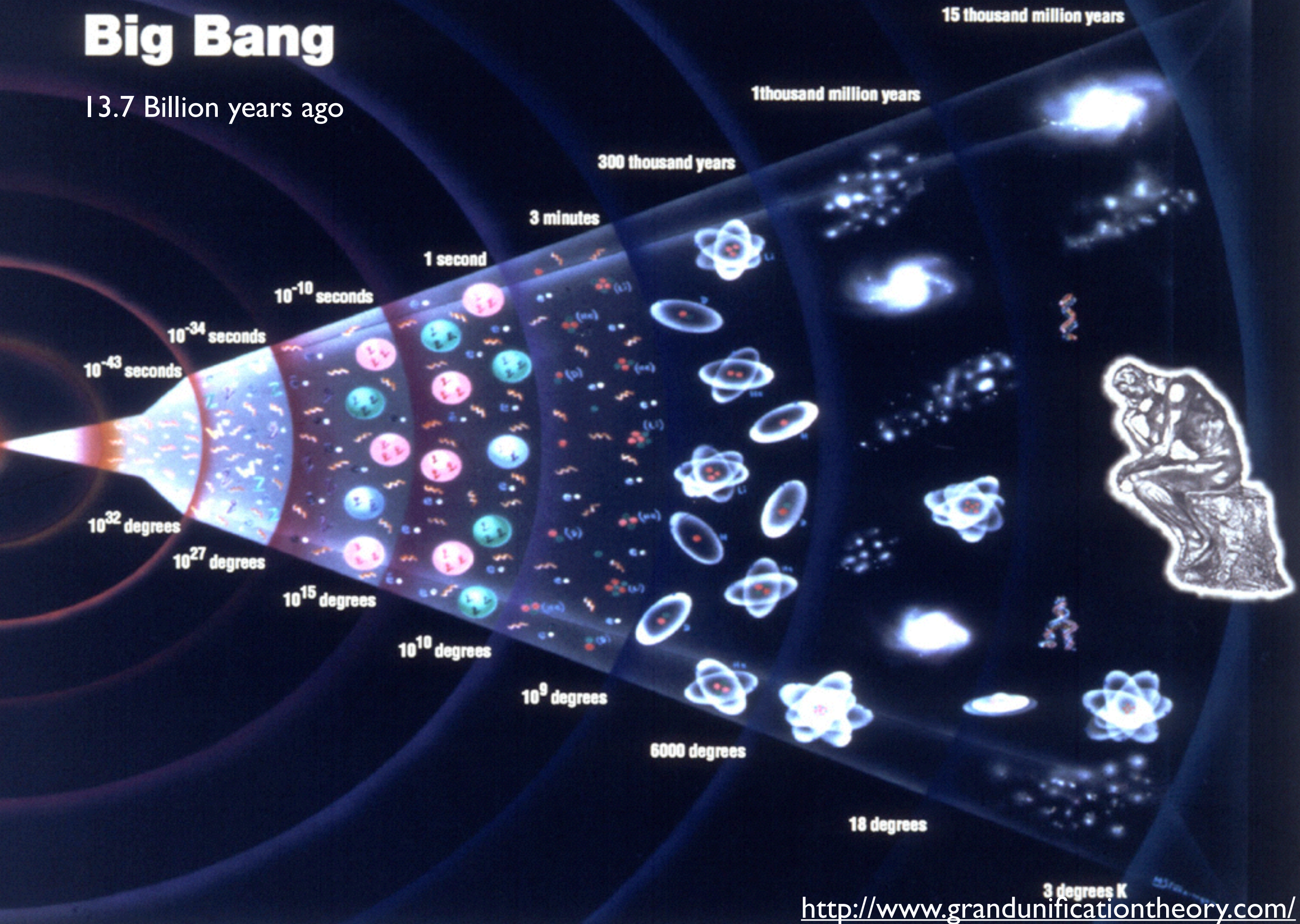
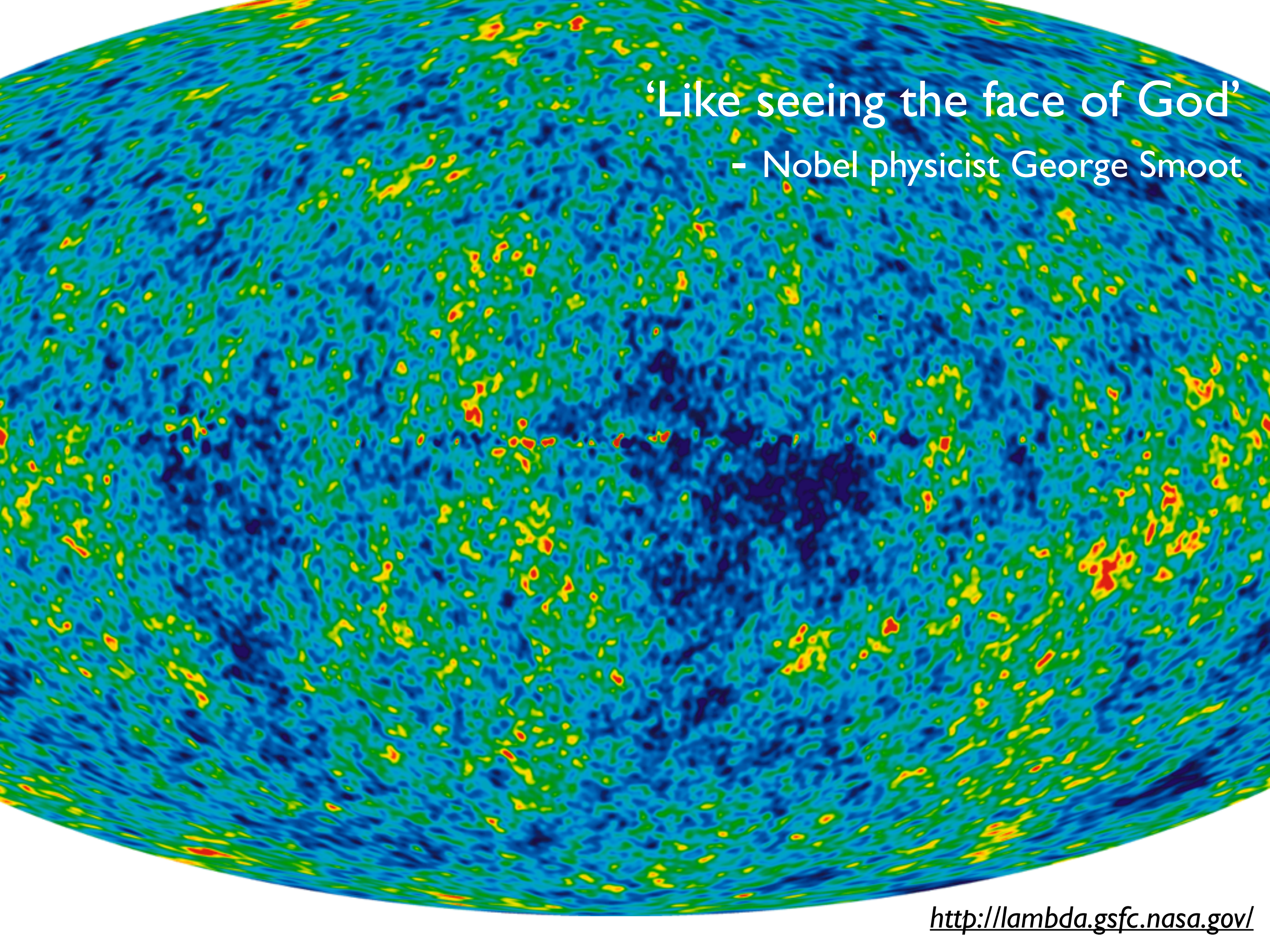




