement in this important process.

IBHA Post-Conference Tour

A TASTE OF EUROPE

JULY 18–27, 2016

International Big History Association

Craig Benjamin, pioneering Big Historian and tour lecturer, on the Jungfraujoch.

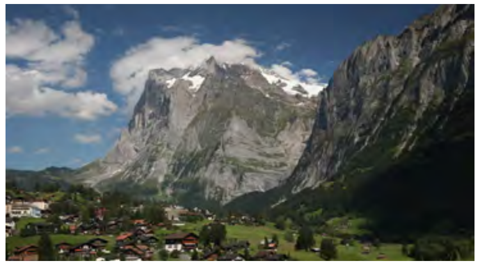
10
DAYS

Jump into world history and scientific discovery in Five European Countries

From First World War battlefields in Belgium and Paleolithic cave art in France to world-class wine vineyards in Germany and thematic lectures provided by leading historians, this tour has it all. Discover distinct style, substance and science in the cultural capital of Paris, among the magnificent *chateaux* in the Loire Valley and in the center of particle physics research at CERN. You'll absorb the best of history and beauty on this fascinating tour through five European countries.

Overview

A TASTE OF EUROPE



Let us handle the details

Expert Tour Director

Local cuisine

Handpicked hotels

Sightseeing with local guides

Private transportation

Personalized flight options

Your tour includes

- 9 nights in handpicked hotels
- Breakfast daily, 4 three-course dinners with beer or wine
- Multilingual Tour Director
- Private deluxe motor coach
- Guided sightseeing and select entrance fees

Your tour highlights

- World-class museums and beautiful gardens in Paris
- Magnificent architecture and rich history at Château de Chenonceau
- Stunning replicas of Paleolithic art in the Lascaux II Cave
- Sweeping, mountainous landscapes in Auvergne
- Impressive scientific technology at CERN, the European Organization for Nuclear Research
- Medieval castle views in the UNESCO-recognized Rhine River Valley
- Daily lectures by leading historians

Where you'll go

OVERNIGHT STAYS

2 nights • Paris
2 nights • Dordogne Region
1 night • Geneva
2 nights • Grindelwald
2 nights • Heidelberg

Itinerary

A TASTE OF EUROPE

Paris | 2 nights

Day 1: Arrival in Paris

Welcome to France! Say goodbye to some of your fellow conference-goers and hello to your Tour Director as you transfer from Amsterdam to Paris by deluxe coach. Stop en route in Ypres, Belgium, which was a site of heavy fighting during the 1916 Battle of the Somme.

- Tour the In Flanders Fields Museum, which focuses on the futility of war
- Visit the Menin Gate, a memorial to British and Commonwealth soldiers whose graves are unknown

Later, enjoy free time to explore and eat lunch in Ypres before continuing on to Paris. If time allows, additional stops will be made in Antwerp and Amiens.

Day 2: Sightseeing tour of Paris & the Musee d'Orsay museum

Included meals: breakfast, welcome dinner

Paris was central to the French Revolution in the late-eighteenth century and largely rebuilt under Napoleon III in the 1860s. A guided tour introduces you to the architecture and history of the City of Light's neighborhoods, called *arrondissements*.

- Drive down the sycamore-lined Champs-Élysées to view the famous Arc de Triomphe, a tribute commissioned by Napoleon
- Pass Pont Neuf and the Notre-Dame Cathedral, located on the Seine River
- Make a photo stop at the Eiffel Tower viewpoint to see the wrought-iron landmark
- See the opulent Palais Garnier opera house, Hôtel des Invalides and Place de la Concorde, the city's grandest square

Later, enjoy the Musee d'Orsay Museum's rich collection.

- Enjoy free time for lunch in the afternoon and tonight, sit down with your group and your Tour Director at a welcome dinner.

Dordogne Region | 2 nights

Day 3: Périgueux via the Loire Valley

Included meals: breakfast, dinner

Transfer to Périgueux in the Dordogne Region today. Stop along the way in the Loire Valley, which produces world-class wines and was once known as France's "Playground of the Kings." You'll learn more about the area's royal past on a guided tour of the extravagant Château de Chenonceau.

