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- POLYTECHNIC OF EGYPT -

History of Engineering and Technology

Lecture 4: Engineering in the medieval era.

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Medieval Engineering
(~500 AD→~1400 AD)

Medieval Engineering (~500 AD→~1400 AD)

- Introduction.
- Hagia Sophia.
- From Agriculture and other inventions.
- Developments in isolation.
- Religious influence.
- Military influence.
- Time keeping.
- Consequences of Wind & Water.
- Summary.

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Introduction

Introduction

Agricultural practices, religious interests, military objectives, and commercial activities of medieval times all influenced crafting of the day and thus contributed to an extension of heterogeneous progressions as suggested in the following:

$$\begin{pmatrix} \text{stone, wood,} \\ \text{metal, fiber,} \\ \text{leather,} \\ \text{minerals} \end{pmatrix} \rightarrow \begin{pmatrix} \text{selection,} \\ \text{preparation,} \\ \text{shaping,} \\ \text{assembly} \end{pmatrix} \rightarrow \begin{pmatrix} \text{various} \\ \text{and} \\ \text{numerous} \\ \text{devices} \end{pmatrix} \rightarrow \begin{pmatrix} \text{agricultural interests,} \\ \text{religious interests,} \\ \text{military interests,} \\ \text{commercial interests} \end{pmatrix}$$

$$N(t) \longrightarrow E(t) \longrightarrow D(t) \longrightarrow S(t) \longrightarrow E(t)$$

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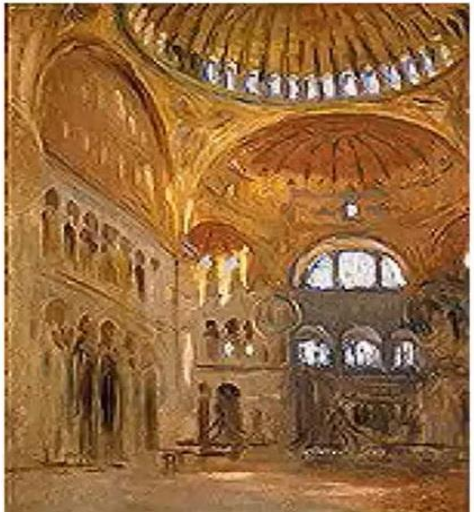
Hagia Sophia

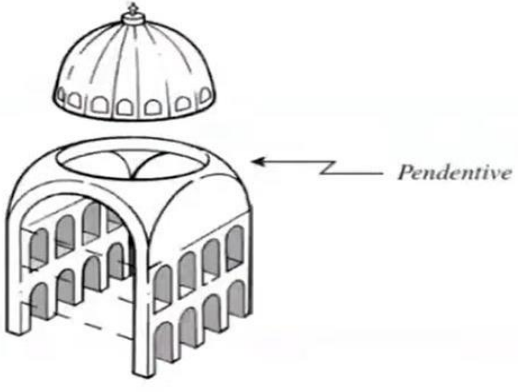
Hagia Sophia, 530 AD

- is a former Orthodox patriarchal basilica, later a mosque, and now a museum in Istanbul, Turkey. From the date of its dedication in 360 until 1453, it served as the Greek Patriarchal cathedral.
- A singular and most remarkable engineering construction project in Europe can be traced to the early Medieval period.
- The ancient Greek city of Byzantium was chosen as the site for this initiative and renamed Constantinople and in 1453 renamed again as Istanbul.