Big Bang

13.7 Billion years ago

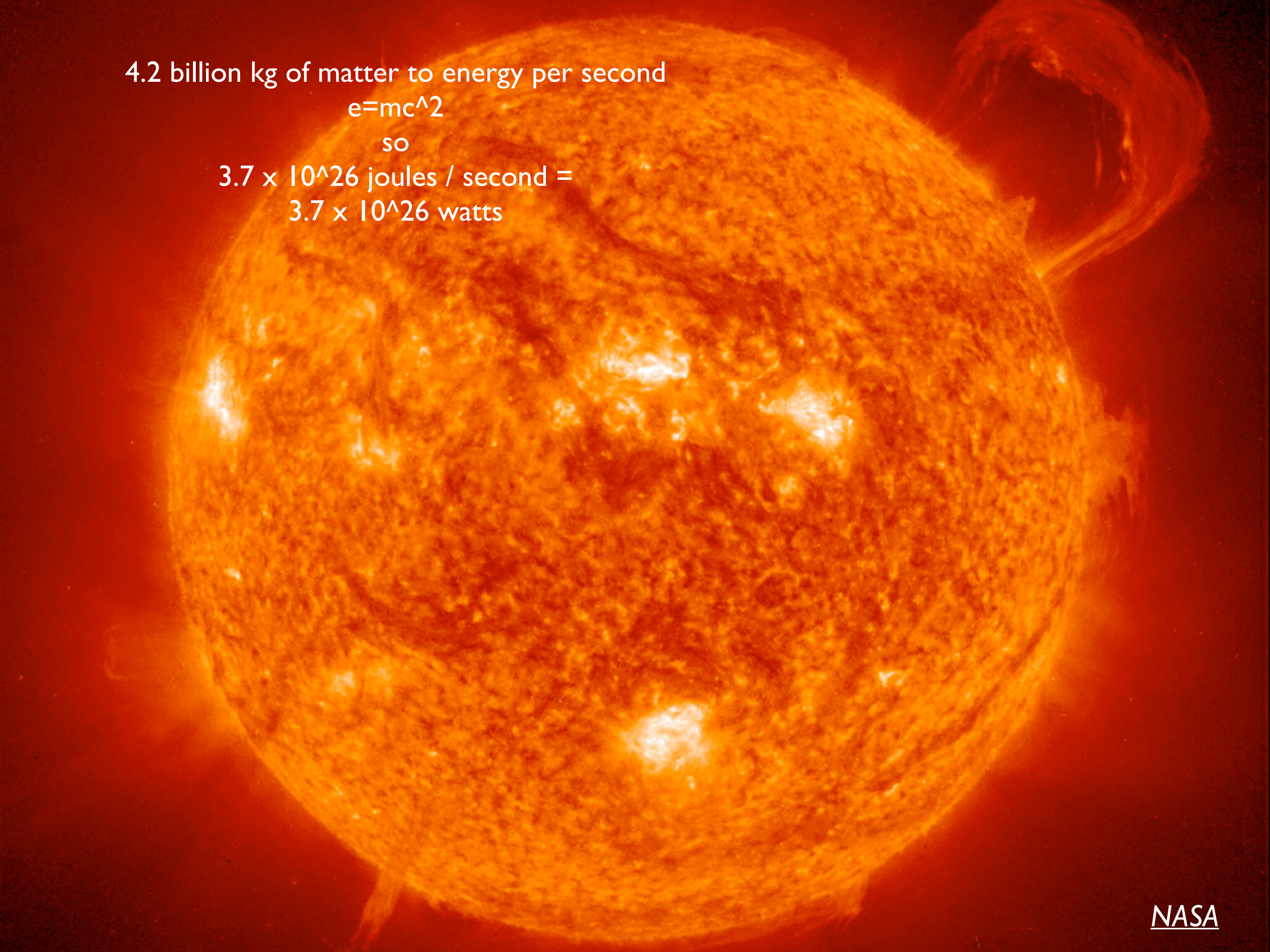




‘Like seeing the face of God’

