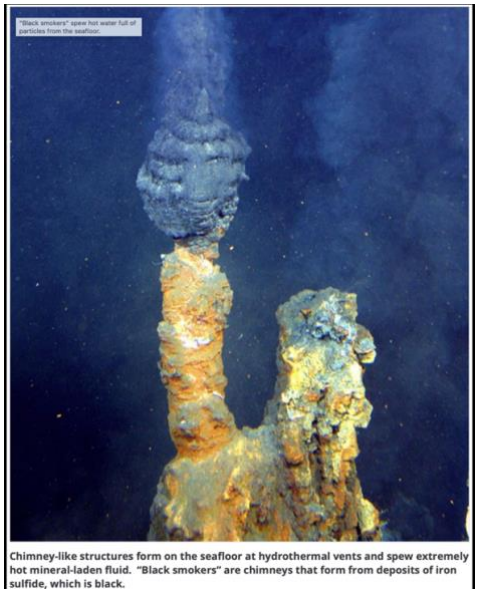
Respiration … Ventilation

<u>Respiration</u>: formation of an H^+ gradient across the mitochondrial inner membrane, enabling oxidative phosphorylation of ADP and regeneration of ATP

<u>Ventilation</u>: intake of molecular O_2 by the lungs and entry into the circulatory system enabling delivery of O_2 to the interstitial fluid surrounding cells

Early on, the atmosphere and waters of Earth lacked any appreciable molecular oxygen (**O_2**). Around deep ocean vents, chemical energy flow provided an environment in which *first life* likely developed. The strategy for living systems *which has persisted* was formation of isolated units (*cells*), each bounded by a *bilayer lipid membrane* (see ***membrane***), capable of metabolically sustaining themselves and reproducing. Groups of cells with differing metabolic capabilities formed an interactive biosphere in which *cooperation* allowed cells to thrive in these deep-water communities. Much later, near the surface, certain organisms became efficient at capturing specific spectra of sunlight, utilizing photon energy to tear water (**H_2O**) apart, pumping protons (**H^+**) across the cell membrane, creating a chemiosmotic (electrochemical) gradient that could be used to phosphorylate **ADP** to form **ATP**. In the process, the oxygen from **H_2O** was released (as a waste product) in the form of molecular oxygen, **O_2 :** the **Great Oxidation Event** had begun.