Hagia Sophia, 530 AD

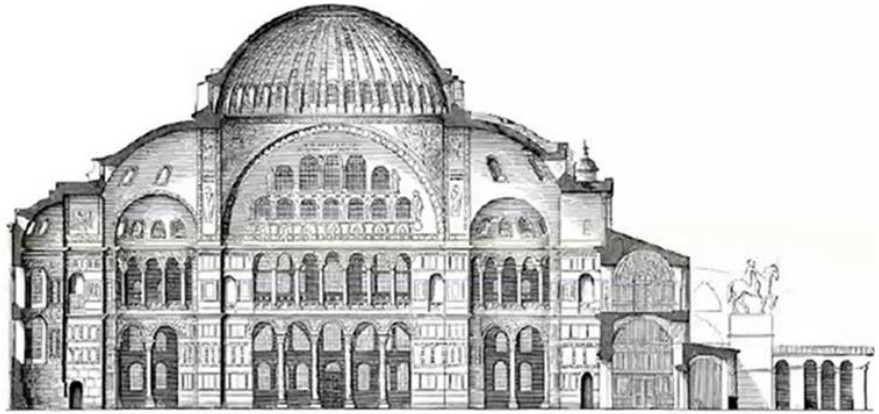
- What resulted about 530 AD with the employment of some 10,000 craftsmen and in the short span of only 5 years, was an architectural and engineering triumph: a large square 37 m×37 m×30 m basilica was for the first time satisfactorily topped by a large dome.

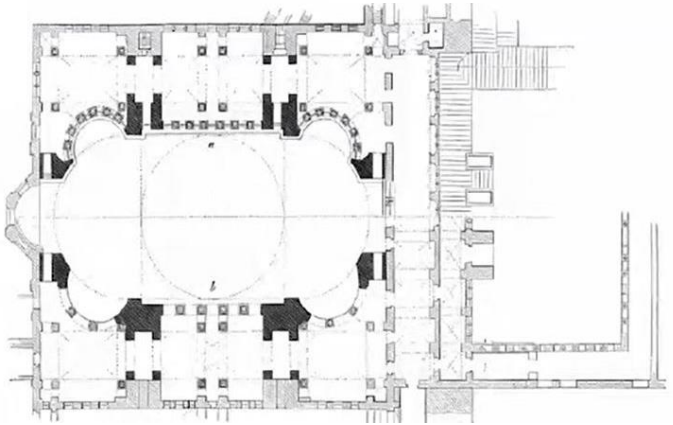




Hagia Sophia, 530 AD

arched windows were placed around the base of the dome so that when viewed from the inside the dome appeared to be floating





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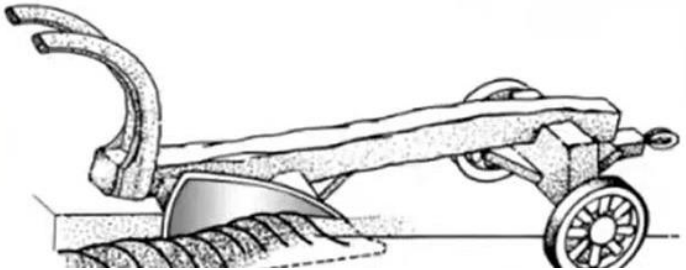
From Agriculture and other inventions

Agriculture Interest

- By about 600 AD, a device slowly appeared in central Europe with very important consequences: the wheeled iron plow drawn by a pair of oxen.
- The iron plow cut deeper, ~15 to 25 cm, while its mould board inverted continuous strips of soil, thus mixing and loosening it for seeding.

the wheeled iron plow drawn by a pair of oxen



Other inventions

In addition to agricultural developments, other inventions occurred:

1. the vertical axis cloth braced windmill in the area of present-day Iran, about 700 AD
2. Techniques of ink block printing in which characters stood out in relief on wood or stone surfaces, slowly diffused from China (~200 AD) to Korea (~600 AD), reaching Japan about 800 AD

Other inventions

Using Horse to Pull Wagons

- **2 devices also appeared in Europe with significant consequences:**

1. the iron horseshoe, ~900 AD which enabled horses to travel on stony ground and on the expanding gravel and cobblestone roads

2. the horsecollar,~1000 AD allowed horses to pull a wagon or plow without choking.

$$\begin{pmatrix} Humans: \\ \sim 5\,km/hr \\ \sim 100\,W \end{pmatrix} \rightarrow \begin{pmatrix} Cattle: \\ \sim 2\,km/hr \\ \sim 400\,W \end{pmatrix} \rightarrow \begin{pmatrix} Horse: \\ \sim 6\,km/hr \\ \sim 800\,W \end{pmatrix}$$

Other inventions

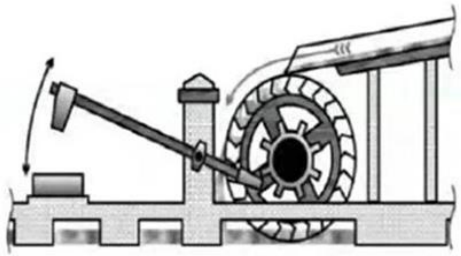
Waterwheel

Underlying much of this progression was the continuing and remarkable development of the waterwheel.