– Nobel physicist George Smoot





4.2 billion kg of matter to energy per second

$$E=mc^2$$

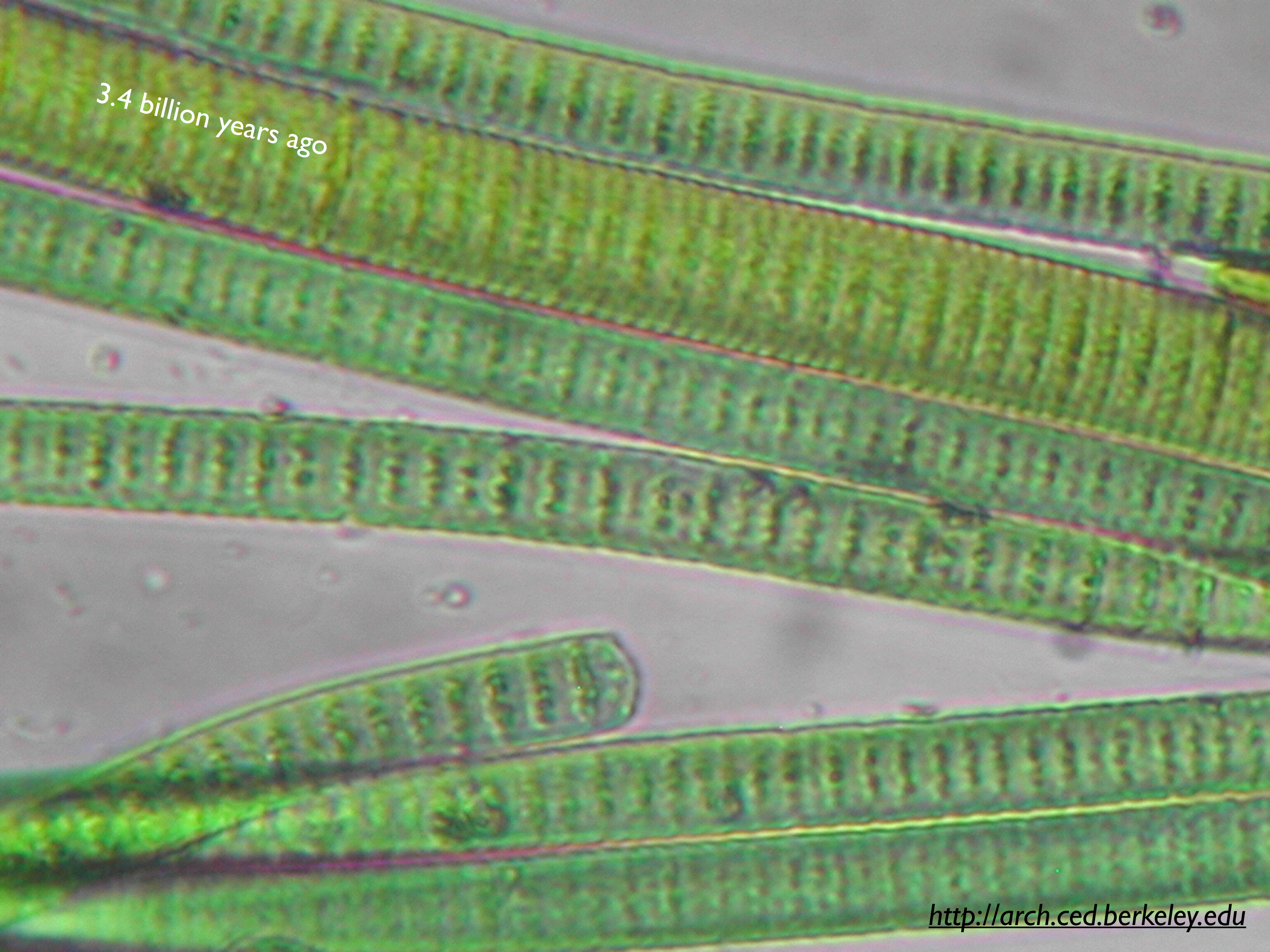
so

$$3.7 \times 10^{26} \text{ joules / second} =$$

