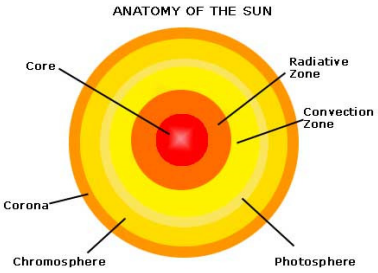
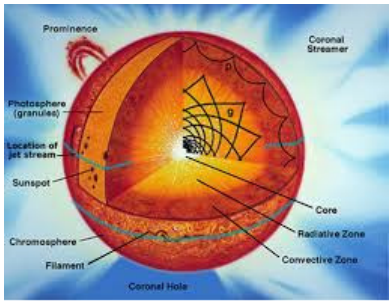
Sun – Part 12 - structure 1

The Sun has a layered structure.





Solar structure

Core

This extends from the centre to about 25% of the radius. Its temperature is around 15.7 million K and its density up to about 150 times that of water. It is the area in which nuclear fusion takes place, producing over 99% of the Sun's energy. The remainder of the Sun is heated by this energy, which is transferred outwards through many successive layers to the surface before escaping into space as sunlight, the kinetic energy of particles.

Peak power production is actually quite low, power density being closer to a reptilian metabolism than a thermonuclear bomb. The huge power output is not due to high power per volume, but a consequence of the Sun's large size. The fusion rate in the core is a self-correcting equilibrium – increased fusion increases core temperature, causing expansion against the outer solar layers. This pressure then reduces the fusion rate, correcting the perturbation. The slower rate cools and slightly shrinks the core, increasing fusion rate, and so on.

Radiative zone

This extends from the outer core to about 70% of the Sun's radius. Thermal radiation, rather than convection, is the main means of energy transfer in this layer, and temperature drops from around 7 million to 2 million K with increasing distance from the core. Density drops 100 times from the core to the outer edge of the zone.

The high energy gamma ray photons released by nuclear fusion in the core are almost immediately absorbed by the solar plasma in the zone, usually after travelling only a few millimetres. Re-emission is in random directions and usually at slightly lower energy. This sequence of emissions and absorptions continues, and it takes a long time for radiation to reach the Sun's surface. Photon travel time estimates range from 10,000-170,000 years. By contrast, neutrinos (2% of total energy production in the core), take only 2 to 3 seconds to reach the solar surface. This is because they rarely interact with matter and are able to escape almost immediately.

Tachocline

This is the transition layer between the radiative and convective zones. A large shear results where the uniform rotation of the radiative zone changes to the differential rotation in the convective zone. Successive horizontal layers slide past one another, the fluid motion of the convective zone above slowly disappearing from the top of the layer to its bottom, matching the calm characteristics of the radiative zone at its base. It is hypothesised that a magnetic dynamo within this layer generates the Sun's magnetic field.

Convective zone

This occupies the outer 30% of the Sun, from its surface to about 200,000 km below. Temperatures are lower than in the radiative zone and heavier atoms not fully ionised, making radiative heat transport less effective. However, at these temperatures, plamsa density is low enough to allow convective currents to develop.

Material heated at the tachocline expands, reducing density and rising. Thermal convection develops as thermal cells carry the majority of the heat outward to the photosphere. At the solar surface, temperatures have dropped to around 5,700 K and density to that of air at sea level.

Turbulent thermal columns in the zone form mottling imprints on the Sun's surface. The numerous small, light areas are called granules. They are separated from one another by darker, cooler intergraunular lanes. Reflecting the dynamic process underlying their formation, individual granules last only around 20 minutes.

Photosphere
This is the outer, visible surface of the Sun, Beyond the photosphere, the energy of sunlight is free to propagate into space. Varying in depth from 10 -100s of km, the photosphere is slightly less opaque than air on Earth, with a particle density of around 0.37% of the particle numbers per volume of Earth's sea level atmosphere.

The average temperature of the solar surface is around 5,700 K. The upper part is cooler, temperature steadily decreasing to about 4,400 K at the so-called temperature minimum.

Temperature minimum
This forms the boundary between the photosphere and the solar atmosphere and is located about 550 km above the base of the photosphere.

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org,