Two hydro-energy applications thus became increasingly specialized and important:

(a) Power for grinding (introduced ~100 A): milling grain, Grinding stone, honing tools, polishing brass, ……

(b) Power for trip-hammering (begun ~1000 AD): crushing Ore, forging metal, stamping coins, pulping rags for paper, Tanning leather, …….



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Developments in isolation

Developments in isolation

- **China 2000 BC**
  - Became technologically productive under a unique set of political and cultural circumstances.
  - a deliberate policy of superior isolation which included the construction of a tangle of protective barriers along its northern borders.
  - 200 BC the various sections were organized into a linked fortification with construction of new sections occurring intermittently until about 1600; the eventual length of this defensive rampant approached 4000 km and is commonly called the *GreatWall*.

Developments in isolation

CHINA

Another extensive construction project was the 2500 km *Grand Canal* south from Beijing and connecting eastern cities with an effective trade route.

- Constructed from ~100 AD to ~1300, it included some 40,000 lakes and it crossed a substantial mountain range requiring very sturdy slipways, an independent lubricating water source at each divide, and a powerful windlass system for moving boats over each summit.
- More than 5 million workers were involved in this largest ever hydraulic engineering undertaking.

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Religious influence

Religious influence

- About *630 CE*, a religious and cultural change occurred in the Middle East.
- The people of Arabia became inspired by the teachings of the Prophet Muhammad *(570–632 AD)*
- Within a century *Islamic thought* and practice had spread to *Asia Minor, India, northern Africa* and from there to *Spain*.
- Islamic scholars collected, translated, transmitted, and contributed to the knowledge of the Medieval World.
- From about 700 AD to 1200, Islamic technology exceeded that of Medieval Europe by their
  - *Medical skills*
  - *Extensive libraries*
  - *Islamic ability to breed spirited horses*
  - *Metallurgical skills with the Damascus sword, patterned carpets, and decorative copper wares*.

Religious influence

- ***Islam engineers*** chose to use the Indian methods of numerics, beginning about ***800 AD***; Europeans did not adopt it until about ***1200.***
- The Arabic mathematician ***Muhammed ibn Musa al-Khwarizmi*** (~780–850 AD) wrote a book on practical mathematics titled *al-Jabr in which Indian numerics were used throughout.* The title of this book led to the English word *algebra* and the ***author's surname name*** is perpetuated by the term ***algorithm.***
- Additionally, the medieval European practice of seeking the ***extraction*** of ***precious materials*** by ***distillation*** has its origin in Egypt as *El-khem, subsequently giving Europe the word* ***alchemy.***

Religious influence

- Islam began building mosques first throughout the Middle East and subsequently elsewhere. These sacred places have
  - *a central dome with interior geometrical pattern wall decorations*
  - *carpeted floors*
  - *wash basins*
  - *a recessed niche facing Mecca*
  - *slender minarets containing balconies from which the faithful are called to prayer.*