$$3.7 \times 10^{26} \text{ watts}$$

4.6 billion years ago





3.4 billion years ago



1.7 million - 200,000 years ago





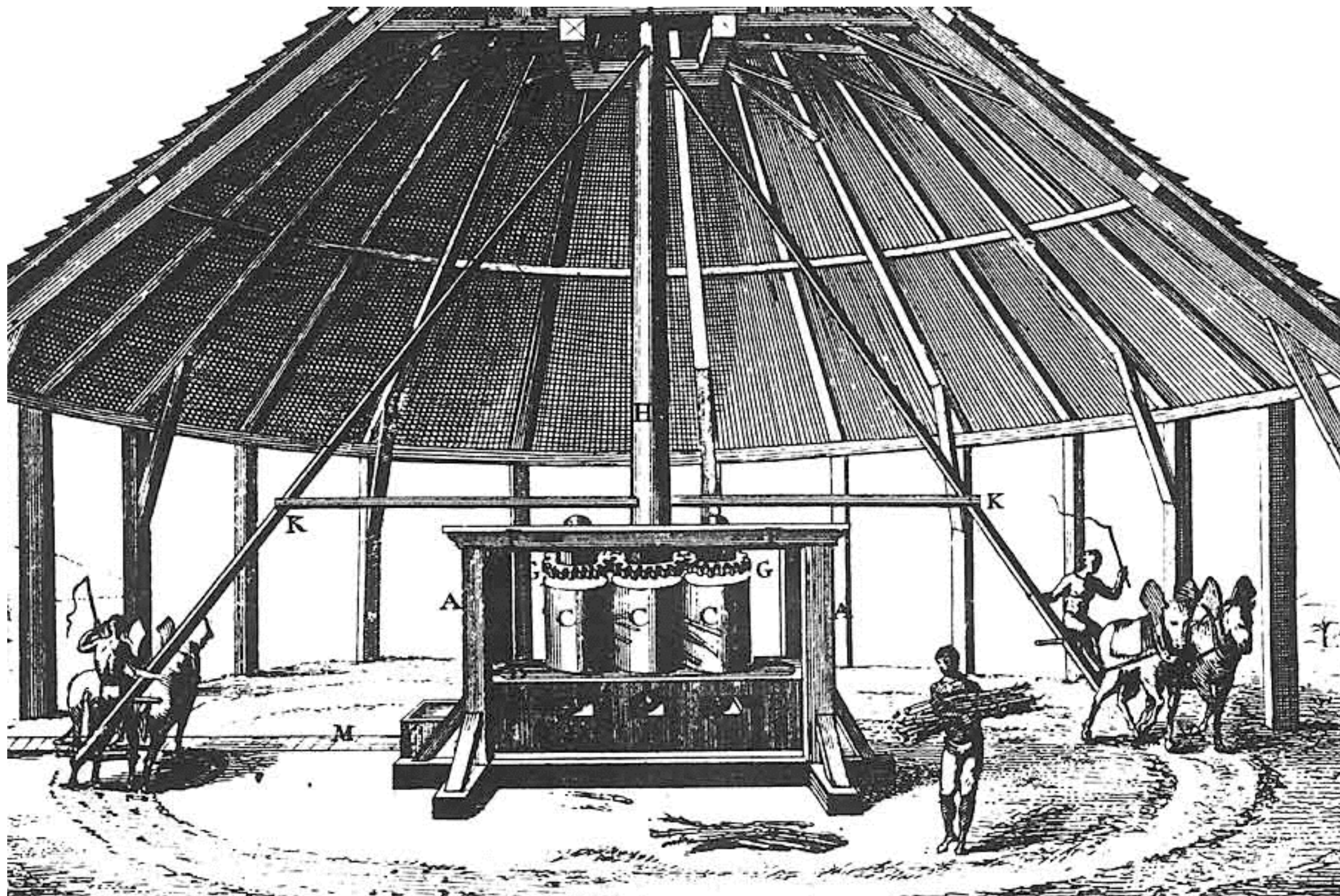


20,000-30,000 years ago