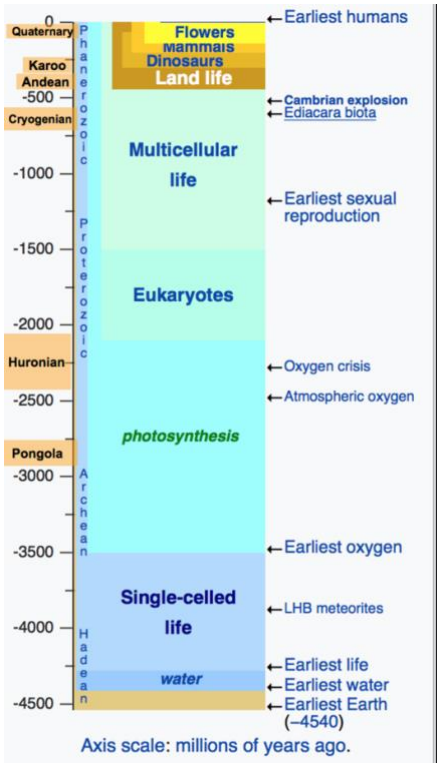


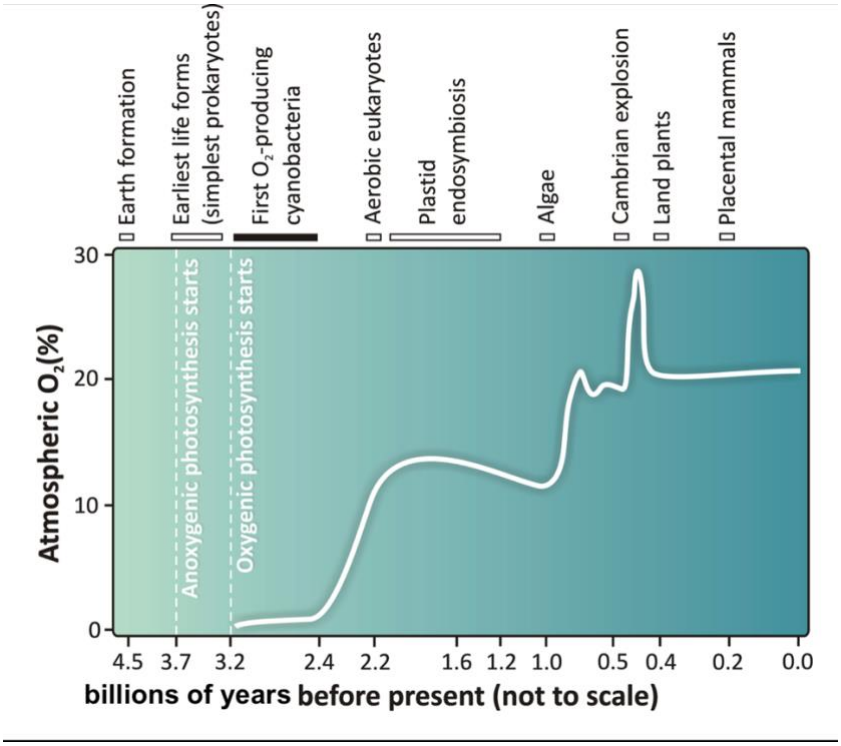
Chimney-like structures form on the seafloor at hydrothermal vents and spew extremely hot mineral-laden fluid. "Black smokers" are chimneys that form from deposits of iron sulfide, which is black.

^ deep ocean vent ^
Pacific Ocean floor

^ stromatolite fossil - age: ~ 2 billion years old ^
near Laramie, Wyoming
(see: ***stromatolite***)

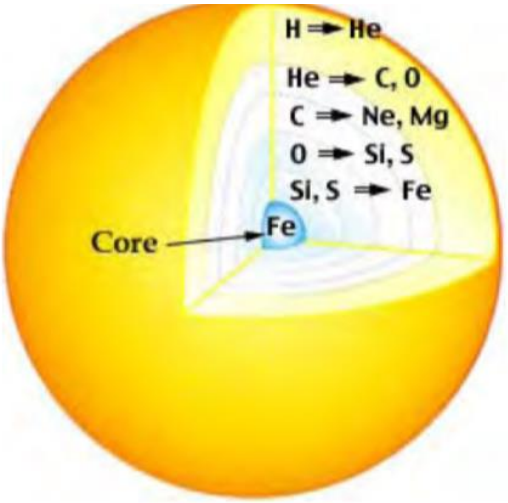
At first, as O_2 was released from cells into the aqueous environment, it reacted immediately with abundant dissolved iron, **Fe**, to form iron oxides, such as Fe_2O_3. As this settled to the ocean floor, sedimentary layers of banded iron deposits began to form. Only after the ancient seas were depleted of iron did molecular oxygen (O_2) begin to accumulate in the water and become abundant in the atmosphere. As this occurred, O_2 - a waste product for photosynthetic cyanobacteria which produced it - was toxic to the multitude of organisms which thrived in the anoxic world. However, not every organism is the same**:** mutation and variation in the genetic code during reproduction result in certain individuals possessing novel abilities which may become advantageous when environmental circumstances change. Bacteria able to utilize molecular oxygen as a terminal receptor for protons (H^+) pumped across the cell membrane came to dominate the aerobic world (see: *oxygen*).