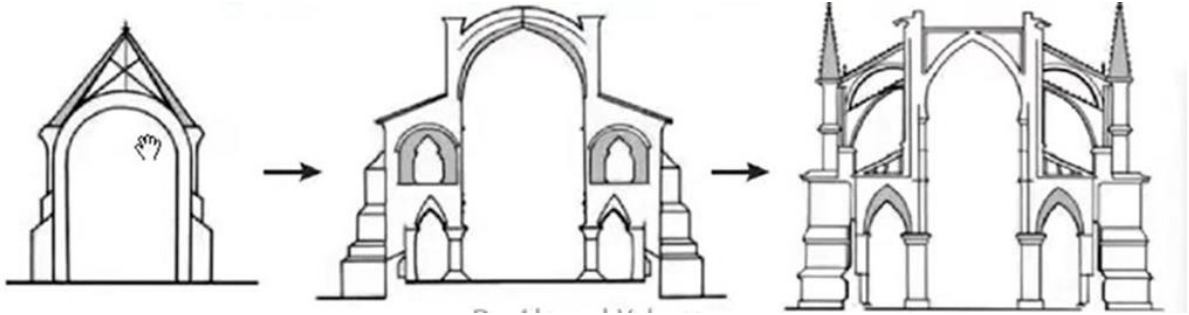
Religious influence

•Construction of large Christian sacred places in central and western Europe began about *1150* with three significant structural innovations enabling the construction of tall and visually impressive cathedrals:

•*Pointed arches as extensions of the Roman circular arch*

•*Flying buttresses allowing taller walls by load distribution*

•*Ribbed ceilings permitting longer structures*



Religious influence

•By *1250* some *250* large and graceful cathedrals had been started in Western Europe

Thus,

$$N(t)\left\{\begin{matrix}\textit{stone, glass,}\\ \textit{wood, brick}\end{matrix}\right\} \rightarrow E(t)\left\{\begin{matrix}\textit{graceful designs}\\ \textit{complex construction}\end{matrix}\right\} \rightarrow D(t)\left\{\begin{matrix}\textit{sacred}\\ \textit{buildings}\end{matrix}\right\}$$

characterizes the primal progression associated with the Gothic style of sacred structures, requiring however long construction times — on time scales of centuries · and involving

- *exceptional scaffolds*
- *extended winches*
- *superior crafting skills.*

•Inclusion of colored stained glass windows, elaborate altars, and ornate stone and wood carvings added considerably to their public appeal.

•Churches with *tall spires* often contained *large bronze bells* which were used to call the faithful to worship.

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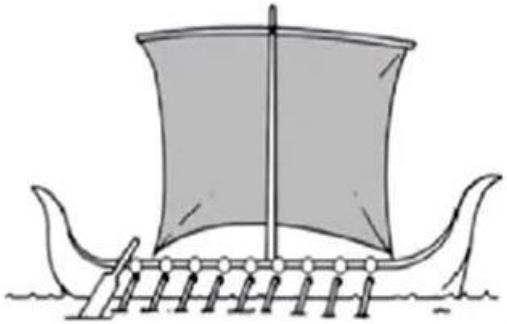
Military influence

Military influence

- About ***800 AD***, a new form of offensive military action of the Medieval period emerged: the raids of the Vikings along the oceanic shores and inland rivers of Europe. What made these forays technically possible were several unique naval innovations:
  - ***Wide shallow-draft boats of overlapping hull boards commonly called clinker-built***
  - ***Multiple oars and single square sail***
  - ***steering for one-person control***



Viking (~900 CE)

Military influence

- Further, a small but highly consequential device emerged in Europe during the middle of the Medieval era: the ***metal stirrup***. This small, device offered great military advantage to a skilled rider with a sword: speed, surprise, powerful swinging action, and fast escape.
- In time, the rider became equipped with ***a shield and other armor***, adding considerably to the power and fear of this kind of military action.

Military influence

- ***Fortification*** developed by ~***1100 AD*** into elaborate ***turreted castles*** of elevated thick-walled stone and masonry defense installations surrounded by ***moat*** and ***drawbridge***.
- In some cases, defensive walls surrounded entire towns. Also, large ingeniously designed fortresses emerged equipped with ***hidden passages*** and ***storage spaces*** containing extensive supplies to withstand a long siege. And so the primal progression

$$N(t)\left\{\begin{matrix}stone,\\brick,\\iron\end{matrix}\right\} \rightarrow E(t)\left\{\begin{matrix}dynamic\ design\\heavy\ construction\end{matrix}\right\} \rightarrow D(t)\ \{fortifications\}$$