< 10,000 years ago

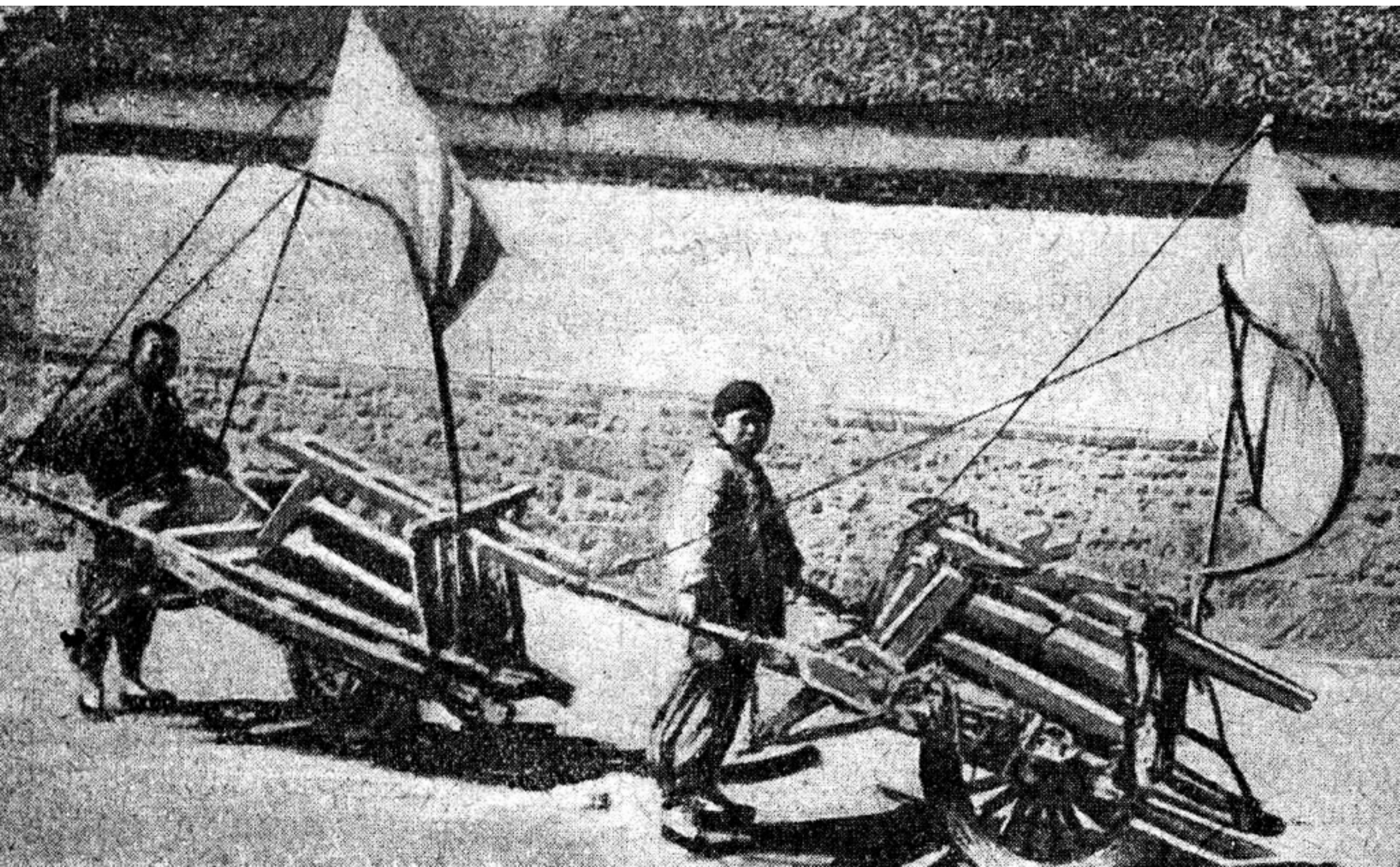


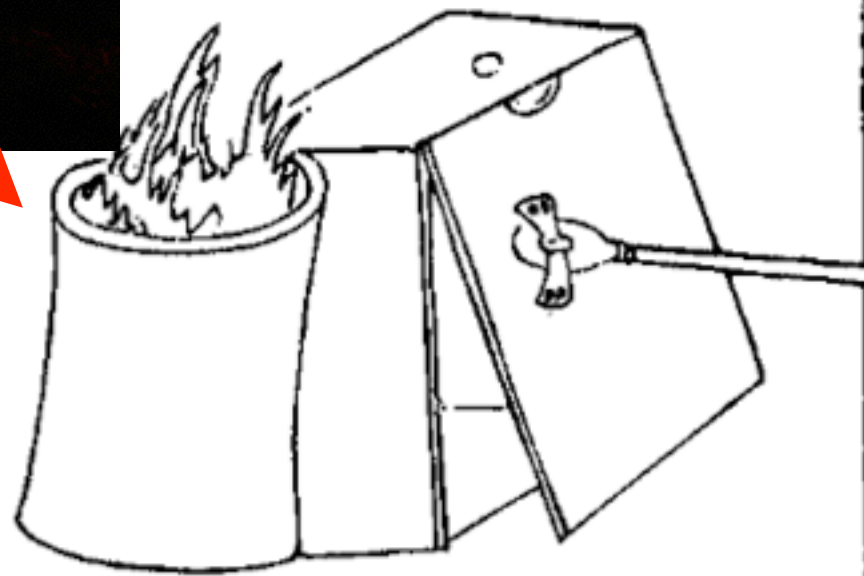








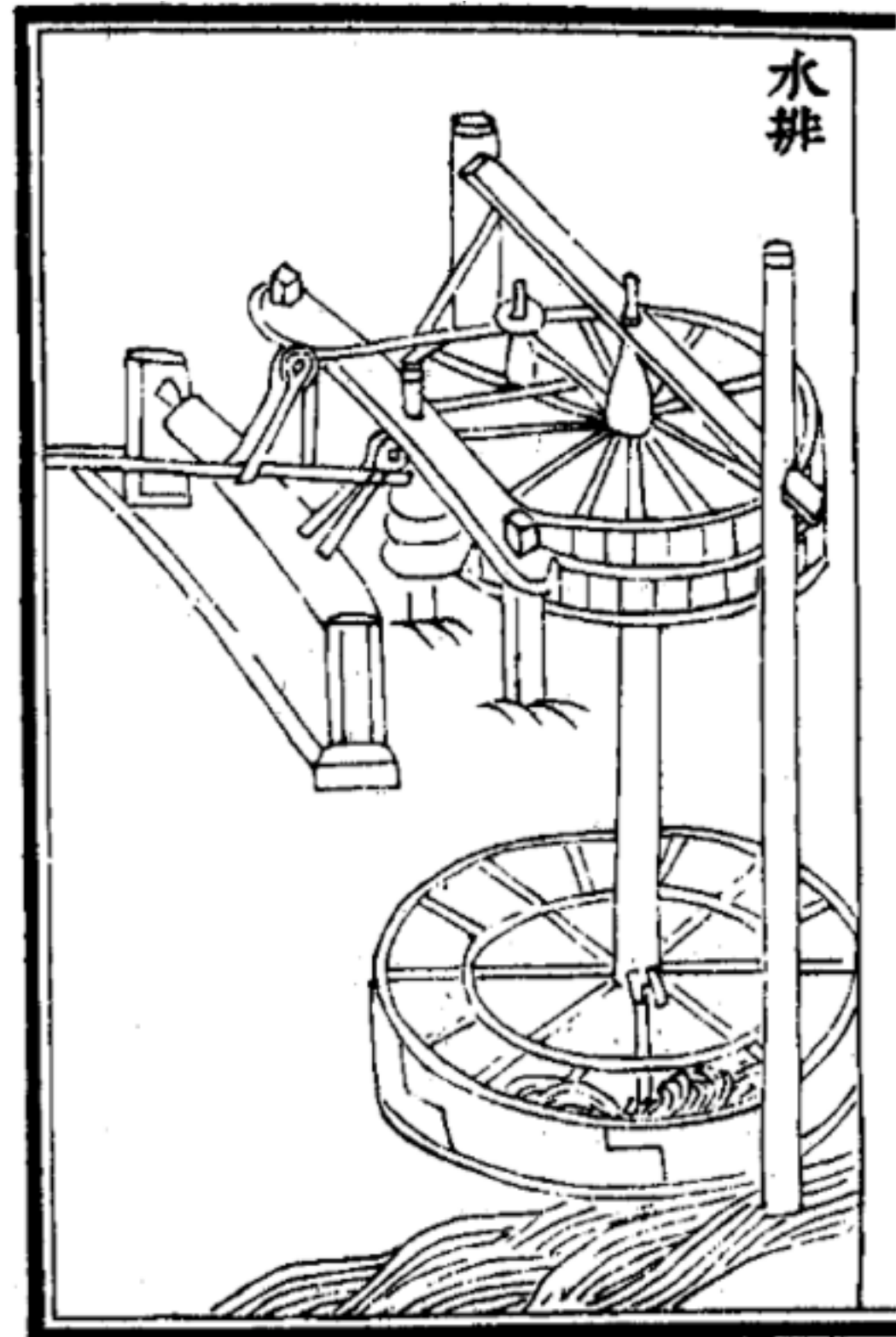
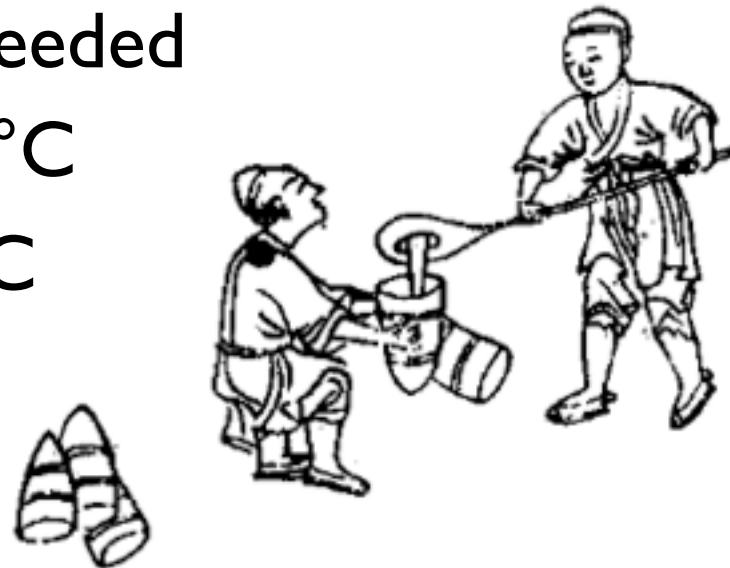