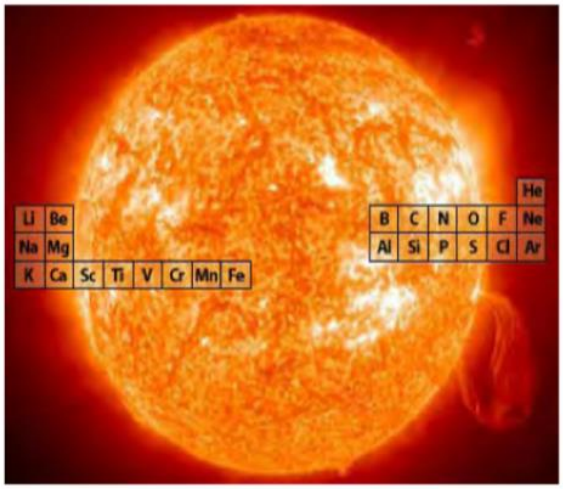




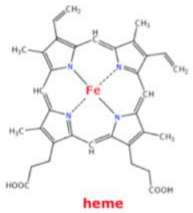
Eventually, *a unique merger occurred***:** a bacterium which avidly utilized molecular oxygen in its metabolic pathway (thus diminishing the concentration of oxygen in the surrounding volume) was *ingested but not digested* by another organism, likely an Archaean (see *archaea*). The internalized partner was kept as a mitochondrion (see *mitochondria*), *dividing along with its host cell and thus persisting as an endosymbiont*. This was a critical step in the emergence of **eukaryotic** organisms. As Earth's waters and atmosphere became transformed into oxygen-rich zones, mitochondria not only protected these new and more complex eukaryotic cells from oxidative injury but also provided ***oxidative phosphorylation***, which generated **ATP** with much greater efficiency - a competitive advantage for survival.

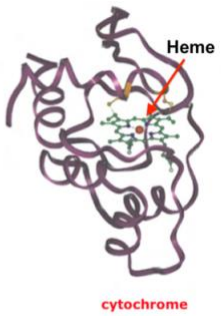
Iron, whose nuclear stability results in the supernova explosion of stars (see: ***iron***), is critical for both **respiration** and **ventilation**.

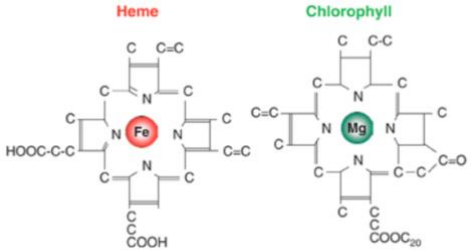




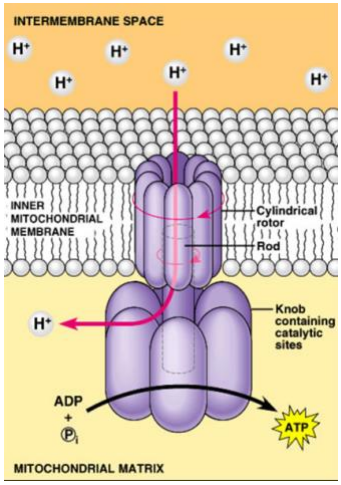
Iron is the central element in **heme** (see ***heme***), which gives color and function to both **cytochromes** and **hemoglobin**. **Cytochromes** drive **respiration** and the formation of an electrochemical (H^+) gradient across the *mitochondrial inner membrane*, generating **ATP**, the energy currency of all life (see ***ATP***). Hemoglobin is responsible for binding and releasing O_2, permitting *centralized* **ventilation** to deliver O_2 to distant cells via the *closed* **circulatory system** used by vertebrates.







Embedded in the mitochondrial membrane, cytochromes enable the electron transport chain to build up a proton (H^+) gradient (see: ***proton***). Protons (H^+) are only able to move back down across this gradient through specific membrane channels in the **ATP synthase** complex. As this occurs, the central portion of this complex *spins*, powering the conversion of ADP to ***ATP**, the common currency of energy in living systems*. This is "**oxidative phosphorylation**".