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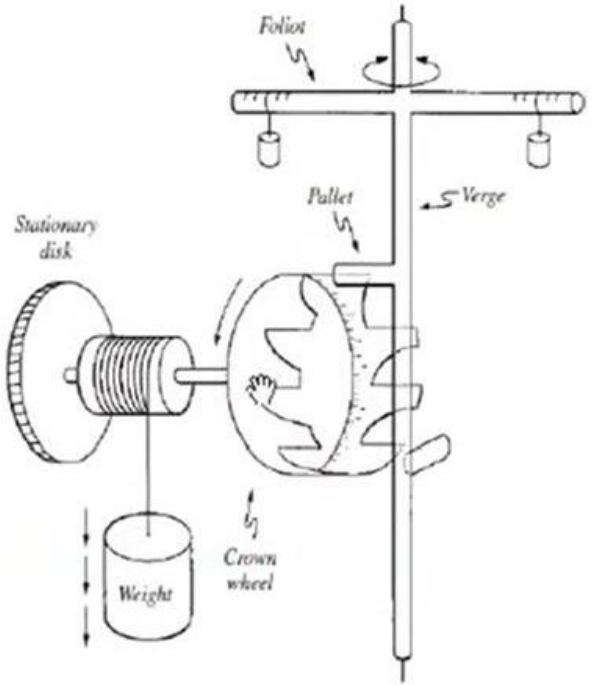
Time keeping

Time keeping

- Attempts to measure time intervals on the scale of fractional days had already been undertaken in Ancient times.
- It began in Egypt about ***3000 BC*** when ***crude sundial shadow sticks*** were used to divide the time from sunrise to sunset into 8 or 12 equal time intervals, regardless of season.
- The Greeks introduced cumbersome ***water clocks*** about ***400 BC*** in order to control the length of debate in their Senate.
- With the exception of candle clocks appearing about ***200 AD***, little change in time measurements occurred for the next ***1000 years***. By then, ***monastery activity*** and ***commercial practices*** led to an increasing interest for a more precise specification of time-of-day. Interestingly, the common expectation of that period was for time coordinates to be heard, as in ***pealing bells***, and not necessarily seen as a pointer referring to a number near the rim of a disk.

Time keeping

- The verge-foliot escapement clock (***1350***)—also known as the weight-driven or ***gravity-driven clock*** — is widely recognized as a most profound creative achievement of ***Medieval times***; additionally, it was also the first substantial-size device made entirely of iron. Numerous improvements soon emerged and the increasing accuracy eventually justified the installation of a minute-hand indicator.



Time keeping

- Large clocks were first mounted in specially designed clock towers as community showpieces and eventually installed in church steeples. Bells were installed and suitable bell-ringing mechanisms attached to peal at ~1/24 of a day-night cycle. An hour indicator only was first used since the inherent inaccuracy rendered a minute hand pointless. The primal progression descriptive of this engineering developments is suggested by

$$N(t)\{metals, gravity\} \rightarrow E(t)\{gears, kinetics\} \rightarrow D(t)\{gravity\ clock\}$$

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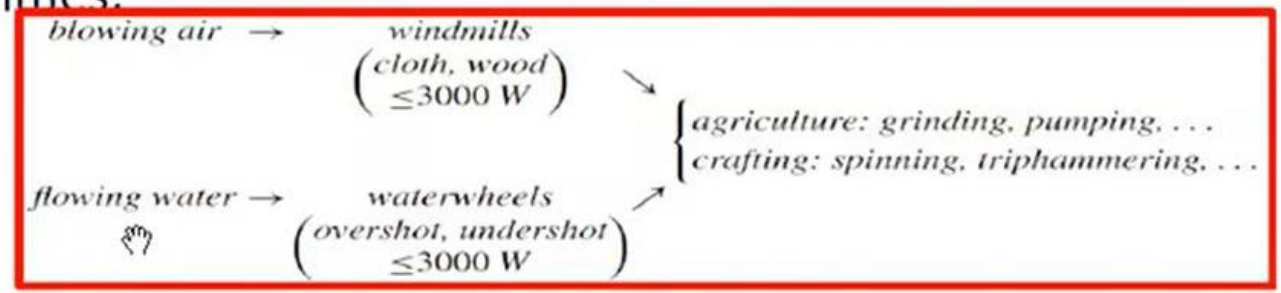
Consequences of Wind & Water