Stone Age - no fire needed

Bronze Age - 950°C

Iron Age - 1500°C

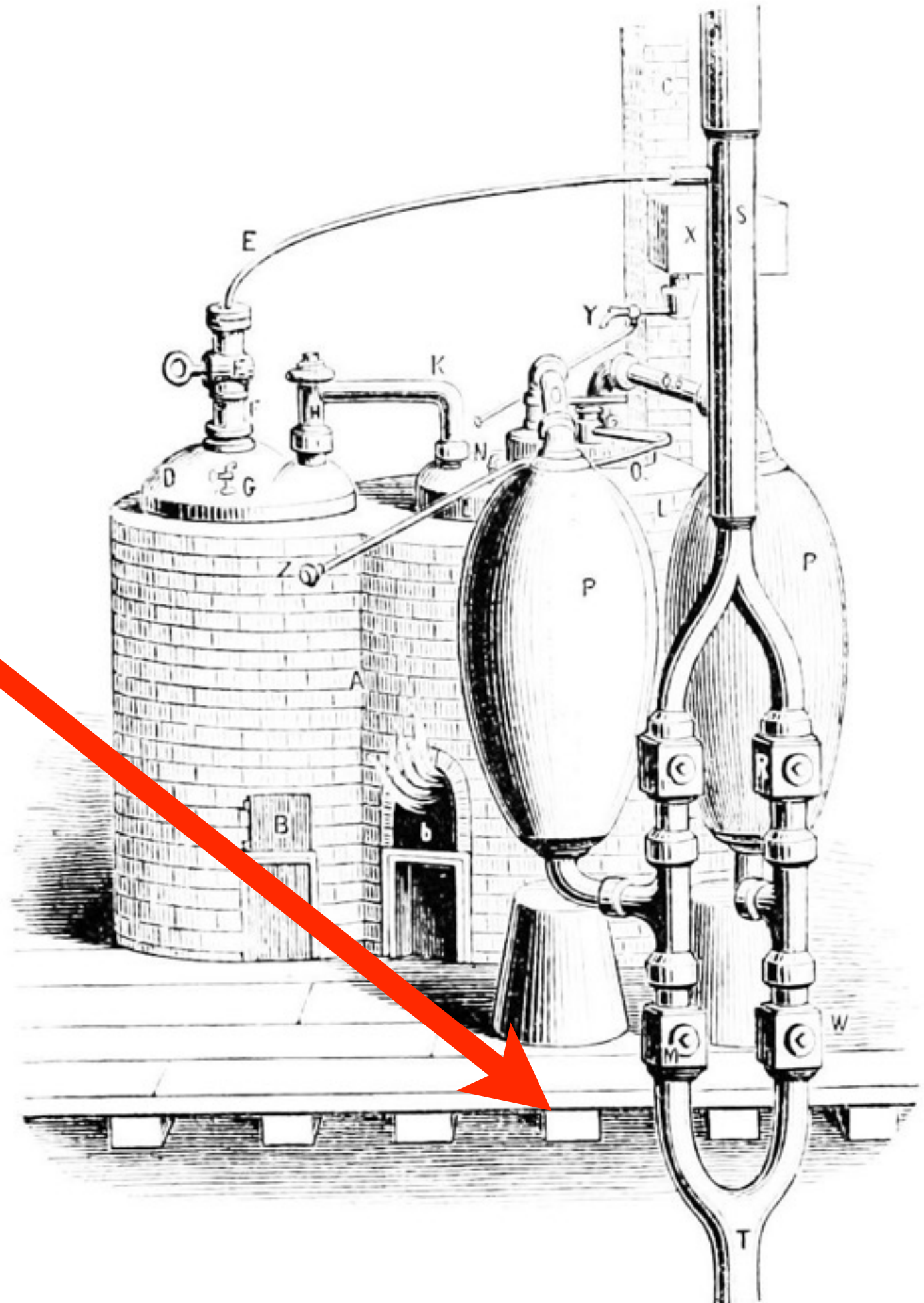




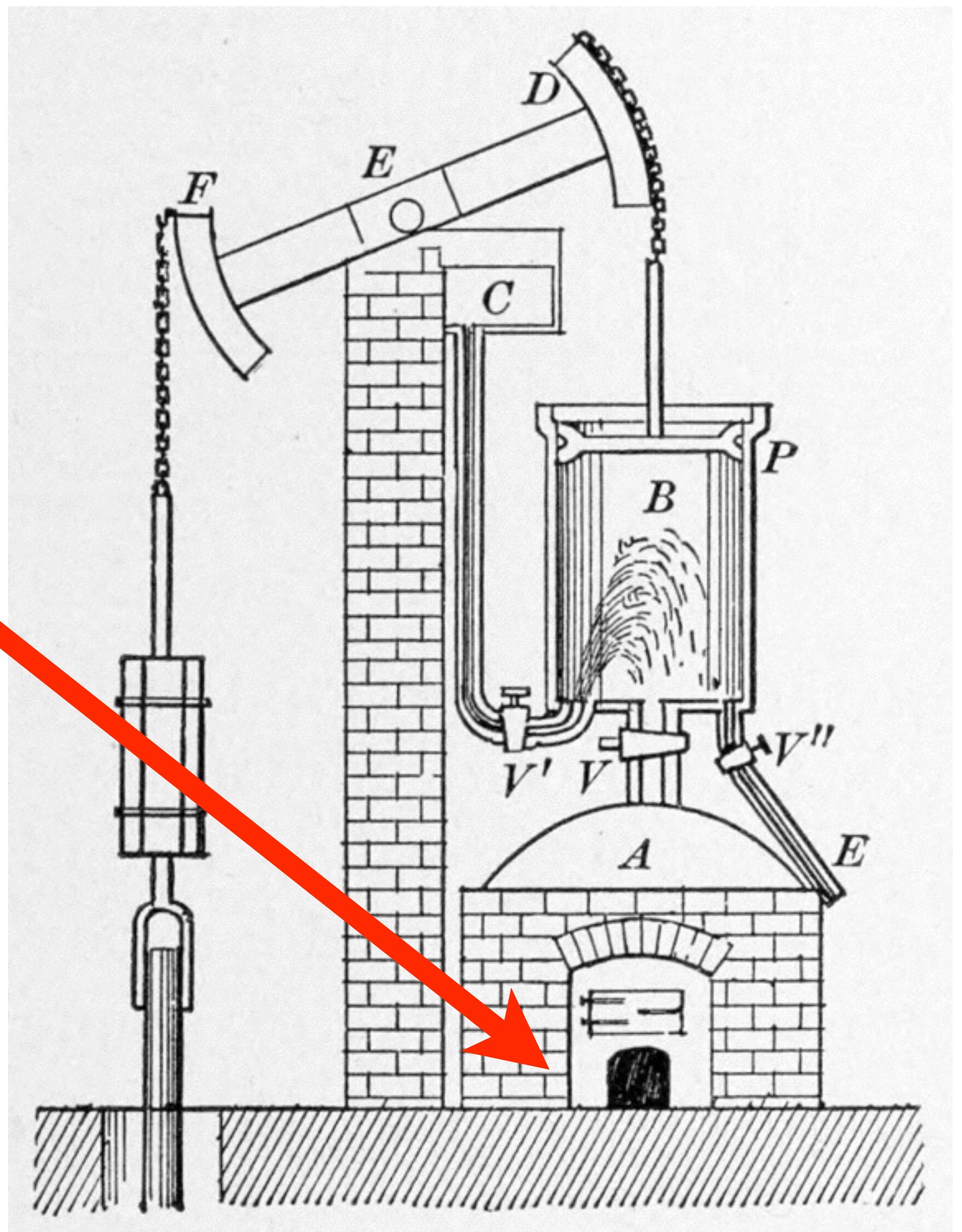
100 BC - Herona (?)