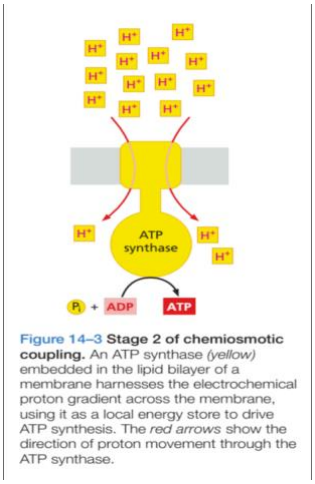
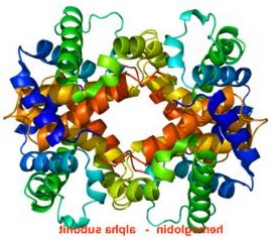
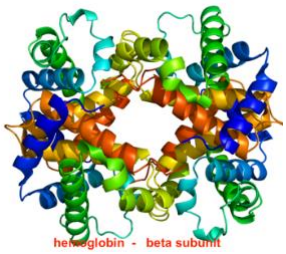
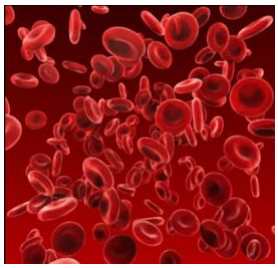


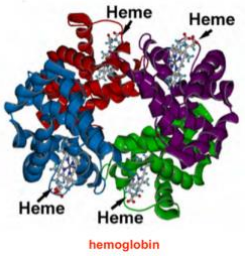
Figure 14–3 **Stage 2 of chemiosmotic coupling.** An ATP synthase *(yellow)* embedded in the lipid bilayer of a membrane harnesses the electrochemical proton gradient across the membrane, using it as a local energy store to drive ATP synthesis. The *red arrows* show the direction of proton movement through the ATP synthase.

Since oxygen (O_2) is required for oxidative phosphorylation to work, oxygen must be delivered to all active cells in a multicellular organism. In vertebrates, including humans, **hemoglobin** (contained in erythrocytes – see ***hemoglobin*** and ***rbc***) is the molecule which functions to bind O_2 in the gills or lungs and then to release O_2 in the capillaries, where it easily diffuses into the interstitial fluid that surrounds each cell.

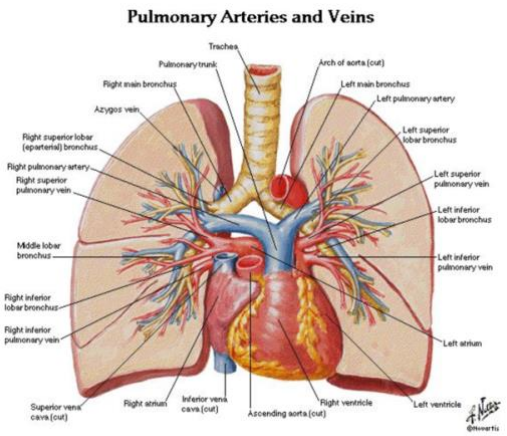


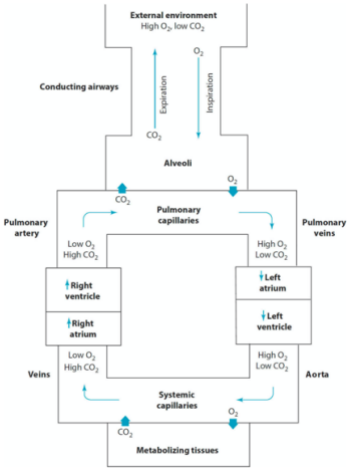


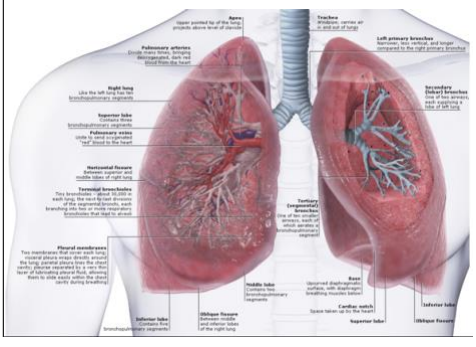




A pair of human lungs contains 480,000,000 **alveoli** (see ***breath***), tiny structures where O_2 is picked up and CO_2 is discarded. **Ventilation** functions to provide the appropriate alveolar concentrations of O_2 (high) and CO_2 (low) for optimal gas exchange. In addition, appropriate **ventilation** must be closely matched by **perfusion** of pulmonary arterial blood flow.







… more on ***respiration*** webpage