- Explore the interior and gardens of the castle, which sits on the River Cher and is a famous late-Gothic/early-Renaissance architectural gem
- Discover how it got the nickname "Château de Femmes"—some of its famous female residents included Diane de Poitiers and Catherine de' Medici

Take free time for lunch at the chateau and then continue on to the Dordogne Region for an included dinner this evening.

Day 4: Lascaux II Cave & Les Eyzies-de-Tayac-Sireuil

Included meals: breakfast

Explore the Dordogne Region to discover prehistoric remnants, ancient history and spectacular Paleolithic art, and then eat lunch during free time.

- Follow a guide as you marvel at the reproductions of Paleolithic paintings in the Lascaux II Cave, a 39-meter replica of the original cave
- Transfer to the village of Les Eyzies-de-Tayac-Sireuil this afternoon, where you'll enter the National Prehistoric Museum and see awe-inspiring archaeological finds from some of the most famous excavation sites in the Vézère Valley

Geneva | 1 night

Day 5: Geneva via Auvergne

Included meals: breakfast

Make your way to the historic city of Geneva, Switzerland today, stopping along the way in the mountainous region of Auvergne.

- Take in scenic surroundings as you drive through the Auvergne Volcanoes Regional Park, a well-preserved site that boasts stunning landscapes, beautiful villages and 10,000-year-old volcanic peaks
- As you drive through the park, stop for photo ops at the Puy de Dôme, a large lava dome, and the Puy de Sancy, the highest volcano in France
- Revel in the park's beauty as you enjoy free time for lunch

Grindelwald | 2 nights

Day 6: Grindelwald via CERN

Included meals: breakfast, dinner

Today, explore the European Organization for Nuclear Research, known as CERN. Follow a CERN staff member on a guided tour of the laboratory, where scientists do groundbreaking research on particle physics.

- View the Large Hadron Collider, a massive particle accelerator that is responsible for some extraordinary discoveries, including the pentaquark

Later, take free time to eat lunch and explore CERN's permanent exhibitions before continuing on to Grindelwald for tonight's included dinner.

Day 7: The Bernese Oberland & Jungfraujoch

Included meals: breakfast

Today, head into the Bernese Alps and discover the UNESCO World Heritage site of Jungfraujoch, a windswept mountain pass known as the "Top of Europe."

- Ride a railway car to the Jungfrau plateau, where you can enjoy free time for lunch 11,617 feet above sea level
- Take a train to view the Sphinx Observatory and enter the Ice Palace

Later, enjoy a spectacular hike on the trails below these formidable mountains.

Heidelberg | 2 nights

Day 8: Heidelberg via Basel & Strasbourg

Included meals: breakfast

Transfer to Germany today, making a brief stop for free time in Basel, Switzerland's third-largest city. Then, continue on to Strasbourg, the capital of France's Alsace region and the official seat of the European Parliament. Take a guided tour of the city's Parliament building and eat lunch during free time. Then, make your way to Heidelberg, which has a history of human occupation dating back at least 200,000 years and is home to one of the most influential universities in the world.

Day 9: Wine Tasting & Rhine River Cruise

Included meals: breakfast, lunch, wine tasting, farewell dinner

Start your day with a guided tour of Bopparder Hamm, the largest wine vineyard in the Middle Rhine Valley.

- Tour the cellar and vineyards before sitting down to a lunch accompanied by a tasting of some signature vintages
- Enjoy magnificent views over the Rhine valley as you learn about the cultivation of wine in the region

Later, take in the spectacular sights of the UNESCO-recognized Rhine River Valley on a scenic cruise from Boppard to St. Goar.

- Marvel at breathtaking landscapes and fine architecture of the Middle Ages
- View medieval castles along the river, including Kurtrierische Burg in Boppard

After disembarking, say goodbye to your group at a farewell dinner.

Day 10: Amsterdam via Cologne

Included meals: breakfast (excluding early morning departures)

Make a brief stop in Cologne, home to a UNESCO-listed cathedral, before transferring back to Amsterdam with your group.

Start planning today | Contact Charlie Thurston **1.617.619.1133 or charlie.thurston@goaheadtours.com**