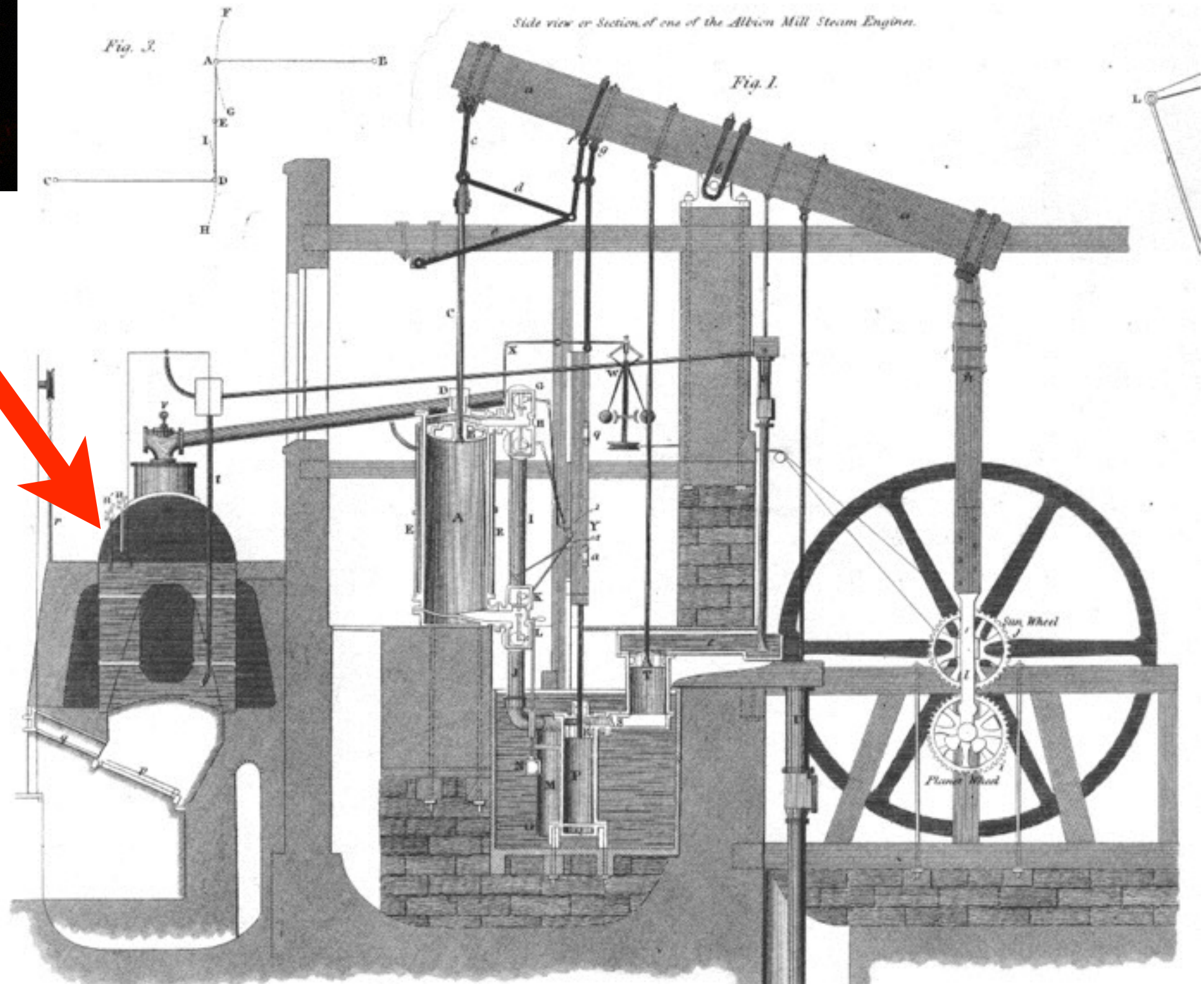
1300s - Huolongjing



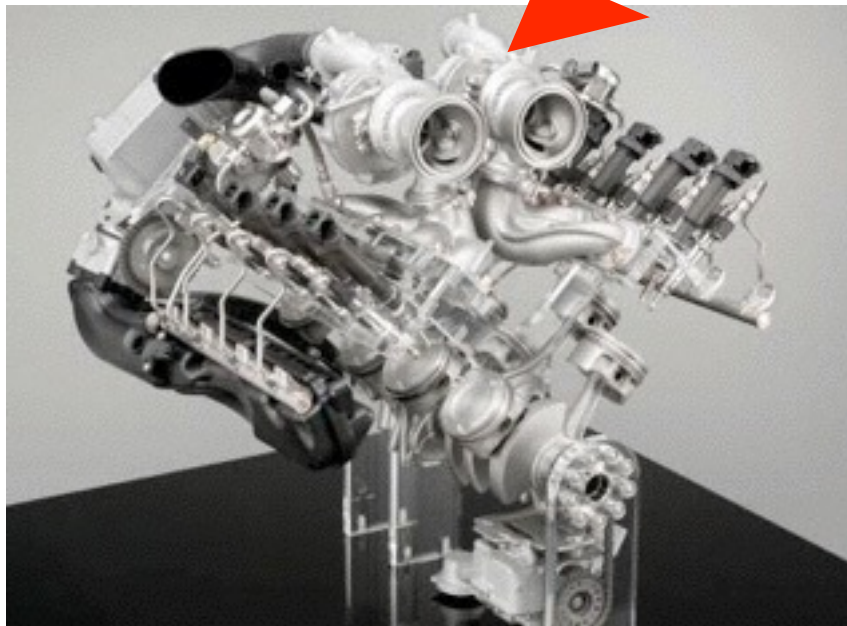
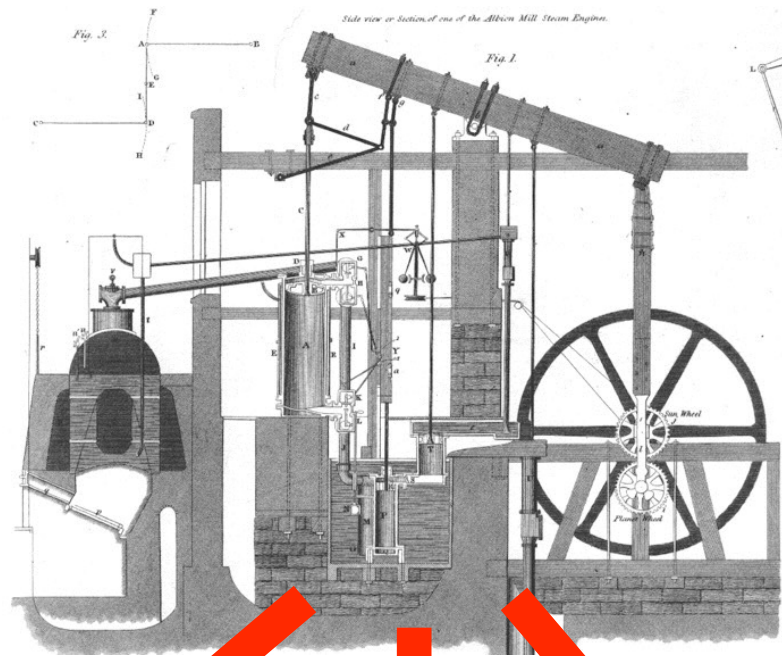
1699 - Savery