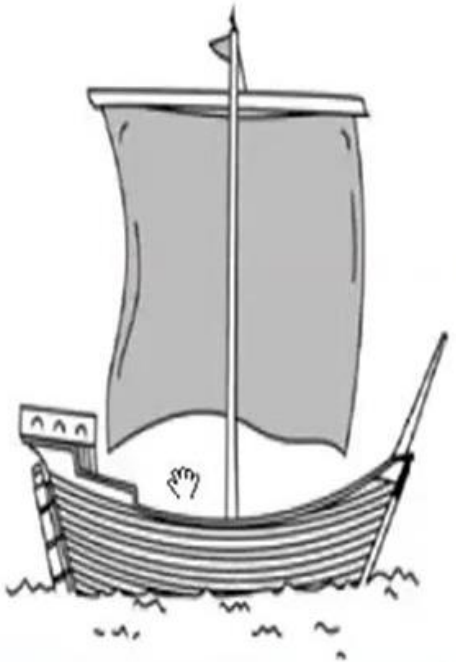
Consequences of Wind & Water

- It was known to the Greeks, and it must have been recognized by many in ***Medieval times***, that the application of wind and flowing water represented the first and extensive use of motive power beyond that available from animals or humans. ***Wind and flowing water*** initiated two distinct heterogeneous progressions which, interestingly, converged to provide equivalent functions in Medieval times:



Consequences of Wind & Water

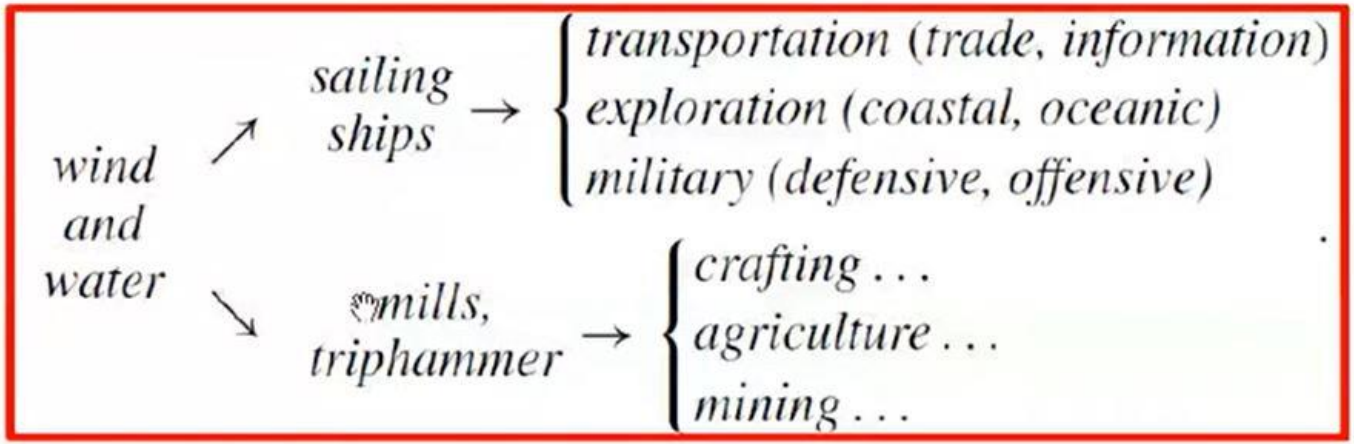
- It is in the emerging area of coastal commercial shipping that wind and water combined to stimulate the redesign of Viking ships by 1100s. Ships were constructed with deeper holds for cargo. Then several important shipbuilding innovations appeared:
  - Stern-post rudder centrally placed
  - Bowsprit forward spar for sail extension
  - Rear castle for the captain and steersman
- The ship which thus appeared, typically a tubby~25m long with a~8m beam, was called a Cog and soon proved to be a most reliable workhorse for coastal trade of northern Europe.