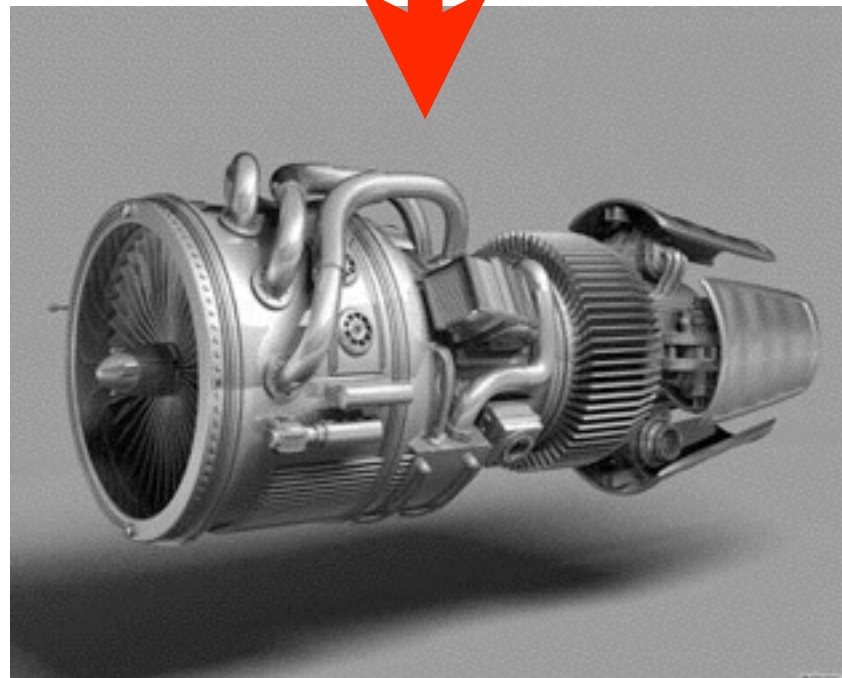
1712 - Newcomen



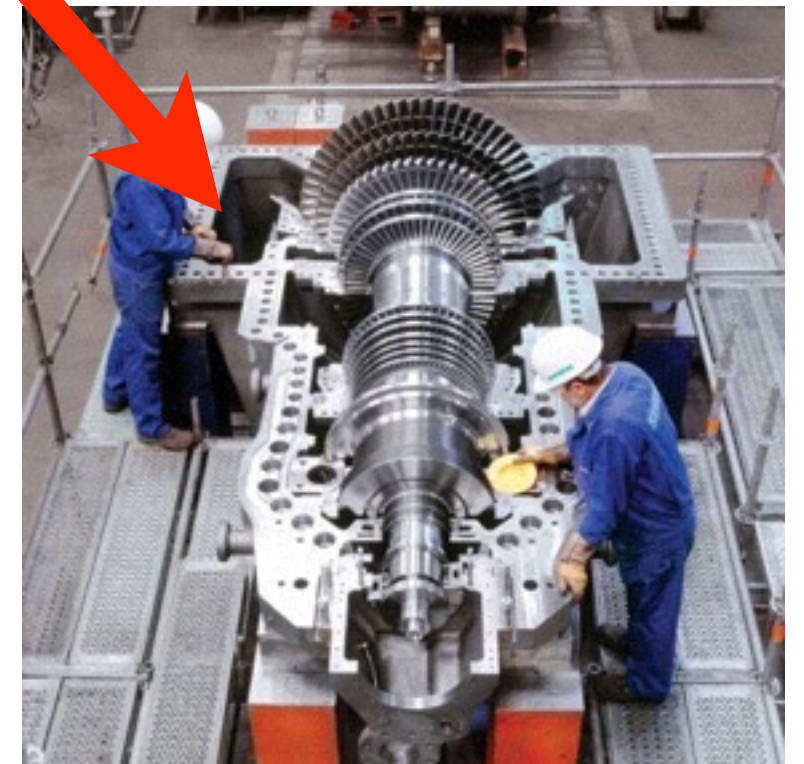
1775 - Watt



I.C.E.

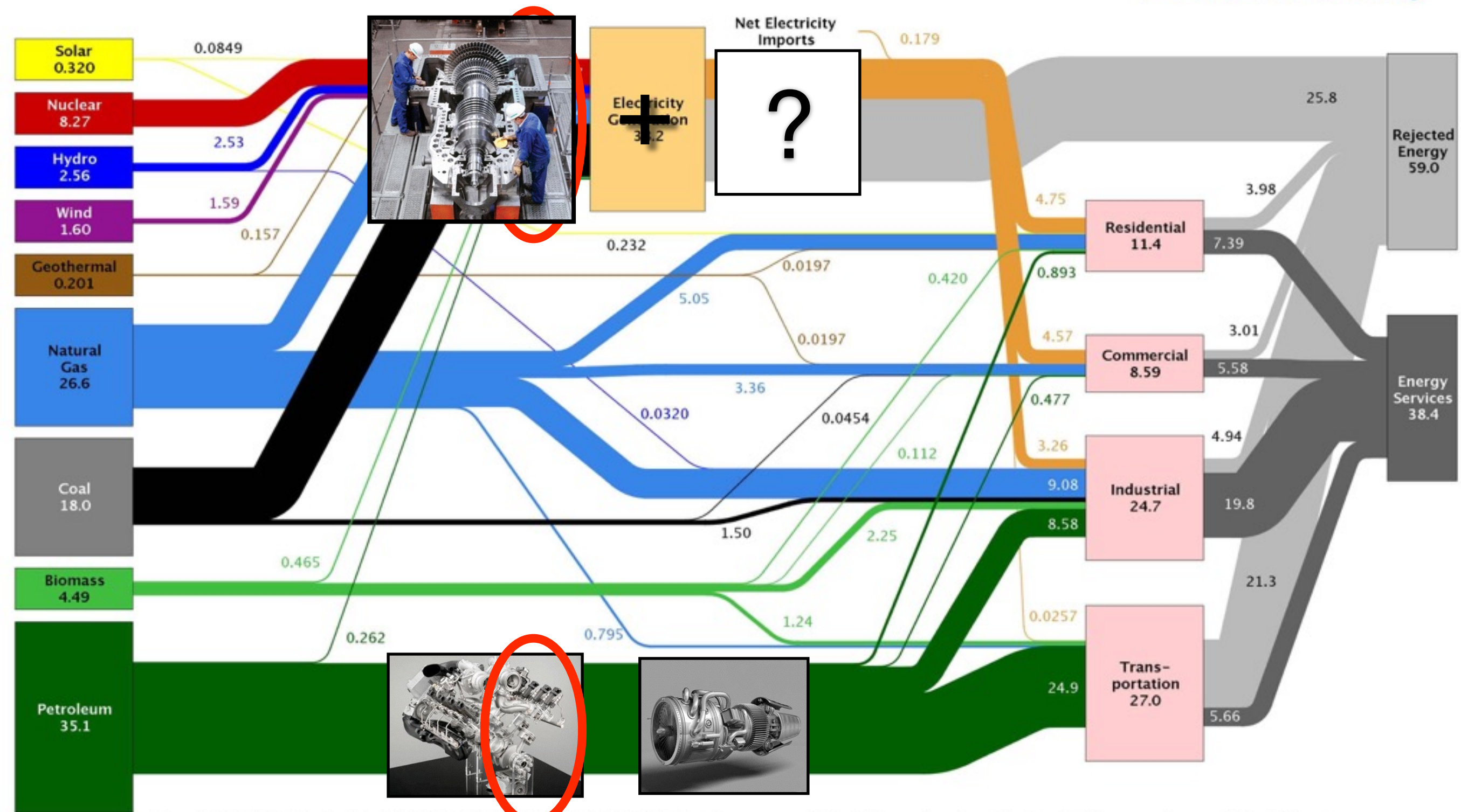


Jet engine



Steam turbine

Estimated U.S. Energy Use in 2013: ~97.4 Quads



Source: LLNL 2014. Data is based on DOE/EIA-0035(2014-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

?

$$\mathcal{E} = -N \frac{d\Phi_B}{dt}.$$