Cog (~1200 CE)

Consequences of Wind & Water

- And so the exploitation of wind and water initiated the divergence and specialization of device development in support of economical interests:



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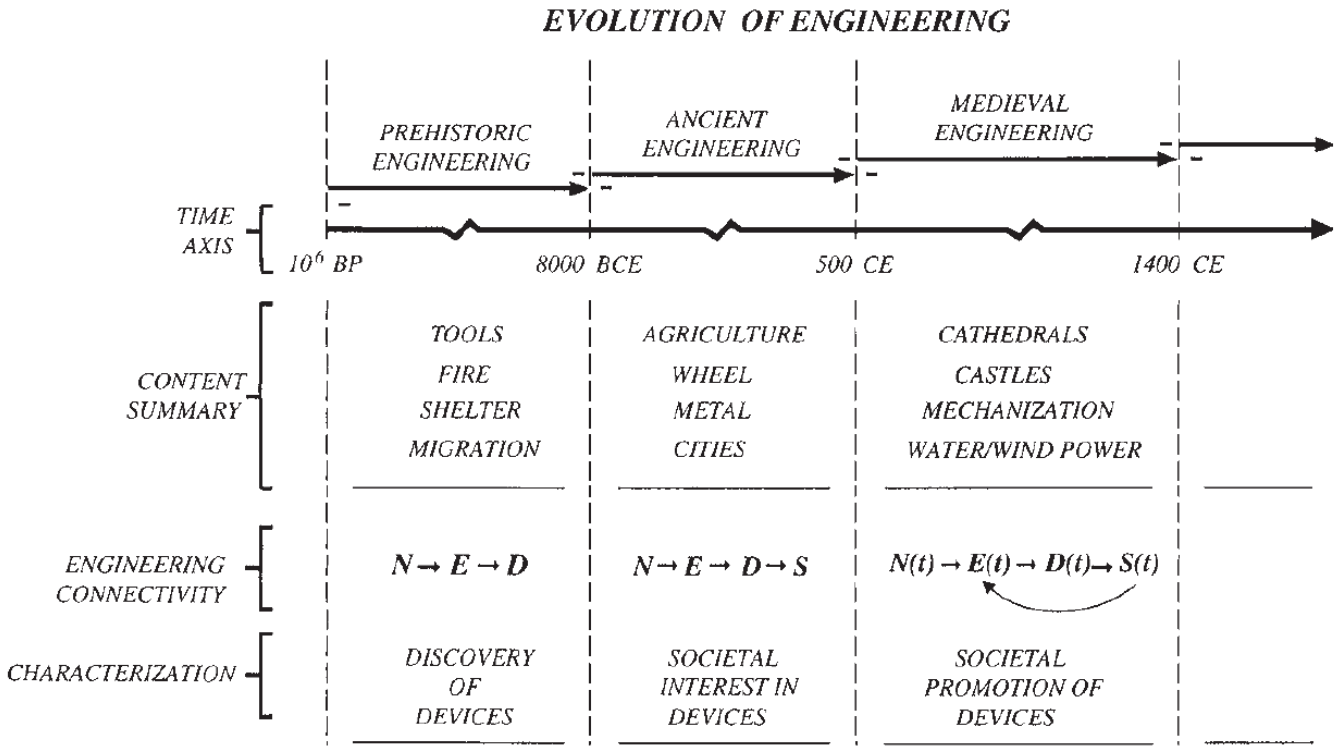
Summary

Summary


EVOLUTION OF ENGINEERING
PREHISTORIC ENGINEERING
ANCIENT ENGINEERING
MEDIEVAL ENGINEERING
TIME AXIS
10^6 BP
8000 BCE
500 CE
1400 CE
CONTENT SUMMARY
TOOLS
FIRE
SHELTER
MIGRATION
AGRICULTURE
WHEEL
METAL
CITIES
CATHEDRALS
CASTLES
MECHANIZATION
WATER/WIND POWER
ENGINEERING CONNECTIVITY
N → E → D
N → E → D → S
N(t) → E(t) → D(t) → S(t)
CHARACTERIZATION
DISCOVERY OF DEVICES
SOCIETAL INTEREST IN DEVICES
SOCIETAL PROMOTION OF DEVICES

Medieval Engineering (~500 AD→~1400 AD)

Thank you !